# BOOK OF PROCEEDINGS
## FOR THE

FISHERIES SOCIETY OF NIGERIA
FISON

# 40th ANNUAL NATIONAL CONFERENCE & GENERAL MEETING

## NASARAWA 2025

## FISHERIES SOCIETY OF NIGERIA (FISON)

**DATE:**
27TH-31ST OCTOBER, 2025

**VENUE:**
School of Postgraduate Studies, Nasarawa State University, Keffi (NSUK)

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# BOOK OF PROCEEDINGS

*for the*

## 40TH ANNUAL NATIONAL CONFERENCE

OF

## FISHERIES SOCIETY OF NIGERIA (FISON) "NASARAWA 2025'"

**HELD AT**

School of Postgraduate Studies,
Nasarawa State University,
Keffi (NSUK)

**27th – 31st OCTOBER 2025**

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# BOOK OF PROCEEDINGS

FOR THE

# 40TH ANNUAL
## NATIONAL CONFERENCE

OF

## FISHERIES SOCIETY OF NIGERIA (FISON) "NASARAWA 2025"


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# The Conference Editor Report for the 40th Annual Conference of the Fisheries Society of Nigeria held between 27th and 31st October 2025 at the School of Postgraduate Studies, Nasarawa State University, Keffi.

All glory and adoration are due to God Almighty, who, in His infinite mercy, granted us a successful 40th annual conference of the Society, tagged "Nasarawa 2025".

The annual conference and general meeting have remained the society's flagship event, providing opportunities to meet, exchange ideas, and build relationships among fisheries and aquaculture professionals and practitioners in the country. While technical sessions, involving presentations and discussion of research breakthroughs of various researchers within the Society, remain a cardinal part of the conference.

In 2025, we started with an advertorial for paper submission in March with the theme "STRATEGIES FOR SUSTAINABLE FISHERIES AND AQUACULTURE: HARNESSING INNOVATIVE TECHNOLOGY FOR RESILIENCE IN THE BLUE ECONOMY". At the October closure, a total of 182 manuscripts were received. Seasoned experts within the society reviewed these manuscripts, and the review reports were shared with the respective authors immediately after the conference. The corrected manuscripts contained the corrections suggested by the reviewers and those suggested during physical presentation. Finally, a total of 169 manuscripts covering 13 Sub-themes were found eligible for the Book of Proceedings and so published in this document.

I am very grateful for the support received from the members of the editorial team, especially the secretary, Dr Zikrullah A. Yusuf, who worked around the clock and kept the secretariat all through. The members of the Local Organizing Committee (LOC), especially the Conference coordinator, Professor A.M. Orire *Ffs*, the LOC Chairman, Professor S.A. Okunsebor, and the Secretary, Mr Manasseh Usman, for providing all the support needed at every point in time a request is made. I am also grateful to all the members of the National Executive Council, most especially the President, Dr Ebinimi J. Ansa *Ffs*, and the Vice President (Fisheries Institute of Nigeria and Linkages), Dr Olalekan R. Oguntade *Ffs*, for their guidance and support throughout the process. I also thank all the scientists who submitted manuscripts and responded to corrections on time, as well as our reviewers who made the work easy and ensured we have improved manuscripts worthy of publication.

It is worth noting a consistent decline in the quality of manuscripts submitted and presented at the conference in recent times. Many researchers find it challenging to adhere to simple instructions regarding submission and formatting. It is my sincere hope that the Society will do more to provide continuous training in relevant areas of research, including manuscript writing. Also, there should be a deliberate effort to encourage mentoring of young academics to reverse the downward trend in the quality of research undertaken and presented for publication.
Once again, I am sincerely grateful to the LOC leadership for considering me worthy to lead the editorial team. I also appreciate everyone who has lent a hand at one point or another to help us achieve the production of the Book of Proceedings within 10 weeks of completing the Conference.

Thank you, and God bless you all.



Professor Akeem Babatunde Dauda *Ffs*
*Conference Editor*

# FISHERIES SOCIETY OF NIGERIA (FISON)
# COMMUNIQUÉ

Issued at the Conclusion of the 40th Annual National Conference Held at the School of Postgraduate Studies, Nasarawa State University, Keffi, Nasarawa State, Nigeria, 27th – 31st October 2025.

**PREAMBLE**

The Fisheries Society of Nigeria (FISON) convened its 40th Annual National Conference at the School of Postgraduate Studies, Nasarawa State University, Keffi, Nasarawa State, from 27th to 31st October 2025, under the theme**: "Strategies for Sustainable Fisheries and Aquaculture: Harnessing Innovative Technology for Resilience in the Blue Economy."**

The conference brought together stakeholders from government, academia, industry, research, and development sectors to deliberate on emerging challenges and opportunities in Nigeria's fisheries and aquaculture sector. The forum facilitated robust knowledge exchange, policy dialogue, and strategic engagement to advance sustainable fisheries and aquaculture in Nigeria.

## 2.0 Highlights of the Conference

### 2.1 Pre-Conference Workshops

Organizers held pre-conference workshops to build technical and research skills. These workshops included:

1. Enhancement of Research through Data Processing and Analysis for Academics Using Statistical Tools for Agricultural Research (STAR), a software application that facilitates the analysis of agricultural data, was facilitated by Prof. S. A. Okunsebor, the Local Organising Committee Chairman**.**
2. Fish Production with Taemprowiz System and Technology: A Business Solution, presented by Mr. Emeka Martins Iloghalu. The Taemprowiz system integrates technological innovations to improve the efficiency of fish farming.
3. Procedures for Online Submission of Journals of Fisheries, delivered by Prof. Akeem Babatunde Dauda, the conference Editor.

Participants learned modern data analysis, new aquaculture systems, and academic publishing processes.

### 2.2 Opening Ceremony

The opening ceremony began with the rendition of the National Anthem and the FISON Anthem. Prof. S. A. Okunsebor, Chairman of the Local Organizing Committee, delivered the welcome address. The National President of FISON, Dr. (Mrs.) Ebinimi Joseph Ansa, *Ffs*, formally declared the conference open.

Representatives from various institutions gave goodwill messages. Prof. Gideon Amoga, for the Vice-Chancellor of Nasarawa State University, Keffi, affirmed the University's commitment to fisheries research and innovation. Delegates from the Federal University of Lafia, Isa Mustapha Agwai I Polytechnic, Lafia, and the Emir of Keffi also attended. They called for strengthening the aquaculture value chain to create jobs and reduce reliance on imported fish.

### 2.3 Investiture of Fellows

The Society issued certificates to new Fellows, who will be formally invested later, at a date to be determined by the National Executive Council. The awardees were: 1. Dr. Okeke Patrick Amaechi 2. Prof. Agbebi Funmilola Omolara 3. Mrs. Mohammed Mairo Ibrahim 4. Dr. Dauda Akeem Babatunde
5. Miss Osunkoya Daisi Muibat

6. Mr. Audu Emmanuel Fatai.
The National President inducted thirty students from the Nasarawa State University, Keffi, and the Federal University of Lafia into FISON. The induction, conducted through the administration of the Society's oath, increased student participation and professional development in the sector.

## 3.0 Keynote Address and Plenary Sessions

### 3.1 Keynote Address
The keynote address titled **"Strategies for Sustainable Fisheries and Aquaculture: Harnessing Innovative Technology for Resilience in the Blue Economy in Nigeria"** was delivered by Prof. Sonnie J. Oniye**.**
The address highlighted the vast potential of Nigeria's fisheries and aquaculture sector to advance the blue economy. It emphasized adopting innovative technologies, such as automated feeding systems (which dispense food to fish at set times), water-quality sensors (which monitor water conditions), artificial intelligence (AI), recirculating aquaculture systems (RAS, which reuse water within fish farms), and Internet of Things (IoT) tools (networked devices that collect and share data). These can enhance productivity, sustainability, and climate resilience. The keynote stressed the need for coordination among government, the private sector, communities, and development partners. It also called for building capacity, improving infrastructure, and promoting inclusive growth**.**

### 3.2 Lead Paper I
Prof. Shola Gabriel Solomon, Ffs, presented the first lead paper. It examined Nigeria's blue economy as a holistic framework for the sustainable management of aquatic resources. The paper identified several challenges: illegal, unreported, and unregulated (IUU) fishing (fishing that violates laws or is not reported), weak regulatory enforcement, climate change impacts, and bycatch exploitation (the capture of non-target species during fishing). Strategic solutions proposed included ecosystem-based fisheries management (managing fisheries with consideration of entire ecosystems), marine protected areas (zones where human activity is restricted to preserve biodiversity), sustainable aquaculture practices, and the integration of AI technologies to improve monitoring and decision-making.

### 3.3 Lead Paper II
The second lead paper was titled **"Nigeria's Aquatic Food System: Partnerships for a Sustainable Future."** Dr. Charles Iyangbe, the Country Representative of WorldFish in Nigeria, presented it. The paper emphasized the role of partnerships in strengthening aquatic food systems. These partnerships can improve nutrition, enhance livelihoods, and achieve sustainability**.**

### 3.4 Lead Paper III
The third lead paper, delivered by Dr. B. D. Olaosebikan Ffs, focused on threatened freshwater fish species in Nigeria. The presentation identified 35 threatened species across 13 families. Major threats included habitat loss, pollution, dam construction, deforestation, and overharvesting. The recommended conservation measures were awareness-raising, field surveys, habitat restoration, integrated basin management (managing all land, water, and living resources within a river basin as a whole), and ex situ (off-site, such as in hatcheries or aquariums) conservation initiatives.

## 4.0 Capacity Building Sessions
Capacity-building workshops on Brackish Water Integrated Multitrophic Aquaculture (IMTA) were held, facilitated by Dr. Victor Tosin Okomoda and Mr. Fasakin Idowu James. IMTA is a fish farming approach combining multiple aquatic species, such as fish, shellfish, and algae, in the same system to improve resource use and environmental balance. The sessions underscored the importance of aquatic

foods for nutrition, employment, and climate resilience, with particular attention to gender inclusion.
The Asia-Africa BlueTech Superhighway (AABS) project was introduced as a significant initiative. It supports sustainable aquatic food systems through research, innovation, and South-South cooperation. Integrated farm management approaches were discussed. The focus was on resource efficiency, environmental sustainability, economic viability, and the development of structured farm management systems.

**5.0 Technical Paper Presentations**
Of the 182 submitted manuscripts, over 90% were presented on various conference sub-themes through physical and virtual. The presentations showcased current research trends and practical solutions in fisheries, aquaculture, aquatic ecology, nutrition, and value chain development.

**6.0 RESOLUTIONS AND RECOMMENDATIONS**
The 40th Annual National Conference of the Fisheries Society of Nigeria successfully provided a robust platform for dialogue, knowledge sharing, and strategic planning towards sustainable fisheries and aquaculture development in Nigeria. The conference reaffirmed the critical role of innovation, research, partnerships, and capacity building in strengthening resilience within the blue economy.

After extensive deliberations, the conference adopted the following resolutions and recommendations:
1. All levels of government and private sector actors should increase investments in aquaculture and fisheries. Priorities should include infrastructure, research, and the adoption of new technologies to boost productivity and sustainability.
2. Strengthen regulatory enforcement and combat illegal, unreported, and unregulated (IUU) fishing through enhanced monitoring, capacity building, and community engagement.
3. Promote ecosystem-based and climate-resilient management practices, including the protection of threatened species and restoration of aquatic habitats.
4. Foster multi-stakeholder partnerships, including academia, industry, government, and development partners, for knowledge sharing, value chain development, and innovation.
5. Expand extension services and targeted training, especially for women and youth. These actions will help build capacity and create jobs in the sector.
6. Advocate for the integration of fisheries and aquaculture priorities into national development plans and food security policies.
Participants resolved to work together and review progress on these recommendations at regular intervals. They will use FISON's platform for ongoing policy dialogue and action.

**7.0 Appreciation**
The Fisheries Society of Nigeria (FISON) expresses deep appreciation to Nasarawa State University, Keffi, for hosting the conference and to the Local Organizing Committee for their dedication. Special thanks go to the sponsors and partners whose generous support made the conference possible. These include the Nasarawa State Government, the Nigerian Institute for Oceanography and Marine Research (NIOMR), Federal University of Lafia, Isa Mustapha Agwai I Polytechnic, Lafia, WorldFish Nigeria, industry partners, development agencies, and all presenters, facilitators, and participants.

**8.0 Commitment**
FISON will create a monitoring committee to oversee the implementation of conference recommendations and collaborate with relevant stakeholders in policy advocacy. The Society will also strengthen efforts to form partnerships, mobilize resources, and hold periodic capacity-building activities. The society is firmly committed to seeing the Fisheries Institute of Nigeria come into the light of day, and the respective Bill for its enhancement is endorsed with the support of all the stakeholders

**9.0 Policy Advocacy Statement**

The Fisheries Society of Nigeria calls on the Federal and State Governments to prioritize fisheries and aquaculture as a strategic pillar for national food security, economic diversification, and environmental sustainability. FISON reiterates its commitment to supporting evidence-based policy formulation, stakeholder engagement, and the adoption of innovative practices to advance Nigeria's blue economy.

**10.0 Closing Endorsement**

The 40th Annual National Conference of FISON, held at Nasarawa State University, Keffi, is hereby endorsed as a landmark event that has set a renewed agenda for the transformation of Nigeria's fisheries and aquaculture sector. FISON pledges to continue leading advocacy, research, and professional development for a resilient, inclusive, and sustainable blue economy.

**Signed:**
**Dr. (Mrs.) Ebinimi Joseph Ansa, Ffs**
*National President, FISON*
*On behalf of the Society*

# ADDRESS OF THE NATIONAL PRESIDENT DR (MRS.) EBINIMI JOSEPH ANSA (*Ffs*) AT THE 40TH ANNUAL GENERAL MEETING AND CONFERENCE OF THE FISHERIES SOCIETY OF NIGERIA (FISON) HELD AT THE NASARAWA STATE UNIVERSITY, KEFFI ON 28TH OCTOBER 2025

*Distinguished Senators and Honourable Members*

*His Excellency, The Honourable Minister, Federal Ministry of Marine and Blue Economy,*

*The Executive Governor of Nasarawa State*

*The Permanent Secretary, Federal Ministry of Marine and Blue Economy, all other Permanent Secretaries here present*

*Royal Father of the day*

*Members of the State House of Assembly*

*Commissioners here present*

*Vice-Chancellor, Nasarawa State University, Keffi,*

*Vice-Chancellor, Federal University, Lafia,*

*Executive Directors of the Research Institutions here present*

*Rectors and Provosts, of our Fisheries Colleges and Polytechnic*

*Federal and State Directors of Fisheries*

*Board of Trustees of FISON*

*All Past Presidents of FISON*

*My colleagues, Members of the National Executive Council of FISON*

*Chairman/Former Chairmen Council of Fellows and all Fellows of FISON*

*Presidents and Captains of Fisheries Industries and Associations*

*Our great Fishers and Fish Farmers,*

*Distinguished Members of FISON*

*Distinguished Students*

*Distinguished Guests,*

*Gentlemen of the Press*

It is with profound honour and gratitude to the Almighty God, that I welcome you all to the 40th Annual Conference and General Meeting of the Fisheries Society of Nigeria (FISON), proudly tagged *NASARAWA 2025*. This year's conference is a remarkable milestone in the history of our Society—not only because we are celebrating our 49th anniversary of advancing fisheries and aquaculture in Nigeria, but also because we gather at a critical moment for our nation's blue economy.

The theme of this year's conference, *"Strategies for Sustainable Fisheries and Aquaculture: Harnessing Innovative Technology for Resilience in the Blue Economy,"* speaks directly to the urgent need to build a

resilient, up-to-date, and sustainable fisheries and aquaculture sector capable of responding to current and future challenges.

I wish to express my deepest appreciation to the management and staff of Nasarawa State University, Keffi, Federal University, Lafia, the Nasarawa State Government and the Fisheries Society of Nigeria, State Chapter of Nasarawa State for their warm hospitality and unwavering support in hosting this important national event. We are equally grateful to our partners, sponsors, and collaborators—WorldFish, FAO/FISH4ACP, ECOWAS, FCWC, CAOPA, FCFFT New Bussa, FCFFT Baga, FCFMT, NIOMR, HYPREP, Aller Aqua, Atlantic Shrimpers Ltd., and many others—for their consistent support and commitment to the growth of our sector.

The Fisheries Society of Nigeria (FISON), founded in 1976, serves as the principal professional organisation in the Nigerian fisheries sector. FISON maintains a role of leadership and authority, undertaking a range of responsibilities. We take up these responsibilities passionately and are not deterred till we have a breakthrough. Let me highlight a few points in my welcome address for us to reflect on during and after the conference.

**1. Advancing Professionalism – Progress on the FIN Bill**

A critical priority for FISON is the formal establishment of the Fisheries Institute of Nigeria (FIN) through legislation. I am pleased to inform this distinguished gathering that significant progress has been made in the redrafting of the FIN Bill. This bill is designed to be sponsored as an Executive Bill by the Honourable Minister of Marine and Blue Economy and submitted to the Federal Executive Council for onward transmission to the National Assembly.

Once passed into law, FIN will serve as a professional regulatory body, setting standards for training, certification, and practice in fisheries and aquaculture. It will ensure:

- The promotion of professionalism and accountability in the sector,
- Harmonization of standards with global best practices,
- Improved research-extension-industry linkages, and
- Strengthened capacity to harness the full potential of Nigeria's blue economy.

We look forward to the continued support of all stakeholders to make this a reality.

**2. Embracing Technology and Innovation for Sectoral Resilience**

Technology is reshaping the global fisheries and aquaculture landscape. From precision aquaculture, smart monitoring systems, feed innovations, and genetics to digital traceability, innovation drives sustainability. Nigeria must not be left behind. In line with this FISON is collaborating with the Atlantic International Research Centre (AIR-Centre), CAOPA, WANSAFA and other partners in bringing new technologies and ideas to foster sustainable resources management and economic growth in the fisheries sector, particularly for small-scale fisheries.

FISON continues to work with partners to promote the adoption of modern technologies among fishers, fish farmers, processors, and value chain actors. Our commitment is to equip our members with tools and knowledge that enhance productivity, reduce losses, improve environmental stewardship, and attract investment.

**3. Strengthening Research, Education, and Industry Linkages**

No sustainable blue economy can thrive without strong research, education, and industry collaboration. Our fisheries and aquaculture institutions—FCFFT New Bussa, FCFFT Baga, FCFMT, NIOMR, NIFFR, ARAC, universities, other tertiary institutions and research centres—remain vital to building the human capacity required for innovation and sectoral growth. FISON is currently represented on the advisory board of the TETFUND Centre of Excellence in Aquaculture and Food Technology (TCEAFT)

University of Benin and is in the process of signing an MoU with the centre, led by Professor Ijeoma Oboh *Ffs*.

FISON is working to deepen these linkages by encouraging joint research projects, innovation incubation hubs, and policy advisory roles. Our partnership with WorldFish and other development partners further strengthens these efforts. I am particularly excited about the introduction of the new WorldFish Nigeria Representative. Dr. Charles Iyangbe, during this conference—a strategic development that signals stronger global collaboration.

**4. Promoting Knowledge Dissemination and Access**

As part of our commitment to advancing fisheries knowledge, this year's conference features a pre-conference workshop on the transition of the Nigerian Journal of Fisheries to an online platform. This is a landmark step in ensuring broader access to research outputs, faster dissemination of new knowledge, and increased visibility of Nigerian fisheries research globally. Our editorial team and collaborators, worked tirelessly to ensure the birthing of the online journal. Let us patronize our journal in one or more ways, such as recommending submission of research articles by our postgraduate student, sending our own research manuscripts for publication, charity they say begins at home!

In addition, due to popular demand for hard copies of our proceedings, we will launch the Abuja 2024 Conference Proceedings, a valuable reference for policymakers, practitioners, and researchers. Please do not leave the conference without buying a copy. We request all our research and tertiary institutions from across Nigeria to pickup copies for their institution's libraries. I am grateful for the preorder of copies by HYPREP and World Aquaculture Society through our fellows – Prof. N. Zabbey *Ffs* and Dcn Foluke Areola *Ffs* respectively. Your commitment to the success of the production of the hard copy issues are very much appreciated. Thank you for believing in us.

**5. Showcasing Practical Impact and Stakeholder Engagement**

The 40th FISON Conference is not just about papers and policy—it is about real-world impact. This week, participants will experience:

- Technical paper presentations by experts and practitioners,
- A side event by WorldFish on innovation and resilience in aquaculture,
- Farm visits to showcase practical technologies and successful aquaculture models, and
- Exhibitions where industry stakeholders will display products, technologies, and services driving change in the sector.
- Roundtable discussion to address the nagging issues in Fisheries Education in the country

These activities provide opportunities for learning, investment, and partnerships that will strengthen Nigeria's position in the blue economy.

**6. Appreciation to Our Hosts and Partners**

On behalf of the Fisheries Society of Nigeria, I extend heartfelt gratitude to the Nasarawa State Government and Nasarawa State University, Keffi, for their commitment to making this conference a success.

We also acknowledge and appreciate the unwavering support of our partners and sponsors:

- The newly established House Committee on Ocean and Fisheries, ably led by Honourable Engr. Akarachi, we welcome you to our conference, your effort in promoting sustainable practices and healthy collaborations in the Sector is noticed and appreciated.
- To WorldFish, our platinum sponsor – we are grateful for your sponsorship, leadership and global expertise in providing healthy aquatic foods for all in a sustainable way.
- The Federal Ministry of Marine and Blue Economy with its department, research institutions and

colleges, namely FDFA, NIOMR, NIFRR, FCFFT New Bussa, FCFFT Baga, FCFMT, our grand patrons, you have always supported the growth of the Fisheries sector. To our Executive Directors/CEOs and Provosts of the research institutions and colleges FISON is highly appreciative of your consistent support over the decades. Thank you Sirs.

- HYPREP, we thank you, for your environmental remediation initiatives, restoring aquatic habitats, increasing aquatic food production and restoring livelihoods in Ogoni Land and beyond.
- Aller Aqua, Atlantic Shrimpers Ltd, Gabrovic Int., Mideast Fish'ries and other private sector partners, you are very well appreciated for your consistent sponsorship and partnership.
- Our media partners we appreciate your consistent support.
- The Chairman LOC, Professor Okunappreciate àll members of the organising committee, our indefatigable Conference Coordinator, Professor A. M. Orire who have worked tirelessly to make NASARAWA 2025 a reality. May God Almighty bless you all richly and reward the sacrifices you have made and your labour of love.
- Last but not the least I warmly appreciate and welcome my brothers and my sisters at the National Executive Council, we have worked closely together, over the past one year for a few of us and three years for others. We are in different states in Nigeria, and this distance has not hindered us from working remotely to see to the progress of our Society. My four Vice Presidents (VP FIN & Linkages, Dr Olalekan Oguntade *Ffs*, VP Industries, Prof. A.M. Orire *Ffs*, VP Aquaculture, Dr. Godwin Adaka, VP Research & Training, Prof Olukayode Sogbesan *Ffs*), my secretarial team – National Secretary, Dr Abdulkarim Babangida and the Assistant NS, Dr. Sampson Ohaturuonye, our finance team, National Treasurer, Princess Victoria Ojelade *Ffs* and National Financial Secretary Prof. Keziah Absalom *Ffs*, national P.R.O. Dr Awawu Dasuki, National Editor/Editor-in-Chief Nigerian Journal of Fisheries, Prof E.K. Ajani *Ffs*. Meeting at odd hours online has become our norm to accommodate full participation at our online meetings. You are warmly welcome to Nasarawa, thankfully we will have a physical meeting!

**Conclusion:**
As we celebrate 49 years of advancing fisheries and aquaculture in Nigeria, let us remember that the future of the sector depends on our collective will to innovate, collaborate, and professionalize. Sustainable fisheries and aquaculture are essential to Nigeria's food security, economic diversification, and environmental resilience. Let us commit ourselves to:

- Supporting the passage of the FIN Bill,
- Embracing technology and innovation,
- Strengthening research and capacity development,
- Promoting sustainable practices, and
- Building a vibrant and inclusive blue economy, where Fisheries is in the forefront.

Distinguished colleagues, I urge us to use this conference not just to talk, but to build actionable partnerships and strategies that will transform our sector. Thank you all for your dedication, your professionalism, and your service to Nigeria's fisheries and aquaculture development. Once again, you are all welcome to NASARAWA 2025. May this 40th Annual Conference of FISON—NASARAWA 2025—be a watershed moment in our journey toward a stronger, more sustainable blue economy.
God bless you,
God bless FISON,
And God bless the Federal Republic of Nigeria.

**Dr. (Mrs.) Ebinimi Joseph Ansa, *Ffs***
*National President*

# LEAD PAPER PRESENTATION 1

# STRATEGIES FOR SUSTAINABLE FISHERIES AND AQUACULTURE HARNESSING INNOVATIVE TECHNOLOGY FOR RESILIENCE IN THE BLUE ECONOMY

**By**

**Professor Shola Gabriel Solomon (*Ffs*)**
**A Lead Paper Presented at the 40th annual Conference of the Fisheries Society of Nigeria held at Keffi 27th-31st October 2025**

## 1. PREAMBLE

I doubted what I was taught in my secondary school days when the then Geography teacher taught us that this earth is made up of about 73% water until some times in 2014 when I made a trip and we were flying over water for upward of six hours that was when I began to believe my geography teacher. If the ocean could cover almost 73% of the earth surface, it then means the oceans of the world are major determinant of our livelihood and existence.

## 2. IMPORTANCE OF THE WORLD OCEAN

- Support the livelihood of over three billion people.
- Impart the global climatic condition.
- Provides economic opportunities for growing world population.
- Support health of the populace through supply of sea foods and fisheries products.

The negative impact of activities of man globally has resulted in the following:

- Climate change that has resulted into flooding, ocean surge, global warming etc.
- Over fishing that has resulted in decline in catches due to uncontrolled fishing efforts resulting in low catch per unit effort.
- Habitat destruction.
- Pollution both aquatic and terrestrial.

The obvious consequences of all the above is visible to the blind eye

- Destruction of coastal communities
- Marine biodiversity is altered
- Threats to global food security as the entire world is dependent on the oceans for protein supply and protein security

## 3. UNDERSTANDING THE CONCEPT OF BLUE ECONOMY

**Dictionary meaning:**

An economic system that seeks to conserve marine and fresh water environments while using them in a sustainable way to develop economic growth and produce resources such as energy and food.

**World Bank Definition:**

The blue economy is the sustainable use of ocean resources for economic growth, improved livelihood and job while preserving the health of ocean ecosystem.

**Federal Ministry of Marine and Blue Economy Definition**

The blue economy in the Nigeria context represents a holistic and sustainable approach to harnessing the potentials of ocean, coastal and inland waters, living and non-living things for economic growth, ecological conservation and societal development. It promotes economic growth, social inclusion, preservation and

improvement in livelihood while at same time ensuring environmental sustainability of the ocean, coastal and inland water area.

## 4. THE KEY CHALLENGES TO SUSTAINABILITY IN FISHERIES AND AQUACULTURE

### a. IUU and Overfishing

The issue of illegal, unreported and unregulated (IUU) fishing and overfishing remain a challenge to sustainability in Nigeria. The illegal fishing methods includes unauthorized nets that are less than 3mm mesh size in some instances even mosquito nets are used to wipe juveniles fish from the water bodies. The use of explosives, chemicals, phytotoxic plants all constitute a challenge to sustainability. It is reported that, over 35% of fish stocks are over exploited globally.

### b. poor Enforcement of Regulation

It is a near tragedy that in 2025 people still use obnoxious fishing methods unchallenged. Small fish and fingerlings are still marketed on the street. Phytotoxic plants are still being used for fishing in Nigeria inland waters bodies unchallenged.

### c. Free Entries to Water Bodies

Whosoever have the skills to move canoe, boats and skillful to throw nets go on our water bodies unlicensed and unchallenged. This still remains a challenge to sustainability.

### d. Inability of Regulatory Agencies to Enforce Close Season

The policy of close season to allow for regeneration of stocks appear to be a policy on paper in Nigeria. Even water bodies marked for fishing festivals fishermen go there by night for fishing unchallenged.

### e. By-catch exploitation

The use of non-targeted fish species including shell fish mortality remains a challenge within Nigeria EEZ

### f. Negative Impact of Climate:

Acidification and warming of the oceans, flooding that has wrecked aquaculture practices along the coast of inland water bodies remains a challenge to sustainability. The flood disaster in Nigeria in 2012 wiped away many fish farms.

The challenges facing sustainability of Fisheries and Aquaculture as listed above is not because of lack of legislation but very poor enforcement of regulations.As at today we twelve key laws related to Fisheries and Aquaculture in Nigeria which are

i Fisheries Act of 1992
ii Nigeria Fisheries Regulation
iii Exclusive Economic Zone Act
iv Nigeria Maritime Zone act
v Environmental Impact Assessment Act
vi Marine pollution prevention Act
vii Marine oil Pollution Emergency Act
viii Coastal and Inland shipping(cabbotage) Act
ix National inland waterways Authority Act
x Nigeria Export Processing zones act
xi Nigeria content development and monitoring Act
xii Endangered Species(control of international trade and tariffs) Act

## 5. SUGGESTED STRATEGIES FOR SUSTAINABILITY

### i. Ecosystem Based Fisheries Management (EBFM)

This is an approach that is believed to guarantee sustainability using management approaches that put in consideration the health of the ecosystem, human needs and biodiversity. Also the strategies incudes technology based catch limits, deliberate approach to protect the habitats and the management of multi-species interactions.

### ii. Marine Protected Area (MPA)

This is a strategy if well practiced can guarantee sustainability as it safeguards critical areas like the fish breeding grounds that is important for recruitment into the population and other critical habitats in the ecosystem. The MPA plays an important role in stock recovery and biodiversity conservation.

**(iii). Sustainable Aquaculture Practices** The concept of integrated multi-Trophic Aquaculture (IMTA) Has been discovered to be a good tool for sustainability. The approach is to combine species such as fin and shell fishes and aquatic sea weeds for full exploitation of ecological niches and waste recycling.

## 6. INNOVATIVE TECHNOLOGY FOR SUSTAINABILITY IN FISHERIES AND AQUACULTURE

1. Using AI in enhancing Fishing Craft and gears

-The challenge with traditional gears such as trawl nets, gill nets is low selectivity and high by-catch rates.
-Recent advances have ushered in AI- integrated fishing systems using smart nets, equipped with on board cameras and embedded deep –learning algorithms
which can distinguish between target and non-target species. This results in decision to release by-catch there by reducing unintended captures by up to 90% (Mandal *et al*., 2025).
-Fishing vessels are also evolving systems like AI – RCAS merge electronic monitoring with convolutional neural net-work to automatically identify species and count catches in real time thereby enhancing compliance with sustainability protocols (Kim et al 2024).

Smart gears outfitted with stereo cameras and embedded AI such as scantrol deep vision system(sdvs) can automatically measure and identify individual fish during retrieval thereby allowing immediate release of juveniles and and non-target species(Barbedo 2022)

### (a)AI in Fish Population Estimation

AI has emerged as a transformative tool in the monitoring and estimation of fish population offering unprecedented accuracy, efficiency and scalability compared to traditional methods. Historically, fisheries management relied on manual fish counting, net sampling and visual inspection which are labour intensive and prone to human error.

The integration of AI –powered tools such as;

- ❖ Imaging system
- ❖ Under water drones
- ❖ Acoustic sensor
- ❖ Machine learning models

Has significantly revolutionized data collection fish behavioral analysis and importantly fish stock assessment in marine and fresh water ecosystem

- ❖ These devices utilize high resolution cameras coupled with computer vision algorithms to detect and count fish in real time.
- ❖ Machine Learning (ML) models are being used for population estimation and behavioral prediction.

This models process large data sets including video, audio, environmental and historical data to infer trends in fish migration, breeding and feeding.

According to Cheng *et al.*, AI has facilitated the classification of fishing vessels behaviors and associated catches estimation thereby enabling regulatory authority to monitor compliance and enforce regulation.

## 7. ROLE OF AI IN REDUCING BY-CATCH AND OVERFISHING

One of the detrimental consequences of industrial fishing is by-catch the unintentional capture of non-targeted species such as Dolphins, Turtles and Juvenile fish

- Traditionally mitigating by-catch is left to fisher's discretion.
- Adventt of AI learning machine algorithms and computer vision tools can now identify target fish species with greater accuracy.
- Mundal *et al.*, 2025 observed AI enable sensor was integrated into fishing gear that was able to distinguish species in real time minimizing by catch by triggering automatic gear adjustment.
- AI powered acoustic sensors and sonar mapping tools also help in identifying fish school composition beneath the surface thereby allowing fishers to avoid endangered or Juvenile population
- AI powered tracking and surveillance reduce the incidence of IUU fishing (illegal unreported and unregulated) making quota system enforceable.
- Saleh et al., 2023 illustrated how underwater drones guided by AI models can assess sea floor condition in real time guiding trawlers to avoid ecological sensitive zones like breeding grounds.
- Smart fishing gears such as AI enable traps and selective nets further promotes sustainable harvest. They are sensory input and image processing to release non-target species automatically.

## 8. IOT APPLICATION IN FISHERIES AND AQUACULTURE

Internet of things (IOT) refers to a network of interconnected physical devices equipped with sensors and soft wares that collects and exchange data over the internet. IOT enables real time monitoring of environmental parameters such as; temperature, dissolved oxygen, pH turbidity EC, TDS etc

- IOT sensor monitor water parameters that are critical to fish health.
- Real time data from sensor help to detect anomalies and prevent disease outbreak.
- Use of smart buoys and floating sensor model relay data to centralize platform for analysis. This reduces the need for manual sampling.
- They apply PCA method to identify the primary factors influencing the variation of Ammonia Nitrogen content.
- Automated feeders integrated with IOT devices dispense feed at scheduled intervals or based on fish activities detected by sensors. This improves fish conversion ratios and minimize waste.
- The Arvo-Tec command module known as WOLF encompasses feeding, measurement, light control (photo period) and alarm functionalities execute feeding control with precision.
- GPA and RFID Tracking
  IOT based GPS tracking system are used for monitoring fishing vessels reducing illegal fishing activities and enhancing safety.
  RFID (radio frequency identification) tags are used to track fish from harvest to market ensuring quality and traceability Huang *et al.*, 2018.
- For example, Aqua cloud platform in Norway integrate IOT and AI to monitor salmon farm using predictive models to control lice infestations.

## 9. THE ROLE OF GEOGRAPHIC INFORMATION SYSTEM (GIS) IN FISHERIES SUSTAINABILITY

- GIS involves the use of spatial data and geospatial technologies to capture, store analyze and visualize geographic information for decision making and planning purposes.

- GSI addresses the gap in fisheries sustainability by providing insight into aquatic ecosystem, fish population dynamics and human interaction with marine resources.
- GSI operates on two major data types; Raster and Vector
- Raster data represent continuous surfaces like oceans temperature or chlorophyll concentration. Vector data represents discrete features such as; fishery zone, fishing vessel and protected areas.

**A. Use of GIS in Habitat Mapping**

Aquatic environment contains habitat environments such as coral reefs, mangroves, estuaries, flood plains and deep sea trenches.

I. The habitats are crucial for various life stages of fish such as spawning, nursery, feeding and migration. Effective fisheries management requires deserted spatial knowledge of these habitats.
II. GSI allows for accurate mapping of this environment using data from satelite imagery. Aerial photography, sonar mapping and in situ field and surveys.
III. Raster data such as bathymetry (underground topography) substrate type temperature gradient and salinity level can be overlaid vector data and this facilitate habitat classification
IV. In Nigeria mapping the flood plain of the Niger-Benue River using GIS provided insight into fish breeding zones, seasonal wetland dynamics and flood retention areas (Atu *et al.*, 2013)
V. Habitat classification through GIS is essential for ecosystem based fisheries management by delineating EFH (Essential Fish Habitat).

**B. Use of GIS in Stock Assessment and Specie Distribution Modelling**

- GSI plays pivotal role in SDM (Species Distribution Modelling) and fish stock assessment helping researchers to know where the fish are located in what number.
- Stock assessment is based on catch data sampling and survey. But when this data are specifically analyzed by GIS it will reveal patterns that may be invisible ordinarily.
- SDM involves predicting the model that geographic distribution of fish species using statistical and machine learning correlate known occurrence data with environmental factors like, Temperature, Depth Salinity.
- GIS serve as a platform to integrate this layers and apply models such as Max Ent (Maximun entropy), GLM (Generalized Linear Model) and ENFA (Ecological Nich Factor Analysis).
- In eastern pacific for example, GIS and SDM have been used to identify the potential corridors and spawning grounds of TUNA species based on oceanographic conditions derived from satellite data (Bloek *et al.*, 2011).
- In fresh water system GIS based models predicted distribution of Tilapia, Catfish and other species in Nigeria reservoir and rivers using water pH, turbidity and temperature (Onyeka and Asuquo 2014).

**C. USE OF GIS IN VESSEL TRACKING & FISHING EFFORTS**

- GIS when integrated with satellite based monitoring technologies such as VMS (Vessel Monitoring System) and AJS (Automatic identification system) help to prevent IUU fishing (Illegal Unreported and Unregulated).
- Procedurally VMS and AIS devices transmit like GPS coordinates, speed and hatching of fishing vessels at regular intervals which allows managers to visualize vessel roots to see if vessel is at restricted area such as breeding ground etc.

**d. Benefit of GIS in Fisheries Management**

- Improves data visualization
- Enhance evidence based decision making
- Better result allocation

- Support for ecosystem based management

Challenges in Using GIS in Fisheries
- Inadequate technical capacity
- Data scarcity
- Infrastructural limitation

## 10. POLICY RECOMMENDATION

**Capacity Building:**
The Federal Ministry of marine and blue economy should take the lead in training and re-training of fisheries personnel and students in GIS related technologies for stock assessment of our inland water bodies and protection of the ocean.

**Data Infrastructure:**
It has become very important that as a nation we develop national geospatial data repositories for fisheries and aquatic environment in Nigeria, Federal department of fisheries in conjunction with all training institutions in the fisheries sector should take responsibility.

**Collaboration:**
It appears to me that FDF is too far from the fisheries institution in Nigeria and from the various department of fisheries in Nigeria universities I recommend active partnership between FDF academia and the fisher folks for data sharing and technology deployment in fisheries management.

**Deployment of AI Tools:**
I recommend strongly the training in use of AI tools in fish population studies and stock assessment through advanced imaging systems, underwater drones etc.

**Enforcement of Fishery Laws:**
Evidence abounds of negligence in enforcement of Nigeria fisheries laws of 1992. Juveniles' fish skill litters our market explosives phytotoxic plants and chemicals are still being used in fishing. In view of this I recommend formation of inland and marine water guards for the purpose of enforcement of laws that borders in sustainability.

# LEAD PAPER PRESENTATION 2

# NIGERIA'S AQUATIC FOOD SYSTEM: PARTNERSHIPS FOR A SUSTAINABLE FUTURE

**Delivered by**
**Dr. Charles Iyangbe**
**Country Representative, WorldFish Nigeria**

**Opening**
Distinguished members of the Fisheries Society of Nigeria, esteemed colleagues, industry leaders, development partners, government representatives, and civil society actors, it is an honour to stand before you today as we celebrate FISON's 40th anniversary. This milestone marks four decades of impactful contributions to Nigeria's fisheries and aquaculture sector, advancing research, informing policy, and driving innovation. As the new Country Representative of WorldFish Nigeria, I am humbled to deliver this plenary. My background in business development and partnerships, including my experience as Regional Director for different international organizations, has shown me the transformative power of linking smallholder farmers to markets, finance, and innovations. I am convinced that science-driven solutions must be paired with scalable, business-driven strategies to sustainably transform Nigeria's fisheries and aquaculture sector. I'm excited to work with FISON and other stakeholders to harness the sector's potential and drive meaningful impact.

***Permit me to share with you some key insights about WorldFish***. WorldFish is a non-profit international research and innovation organization, one of the CGIAR Centers that has, for over 50 years, worked at the intersection of science, food systems, and sustainable development. As a member of CGIAR, the world's largest agricultural research partnership, WorldFish is dedicated to harnessing the potential of aquatic foods to nourish people, boost incomes, and restore ecosystems. Our work spans Asia, Africa, and the Pacific, with research and innovation in more than 20 countries. Over the past five decades, WorldFish has pioneered breakthroughs in science and technology such as the development and global dissemination of the Genetically Improved Farmed Tilapia (GIFT), now farmed in over 15 countries; advanced fish feed innovations that cut costs while improving nutritional value; and climate-smart aquaculture systems that strengthen resilience for millions of smallholder farmers and fishers. Globally, WorldFish's work has reached more than 11 million people directly through improved livelihoods, nutrition, and ecosystem restoration, and indirectly impacted over 50 million through policy influence and research adoption. Today, as we celebrate this legacy, we are equally committed to shaping the future of aquatic food systems for Nigeria and the world.

***Let me state here that the Nigeria's fisheries sector exists within a global, regional, and domestic context marked by interesting facts***. Globally, fisheries and aquaculture are crucial for food and nutritional security, providing over 20% of animal protein for 3.3 billion people (FAO, 2022) and supporting over 60 million jobs directly and millions more along the value chain.

In Africa, the significance is even more pronounced, with fish accounting for 18-20% of animal protein intake. Aquaculture is one of the continent's fastest-growing food production sectors. However, despite this growth, Africa still relies heavily on imports to meet its fish consumption needs, highlighting opportunities for growth and development in the sector. Here in Nigeria, fish is far more than food, it is culture, commerce, and community. The sector provides livelihoods for more than 10 million Nigerians, and aquaculture contributes over 500,000 metric tonnes annually, making Nigeria the largest aquaculture producer in sub-Saharan Africa (Federal Department of Fisheries, 2021). And yet, a sobering reality

remains: our national fish demand is estimated at 3.6–3.9 million metric tonnes annually, but domestic production accounts for only about 1.2 million tonnes (FMARD, 2023). This leaves a staggering gap of 2.4 million tonnes, filled through imports that cost the country more than USD 1.2 billion every year. Even more telling is the pattern of consumption. The average Nigerian consumes 11.3 kg of fish per year, well below the global average of 21 kg. Clearly, our production systems are not keeping pace with population growth and demand. Capture fisheries, though important, are increasingly strained by overfishing, pollution, and environmental degradation. The future of our food and nutritional security lies in transforming aquaculture. However, within this challenge lies enormous opportunity. Nigeria's rich aquatic ecosystems, from inland rivers and lakes to coastal lagoons and the Atlantic shoreline, represent vast, untapped potential for expansion. Integrated Multi-Trophic Aquaculture (IMTA), offshore cage culture systems, value chain innovations, and modern tools such as nuclear and genomic technologies for fish breeding are just some of the scalable solutions available to us. If we harness science, policy, and partnerships effectively, Nigeria can not only bridge its fish supply gap but also emerge as a net exporter of fish and seafood in the coming decades, strengthening food security, creating jobs, and driving a productive blue economy.

***It is no longer strange to us that the Nigerian aquaculture industry is at a crossroads, with pressing challenges that demand transformative solutions.*** These well-documented issues require immediate attention and innovative solutions to unlock the sector's full potential.

- Firstly, ***the high cost and scarcity of quality fish feed and genetically improved fingerlings*** continue to constrain production. Catfish genetic improvement programs are urgently required to reverse the declining growth performance observed in current stocks.
- ***The second challenge is the overreliance on Catfish.*** With catfish accounting for over 90% of aquaculture output, the sector faces risks of market saturation and stagnation. Diversification into tilapia, shellfish, and seaweed is now critical for resilience and growth of the sector.
- ***Thirdly, the influx of exotic species is worrisome.*** Efforts to diversify aquaculture have unfortunately led to the uncontrolled introduction of exotic species such as *Pangasius* and *Bramas*. Of particular concern is their culture in cages and flood-prone environments, raising the risk of escapees into natural ecosystems. Recent flooding events that wiped out entire farms highlight the urgent need for risk assessment and management protocols.
- The fourth problem is connected with ***technology gap***. A large proportion of farmers still depend on low-yield, traditional methods. There is an urgent need to scale up affordable, adaptable, and climate-smart technologies to boost productivity.
- **The fifth major challenge is *post-harvest losses*, where 50-80% of fish harvests are lost due to poor handling, inadequate storage, and outdated processing practices. Investing in locally developed cold-chain systems and storage solutions can significantly reduce waste and improve food security**.
- ***Finance and land access*** **continue to be key constraints.** Small and medium enterprises (SMEs), as well as youth and women, face persistent challenges in accessing finance and secure land tenure. Expanding offshore cage culture and Integrated Multi-Trophic Aquaculture (IMTA) systems offers inclusive pathways for scaling aquaculture.

***Where many see challenges, WorldFish sees opportunities; but only if we embrace deep collaboration across stakeholders***. At WorldFish, our mission is to harness the potential of aquatic foods to nourish people and sustain our planet. As you may be aware, we recently celebrated 50 years of global impact, and our work in Nigeria, though young, at just six years, is growing steadily and strategically. Some highlights include WorldFish blueprints in Nigeria are:

- **Asia–Africa BlueTech Superhighway (AABS)**: With support from the UK's Blue Planet Fund, WorldFish is advancing innovation in Nigeria through the AABS. This initiative is piloting Brackish-water Integrated Multi-Trophic Aquaculture (IMTA) systems in coastal states including Lagos, Ogun, and Ondo. Locally fabricated cage systems are being deployed while a wide range of stakeholders, farmers, extension agents, policymakers, lecturers, and government representatives are receiving training on innovative aquaculture practices. AABS is creating the scientific and practical foundation for scalable, climate-resilient aquaculture systems that can improve productivity and secure sustainable livelihoods across Nigeria's blue economy.
- **Genetically Improved Farmed Tilapia (GIFT) Scale-Up Program**: Since 2019, WorldFish has been at the forefront of enhancing aquaculture productivity in Nigeria through the GIFT scale-up program. This initiative focuses on decentralizing seed distribution in the Southwest and Niger Delta, introducing monosex GIFT tilapia to boost yields and diversify production beyond catfish. To date, the program has supported over 350,000 producer households with access to higher-performing fish breeds, quality aquatic animal feed, and best aquaculture practices. A major milestone was achieved in 2022, when WorldFish transferred 60,000 GIFT fry to Premium Aquaculture Ltd, marking a turning point in the decentralized GIFT seed supply system and paving the way for wider farmer adoption.
- **FASA Project**: Through the FASA project (Development and Scaling of Sustainable Feeds for Resilient Aquatic Food Systems in Sub-Saharan Africa), WorldFish is addressing one of the biggest constraints in aquaculture—the high cost of fish feed. By developing low-cost, nutritious, and locally sourced feed alternatives, the project reduces dependence on expensive imports while ensuring nutritional adequacy for farmed fish. In Nigeria, alongside Zambia and Kenya, the initiative is directly reaching 5,000 smallholder farmers, equipping them with feed innovations that lower production costs, improve profitability, and strengthen resilience across aquatic food systems.
- **Technologies for African Agricultural Transformation (TAAT)**: – Phases 1 & 2 Funded by the African Development Bank, TAAT is a flagship program advancing aquaculture across Africa, with activities in Benin, Burundi, Cameroon, Côte d'Ivoire, DR Congo, Ghana, Kenya, Malawi, and Zambia. The first phase focused on boosting agricultural productivity and household incomes. Building on this, Phase 2 (2022–2027) is expanding access to climate-resilient and productivity-enhancing technologies, particularly for low-income countries. Through partnerships with national research and extension systems and the private sector, TAAT supports aquaculture value chain actors with training on quality tilapia and catfish seed production, development of low-cost local fish feeds, and innovations for value addition. By strengthening extension and market linkages, TAAT is helping to scale aquaculture production, improve farmer livelihoods, and build resilience in Africa's aquatic food systems.
- **Promoting Sustainable Cage Aquaculture in West Africa (PROSCAWA)**: Implemented in Nigeria and Ghana with support from the International Fund for Agricultural Development (IFAD), PROSCAWA (2020–2023) worked with smallholder farmers to promote sustainable tilapia cage aquaculture. The project aimed to boost employment, incomes, and household nutrition by enabling rural communities to adopt productive cage farming practices in local waterbodies. The initiative demonstrated the viability of smallholder cage culture, with farmers harvesting 4.3 tonnes of fish in Ghana and 3 tonnes in Nigeria. Fish sales from both sites generated USD 16,700 in just six months, highlighting the potential of cage aquaculture to diversify farming systems, strengthen livelihoods, and contribute to food and nutritional security in West Africa.

***Beyond specific projects, our key role is to connect the dots, catalyse action, and foster synergies between research, policy, investment, and farmer practices.*** As I take the helm of WorldFish Nigeria, my vision is to drive solutions that are grounded in science, commercially viable, socially inclusive, and environmentally sustainable. Nigeria is at a pivotal moment where aquaculture can revolutionize food systems, generate employment opportunities, and enhance resilience to climate change. Let's work

together to harness this potential and create a more sustainable future for all.

My roadmap is anchored on five strategic pillars:

1. ***Scaling Through Local Partnerships****: Together with you all, we will move beyond pilots by connecting private investors and companies with communities to build commercially viable aquaculture systems that is driven by local context.*
2. ***Evidence for Policy and Investment****: We will generate robust data from pilots, engaging potential donors and policymakers with evidence, and advocating for enabling policies and counterpart funding to scale innovations nationally and internationally.*
3. ***Innovation and Intellectual Property****: We will localise cage systems and IMTA technologies, while protecting homegrown innovations to attract investment and shape Nigeria's aquaculture identity.*
4. ***Inclusion and Community Empowerment****: We will ensure that youth and women are equitably positioned to benefit from aquaculture growth. With Nigeria's unemployment challenge, aquaculture holds the potential to create hundreds of thousands of decent jobs if inclusivity is prioritized.*
5. ***Long-Term Sustainability****: Recognize the emerging realities about climate change, we will embed climate adaptation in fisheries and aquaculture through IMTA, ecosystem restoration, and resource-efficient production systems to protect aquatic ecosystems and strengthen resilience against climate change.*

By collaborating with you, our valued stakeholders, WorldFish Nigeria aims to position aquaculture as a driver of prosperity, equity, and sustainability for future generations. The transformation of Nigeria's fisheries and aquaculture sector requires a collective effort.

To achieve this, we need policymakers to trigger the design and implementation of enabling policies that incentivize investment, streamline regulations, and support infrastructure development. Researchers should focus on demand-driven, climate-resilient innovations that are practical, scalable, and farmer-friendly. The private sector must view aquaculture as a modern, profitable industry driving Nigeria's Blue Economy. FISON and its members should continue bridging research, policy, farmers, and markets, while championing advocacy, knowledge sharing, and capacity development.

***Together, we can unlock the full potential of Nigeria's aquaculture sector and create a more sustainable future***. Colleagues, Nigeria's fisheries and aquaculture sector is at a critical turning point. The challenges are significant, but the opportunities are greater still. Let us not be content with being a major fish-importing nation. Let us set our sights higher to become Africa's leader in aquaculture, overtaking even Egypt in the years ahead. This is not a dream; it is an achievable goal, if we work together. As we mark 40 years of FISON, let us also commit to the next 40 years of transformation, a Blue Transformation that positions Nigeria not only to feed its people but to power its economy, protect its environment, and uplift its communities.

Together, we can turn Nigeria's vast aquatic resources into engines of growth, resilience, and prosperity.

Thank you.

# LEAD PAPER PRESENTATION 3

# ASSESSING CONSERVATION PRIORITIES FOR THREATENED FRESHWATER FISHES OF NIGERIA

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**Abstract**
*This paper presents an overview of the status and distribution of freshwater biodiversity in West Africa, focusing on Nigeria, based on 20 years of IUCN project in the region. The richness of freshwater fishes in Nigeria, their threat status, key life history traits of threatened fishes, causes of threat, and conservation options are discussed. About 10% of freshwater fishes of Nigeria are threatened. 311 of the freshwater fishes of Nigeria were assessed, 43 are categorized as threatened by the latest IUCN Red Listing assessment of 2019. Eight (8) are Critically Endangered, twenty-two (22) are Endangered and eight (5) are vulnerable, and eight (8) are Near Threatened. 256 are of Least Concern while 12 were Data Deficient. Twenty-nine (29) species are endemic to the country. Most of these threatened fishes are all small-bodied fishes (<10cm TL), inhabiting marginal aquatic systems like swamps, backwaters, streams and pools, habitats that are easily destroyed by human activities. The study revealed low impact of wild collection, while the most important threat to these fishes is habitat degradation and loss, deforestation, climate change and pollution mainly from urban and industrial development, agricultural activities and petroleum industry in the Niger Delta. As a consequence of these threats, suggestions for prioritising conservation efforts and potential management interventions were discussed.*

**Keywords:** Fish, biodiversity, conservation, extinction, threat, freshwater

## INTRODUCTION

Freshwater ecosystems are the most endangered ecosystems in the world, though representing 0.5 of global surface water while more than 15,000 fishes they support are the most vulnerable due habitat modification, fragmentation, and destruction, overfishing, invasive species, pollution, deforestation and climate change. (Reid, 2013; Reid et al., 2013). Nigeria, with its extensive network of rivers, lakes, and wetlands, is home to over 300 species of freshwater fishes, representing about 10% of the continent's freshwater fish fauna (Lévêque et al., 2008). The hydrology of Nigeria is dominated by two major river systems, the Niger-Benue and the Chad systems. With the exception of a few coastal rivers that empty directly into the Atlantic Ocean, all other rivers drain into these two major rivers and Lake Chad. The coastal rivers flowing to the Atlantic include the Cross River fed by many tributaries originating in the Cameroon mountains and flows into the Atlantic Ocean with limited delta formation (Olaosebikan and Raji, 2021). The wetlands include the Niger Delta, Lake Chad and other coastal wetlands.

According to IUCN assessment, of the eight fish species-rich areas in West Africa, three are found in Nigeria (the Niger River Delta; Ogun River and Lower Cross River basin). This makes the freshwater fish diversity of Nigeria the highest in Western Africa (Smith et al., 2009). The Niger Delta is also one of the two main regions of endemism in Western Africa with over 20 endemic species. The Ogun and Cross Rivers are also known for their high number of endemic species. The fish fauna of Nigeria compared to other aquatic organisms is fairly well known at conventional taxonomic and biological levels. However, the status of this rich biodiversity in term of ecology and conservation has not been extensively studied

and documented. Earlier works by the author include Olaosebikan (2004), Olaosebikan and Bankole (2004), Olaosebikan and Musschoot (2013) and Adeyemo (2007). The IUCN projects (Starnes and Darwall, 2021) has fortunately provided an update on the global status and distribution of freshwater biodiversity in West Africa from which we can infer the status of Nigeria freshwater fishes.

**Threat Status of Freshwater Fishes in Nigeria**

There are 131 (24%) threatened freshwater fish species within the western African region, of which 21 (4%) are Critically Endangered, 66 (12%) are Endangered, and 44 (8%) are Vulnerable (Laleye et al., 2021). From this assessment, 311 of freshwater fishes of Nigeria were assessed, 43 (35 excluding Near Threatened) are categorized as threatened by the latest IUCN Red listing assessment of 2019. Eight (8) are Critically Endangered, twenty-two (22) are Endangered and eight (5) are vulnerable, and eight (8) are Near Threatened. 256 are of Least Concern while 12 were Data Deficient. Twenty-nine (29) species are endemic (Table 1 and Figure 1). These fishes belong to thirteen (13), namely Nothobranchidae (killifishes) (10), Cyprinidae (5) Alestidae (4), Distichodontidae (2), Dasyatidae (2), Mochokidae (2), Denticipitidae (1), Mormyridae (1), Amphiliidae (1), Claroteidae (1), Auchenoglanididae (1), Synbranchidae (1), Tetraodontidae (1). Table 2 shows IUCN RedList categories of each thse fishes. Majority of these fishes are found in the Niger Delta and to a lesser extent in Cross River and Ogun River basins. The only exception is *Protonothobranchius kiyawensis* which found in the Chad basin (Laleye et al., 2021).

Table 1: Number of Native and Endemic Freshwater fishes per IUCN Red list Category in Nigeria

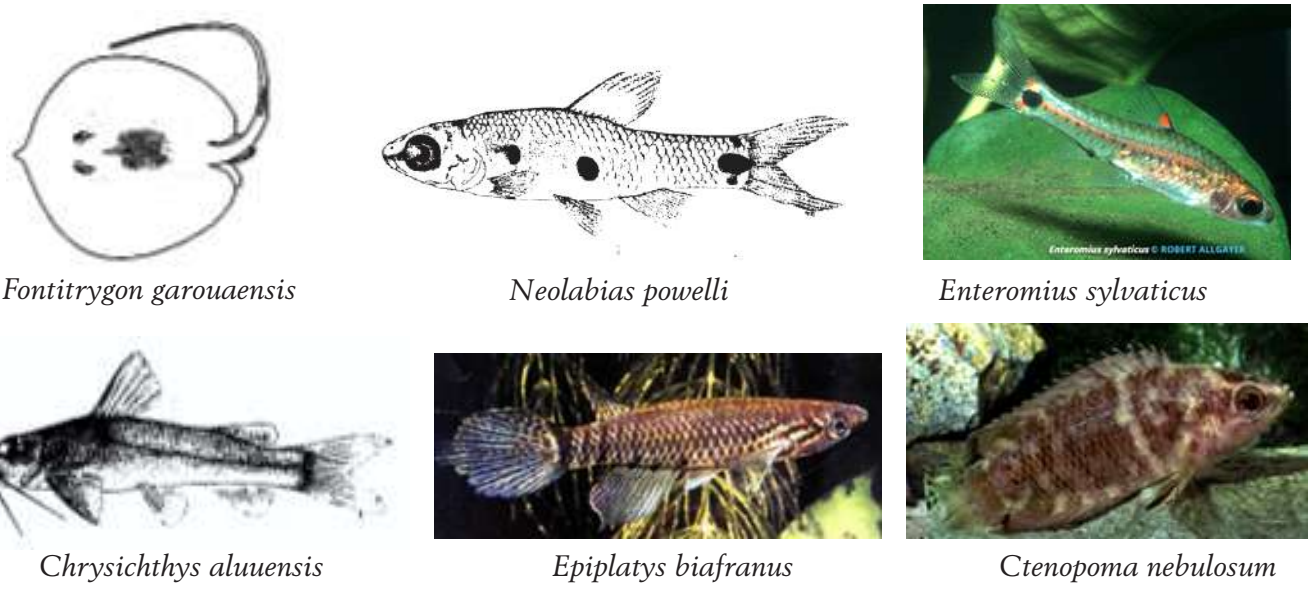
| IUCN Red List category | Number of Native Species | Number Endemic to Nigeria |
|---|---|---|
| Extinct (EX) | 0 | 0 |
| Extinct in the wild (EW) | 0 | 0 |
| Critically Endangered (CR) | 8 | 5 |
| Endangered (EN) | 22 | 7 |
| Vulnerable (Vu ) | 5 | 1 |
| Near Threatened (NT) | 8 | 3 |
| Least Concern (LC) | 256 | 7 |
| Data Deficient (DD) | 12 | 6 |
| **TOTAL** | **311** | **29** |

**Table 2:** Threatened freshwater fishes of Nigeria showing their threat status

| S/No | FAMILY NAME | SPECIES NAME | COMMON NAME | THREAT CATEGORY | OCCURENCE |
|---|---|---|---|---|---|
| 1. | Dasyatidae | *Fontitrygon ukpam* | Thorny freshwater stingray | Critically Endangered (CR) | Native |
| 2. | Dasyatidae | *Fontitrygon garouaensis* | Smooth freshwater stingray | Critically Endangered (CR) | Native |
| 3. | Denticipitidae | *Denticeps clupeoides* | Denticle herring | Vulnerable (VU) | native |
| 4. | Alestidae | *Alestopetersius smykalai* | Blue diamond characin | Endangered (EN) | endemic |
| 5. | Alestidae | *Brycinus brevis* | | Endangered (EN) | native |

| | | | | | |
|---|---|---|---|---|---|
| 6. | Alestidae | *Bryconaethiops quinquesquamae* | | Endangered (EN) | native |
| 7. | Alestidae | *Arnoldichthys spilopterus* | Niger tetra | Endangered (EN) | endemic |
| 8. | Mormyridae | *Marcusenius brucii* | | Vulnerable (VU) | endemic |
| 9. | Distichodontidae | *Neolebias axelrodi* | | Endangered (EN) | Endemic |
| 10. | Distichodontidae | *Neolebias powelli* | | Endangered (EN) | Endemic |
| 11. | Cyprinidae | *Leptocypris crossensis* | | Vulnerable (VU) | native |
| 12. | Cyprinidae | *Barboides gracilis* | | Vulnerable (VU) | native |
| 13. | Cyprinidae | *Enteromius clauseni* | | Critically Endangered (CR) | endemic |
| 14. | Cyprinidae | *Enteromius foutensis* | | Endangered (EN) | native |
| 15. | Cyprinidae | *Enteromius sylvaticus* | | Vulnerable (VU) | native |
| 16. | Amphiliidae | *Phractura ansorgii* | African whiptailed catfish | Endangered (EN) | native |
| 17. | Auchenoglanididae | *Notoglanidium akiri* | | Endangered (EN) | endemic |
| 18. | Auchenoglanididae | *Parauchenoglanis buettikoferi* | | Critically Endangered (CR) | endemic |
| 19. | Claroteidae | *Chrysichthys aluuensis* | | Endangered (EN) | native |
| 20. | Mochokidae | *Synodontis xiphias* | | Critically Endangered (CR) | endemic |
| 21. | Mochokidae | Synodontis gutatus | | Critically Endangered (CR) | endemic |
| 22. | Nothobranchiidae | *Epiplatys biafranus* | | Endangered (EN) | native |
| 23. | Nothobranchiidae | *Epiplatys longiventralis* | | Endangered (EN) | native |
| 24. | Nothobranchiidae | *Aphyosemion bivittatum* | | Vulnerable (VU) | Native |
| 25. | Nothobranchiidae | *Aphyosemion bualanum* | | Endangered (EN) | Native |
| 26. | Nothobranchiidae | *Fundulopanchax arnoldi* | Arnold's killi | Endangered (EN) | endemic |
| 27. | Nothobranchiidae | *Fundulopanchax gularis* | Gulare | Endangered (EN) | native |
| 28. | Nothobranchiidae | *Fundulopanchax powelli* | | Critically Endangered (CR) | endemic |

| | | | | | |
|---|---|---|---|---|---|
| 29. | Nothobranchiidae | *Fundulopanchax scheeli* | | Critically Endangered (CR) | native |
| 30. | Nothobranchiidae | *Fundulopanchax sjostedti* | Blue gularis | Endangered (EN) | native |
| 31. | Nothobranchiidae | *Fundulopanchax gularis* | Blue gularis | Endangered (EN) | native |
| 32. | Nothobranchiidae | *Pronothobranchius kiyawensis* | | Endangered (EN) | native |
| 33. | Anabantidae | *Ctenopoma nebulosum* | | Endangered (EN) | endemic |
| 34. | Synbranchidae | *Ophisternon afrum* | Guinea swamp eel | Endangered (EN) | native |
| 35. | Tetraodontidae | *Tetraodon pustulatus* | | Endangered (EN) | native |



*Fontitrygon garouaensis* *Neolabias powelli* *Enteromius sylvaticus*

*Chrysichthys aluuensis* *Epiplatys biafranus* *Ctenopoma nebulosum*

*Fig. 1: Some of the threatened fishes of Nigeria*

**Key life history traits of threatened fishes in Nigeria**

Life histories underscore the demography of fish populations and therefore dictate intrinsic vulnerability to decline, recovery potential and, ultimately, extinction risk (Winemiller, 2005). Looking at the threatened fishes in Nigeria, there are some characteristics that is common to them and these are enumerated below

**1. Body size**

Body size is a fundamental ecological parameter correlated with growth, which in turn is associated with natural mortality rates, longevity, age at maturity and reproductive output (Pimm, 1982; Peters, 1983). Most of the 35 threatened fishes recorded in Nigeria are small in size of less than 10 cm in total length, 80% are less than 5 cm while the smallest is 1.5 cm. A number of regional studies have shown that maximum body size is predictive of extinction threat for freshwater and marine species. (Jennings et al., 1998; Dulvy et al., 2003; Reynolds et al., 2005).

**2. Habitat of occurrence**

Most of the threatened freshwater fishes inhabit highly vulnerable aquatic habitats like swamp, ponds, streams and seasonal pools. These habitats determine the extent of occurrence and area of occupancy of

these fishes. These are habitats that are susceptible to environmental changes like climate change. Human activities like pollution, sand-filling, draining is a major threat to these aquatic habitats and their flora and fauna. Habitat fragmentation is often a cause of species becoming threatened or endangered due to habitat degradation. The annual killifish, *Pronothobranchius kiyawensis* that inhabit temporary pools in the Sahel region faces serious threat from desertification, climate change and water abstraction.

**3. Small Extent of Occurrence (EOO) and Area of Occupancy (AOO)**

Two of the major criteria for categorizing an organism in IUCN Redlisting are Small Extent of Occurrence (EOO) and Area of Occupancy (AOO). **Extent of Occurrence (EOO)** is the broad geographic region covering all known sites of a species (minimum convex polygon), while **Area of Occupancy (AOO)** is the smaller, actual area *within* the EOO where the species lives, measured using standardized grids (like 10x10 km) to show habitat fragmentation and suitability. Both are used to assess risk under Criteria B and D for threatened categories like Vulnerable, Endangered, and Critically Endangered categories (IUCN, 2012). EOO gives the general location, while AOO reveals the quality and fragmentation of the habitat within that range, providing a more complete picture of extinction risk. Most of the threatened fish in Nigeria falls under Criteria B and D (Small, Restricted Population). This thresholds for AOO indicate high risk of extinction.

**4. Important in aquarium trade**

Twenty-seven of the threatened fishes in Nigeria are small beautiful fishes of ornamental importance (Figure 2). The killifishes are known globally in aquaria and pet fish trade. In Europe and United States of America (USA), there are killifish associations promoting the hobby of keeping these fishes. They are mostly easy to breed in captivity.



*Alestopetersius smykalai* *Fundulopanchax Arnoldi* *Tetraodon pustulatus*

*Fig. 2: Some of the threatened fishes that are of ornamental importance*

**Threats to freshwater fishes in Nigeria**

The most commonly coded threats to freshwater fish species of western Africa according to the latest IUCN assessment (Laleye et al., 2021) are multifaceted and have severe impacts on the country's aquatic biodiversity.

**1. Habitat Degradation and Loss which include deforestation, pollution, and infrastructural development.**

Deforestation involves clearing of forests for agriculture, urbanization, and logging leads to sedimentation and habitat destruction. Pollution can be as a result of industrial, agricultural, and domestic pollutants contaminating water bodies, affecting fish health and survival. While infrastructure development includes but not limited to dams, canals, and other infrastructure projects that alter fish habitats and disrupt fish migration patterns.

2. **Bad Fishing Practices**

Most of the threatened fishes of Nigeria are not directly impacted by unawesome fishing practices except

for the Smooth and Spiny Stingrays which are taken as bycatch in the large variety of fishing gear used by fishing communities along Nigerian river systems which include beach seines, gillnets, weirs, traps, castnets, hook and line, longlines and other traditional artisanal gear such as local fish ponds (Knaap 1994, Abowei and Hart 2008). They are usually consumed event though they are not the target species. *Denticeps clupiodes* are also impacted by gears use in exploiting freshwater sardines.

**3. Invasive Species**

Water hyacinth (*Eichornia crassipes*) This invasive aquatic plant have choked many water bodies thereby reducing habitat diversity and affecting fish populations.

**4. Climate Change**

Climate change has been shown to alters water temperature and flow patterns affecting fish reproduction, growth, and survival. For small sized fishes that inhabit small ponds, swamps, marshes, the effect of climate change is more severe with increased frequency of extreme events like droughts, floods, and other extreme events.

**Conservation Options**

According to Laleye et al., (2021), a number of conservation measures were recommended in the IUCN assessment of Western African Freshwater biodiversity conservation. They include the followings:

**Establishment of protected areas**

There are nearly 2,000 protected areas in western Africa with most of these being small forest reserves, but very few have a focus on freshwater ecosystems, either in relation to their spatial cover or within their management plans (UNEPWCMC, IUCN and NGS, 2018). The findings from IUCN assessments reported here highlight a number of areas notably rich in freshwater fish diversity where site protection would be beneficial. The sites identified in Nigeria include:

1. The Lower Niger Benue with its rich fish fauna, which includes around 289 species;
2. The interconnected network of rivers and coastal lagoons from Lagos Lagoon to Cros Rivers Coastal ecoregion, and;
3. The Niger Delta with its rich fish fauna (an estimated 221 species) threatened by oil pollution.

**Habitat restoration**

Freshwater ecosystems are the most endangered ecosystems in the world, though representing 0.5 of global surface water due habitat modification, fragmentation, and destruction, pollution, deforestation and climate change (Reid, 2013). The western Africa assessments have identified where freshwater fish species are threatened due to habitat loss and degradation. There is need to use this information to inform priorities for habitat restoration to benefit freshwater fish species across the region. Restoring degraded aquatic habitats and the natural processes that sustain them is crucial for the recovery and resilience of fish populations. This can involve physical intervention like removing obsolete dams or barriers to restore connectivity and natural flow regimes; restoring natural processes (seasonal flooding (which creates essential spawning and nursery habitats), improving water quality by reducing pollution, and controlling soil erosion).

**Awareness and Communication**

Public awareness campaigns are crucial for fostering sustainable practices and inspiring behavioral change among various stakeholders, including local communities, fishers, and policymakers. It is therefore important to launch public awareness campaigns at all levels on the current and future threats to freshwater biodiversity and the ways in which individual people can contribute to the future conservation of this resource.

**Research Actions**

IUCN assessment noted some improvement in our understanding of the diversity of freshwater fishes in western Africa, although major gaps in our knowledge persist. This lack of a suitable information baseline represents a major impediment to the conservation of freshwater diversity (Smith et al., 2009). An analysis of the Red List assessments conducted western Africa shows that for 76% of species, specific research actions are recommended. Of these, the most commonly requested research themes are to monitor species "population trends" (for 62% of species), and to understand more about species "population size, distribution and trends" (56%), "life cycle and ecology" (49%), and "threats" (45%) ((Laleye et al., 2021).

**Integrated Catchment Basin Restoration**

An integrated approach considers the entire river basin or watershed, recognizing that upstream activities affect downstream ecosystems. Integrated approach entails holistic management involving coordinated efforts across different sectors (agriculture, industry, urban development) and jurisdictions to manage water resources sustainably. Sustainable land use to promote sustainable land use practices, such as minimizing runoff from farms and protecting riparian zones, helps maintain overall watershed health. To achieve this require developing and enforcing integrated policies and regulations that support ecosystem-based management and balance competing water demands essential for long-term success.

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# AQUATIC BIODIVERSITY AND BIOMONITORING-ABB

# THE FISH FAUNA INVENTORY OF KASHIMBILA RESERVOIR AND SELECTED LOCATIONS ALONG THE STRETCHES OF THE FEEDER RIVER, TAKUM, NIGERIA

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ABSTRACT
*This study conducted a comprehensive assessment of fish faunat in the Kashimbila Reservoir, Takum, Nigeria, over a period of 24 months to characterize species diversity and spatial distribution within this important reservoir ecosystem. This study conducted a comprehensive assessment employed experimental gill netting using nets of varying mesh sizes (1.5–7 inches) with the dimensions of the nets 30 meters in length and 3 meters high, deployed at five sampling sites strategically positioned upstream, within, and downstream of the reservoir. In total, 34 fish species belonging to 15 families were documented, reflecting substantial species diversity across sampling zones. Families caught included Cichlidae, Claroteidae, and Mormyridae notably with variation in species richness observed along the upstream-downstream gradient. The inventory contributes critical baseline data on the ichthyological structure of the Kashimbila Reservoir and supports future conservation and resource management initiatives in Nigeria's freshwater systems in the face of increasing anthropogenic pressures.*

**Keywords:** Fish fauna, Reservoir, Gill netting, Species diversity, Kashimbila Reservoir

## INTRODUCTION

Reservoirs are increasingly recognized as critical aquatic ecosystems that support biodiversity, provide livelihoods, and contribute to food security, particularly in developing regions (Zhao et al., 2020). In Nigeria, inland water bodies such as rivers, lakes, and reservoirs are vital for artisanal fisheries, yet many remain under-documented in terms of their ichthyofaunal composition (Egesa *et al*., 2020). The Kashimbila Reservoir, located in the Takum Local Government Area of Taraba State, is one such ecosystem that has gained ecological and socio-economic importance following its construction for flood control, irrigation, and hydroelectric power generation.

Understanding the fish species composition and diversity within this reservoir is essential for sustainable fisheries management and conservation planning. Recent studies have highlighted the dominance of families such as Cichlidae and Clariidae in the reservoir, with species like O*reochromis niloticus* and C*optodon zillii* frequently recorded in gillnet catches (Bingari *et al*., 2025). However, there remains a paucity of comprehensive ichthyofaunal inventories that capture seasonal dynamics, trophic structures, and species richness in this water body.

This study aims to provide an updated inventory of the ichthyofauna of the Kashimbila Reservoir, contributing to the baseline data necessary for ecological monitoring and resource management. By documenting species composition, abundance, and distribution, this research seeks to inform policy and promote the sustainable utilization of the reservoir's fisheries resources.

## MATERIALS AND METHOD

### Study Area

The study was conducted at the Kashimbila Reservoir, situated in Takum Local Government Area, Taraba State, Nigeria. The reservoir lies within Latitude: 6.874167°N, Longitude: 9.761944°E, in the southern Guinea savanna zone and experiences distinct wet and dry seasons, influencing its hydrology and ecology.The sampling location coordinates were also taken using GPS Garmin map78Sc model

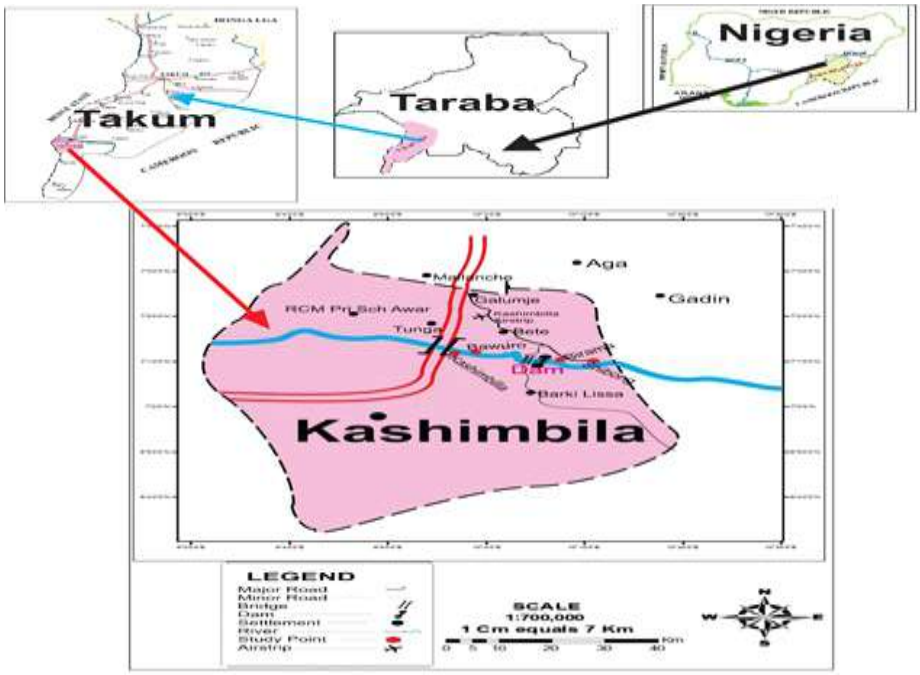



***Figure 1: Map of the study Area***
*Source: Geography Department Taraba State University, Jalingo*

### Experimental Fish Sampling

The assessment of the fish species composition of Kashimbila Reservoir was carried out by employing experimental fish sampling. The collection was done monthly for 24 months from August 2018 to July 2020. In the experimental setup, a fleet of gillnets made up of multifilament gill nets of various mesh sizes was set up at the various sampling stations at the shore, surface, and bottom water habitats. The net sizes were 1.5 inches, 2.25 inches, 3.0 inches, 4.0 inches, 5.0 inches, 6.0 inches, and 7.0 inches. Each net measured 30 meters long and 3 meters high. These nets were set simultaneously at the various sampling sites between 5 pm - 6 pm and were harvested in the morning between 7 am -8 am. Fish caught by each net were sorted and placed into a labelled container with the mesh size and station where it was caught.

### Fish Identification

Fish were identified using relevant identification guides by Olaosebikan and Raji (2000, 2013 editions); Suleiman (2016), Teugels (1986), and in line with Fishbase

## RESULTS AND DISCUSSION

Table 1 Shows the inventory of the fish species in Kashinbila Reservoir. Thirty-four (34) individual species belonging to 15 families were caught in the experimental gill netting across the five sampling locations earmarked for the study for the 2 years. The reservoir itself recorded a consistently high number of species, including *Hydrocynus forskahlii*, *Mormyrus rume*, *Lates niloticus*, and *Distichodus engycephalus because of food availabilty*. This suggests the reservoir serves as a stable and productive habitat that supports both predator and forage fish populations (Akinyemi *et al.*, 2021). The record of *Oreochromis niloticus* and *Lates niloticus* underscores the reservoir's potential for fisheries development,

as these species are significant for both commercial and artisanal fishing in West Africa (FAO, 2022)

**Table 1:** Ichthyo-faunal Inventory of Kashimbila Reservoir and Stretches of the Feeder River

| Family | Fish species | Authority | Locations/Presence | | | | |
|---|---|---|---|---|---|---|---|
| | | | Shibong | Birama | Reservoir | Bawuro | Kashimbila |
| Alestidae | *Brycinus brevis* | (Boulenger, 1900) | ✓ | ✓ | - | - | ✓ |
| Alestidae | *B. nurse* | (Rüppell, 1832) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Alestidae | *H. brevis* | (Günther, 1864) | ✓ | ✓ | - | - | - |
| Alestidae | *H. forskahlii* | (Cuvier, 1819) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Alestidae | *H. vittatus* | (Castelnau, 1861) | ✓ | ✓ | - | - | ✓ |
| Bagridae | *Bagrus bajad* | | ✓ | ✓ | ✓ | - | - |
| Channidae | *P. obscura* | (Günther, 1861) | ✓ | ✓ | - | - | - |
| Cichlidae | *Coptodon zillii* | (Gervais, 1848) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Cichlidae | A tilapian | | ✓ | ✓ | - | - | - |
| Cichlidae | *O. aureus* | (Steindachner, 1864) | ✓ | ✓ | - | ✓ | ✓ |
| Cichlidae | *O. niloticus* | (Linnaeus, 1758) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Cichlidae | *S. galilaeus* | (Linnaeus, 1758) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Citharanidae | *C. citharus* | (Geoffroy Saint-Hilaire, 1809) | ✓ | ✓ | - | - | ✓ |
| Citharanidae | *Citharanus latus* | (Geoffroy Saint-Hilaire, 1809) | ✓ | ✓ | - | - | ✓ |
| Claridae | *C. anguillaris* | (Linnaeus, 1758) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Claridae | *Clarias gariepinus* | (Burchell, 1822) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Clarotidae | *A. occidentalis* | (Valenciennes, 1840) | ✓ | ✓ | - | ✓ | ✓ |
| Clarotidae | *C. nigrodigitatus* | Geoffroy Saint-Hilaire, 1809 | ✓ | ✓ | ✓ | ✓ | ✓ |
| Clarotidae | *C. laticeps* | Rüppell, 1829 | ✓ | ✓ | ✓ | - | ✓ |
| Cyprinidae | *Labeo coubie* | (Rüppell, 1832) | ✓ | ✓ | ✓ | - | - |
| Cyprinidae | *Labeo parvus* | (Boulenger, 1902) | ✓ | ✓ | - | - | ✓ |
| Distichodontidae | *D. engycephalus* | (Günther, 1864) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Distichodontidae | *D. rostratus* | (Günther, 1864) | ✓ | ✓ | - | - | ✓ |
| Latidae | *Lates niloticus* | (Linnaeus, 1758) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Malapterudae | *M. electricus* | (Gmelin, 1789) | ✓ | ✓ | ✓ | - | ✓ |
| Mochokidae | *S. batesonda* | (Boulenger, 1906) | ✓ | ✓ | ✓ | - | - |
| Mochokidae | *S. nigrita* | (Valenciennes, 1846) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Mormyridae | *H. bebe* | (Linnaeus, 1758) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Mormyridae | Mormyrus rume | (Valenciennes, 1846) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Mormyridae | *M. oudoti* | Daget, 1954 | ✓ | ✓ | - | - | ✓ |
| Mormyridae | *M. anguiloides* | Leach, 1818 | ✓ | ✓ | ✓ | ✓ | ✓ |
| Mormyridae | *C. tamandua* | (Günther, 1864) | ✓ | ✓ | ✓ | - | ✓ |
| Schilbeidae | *Schilbe mystus* | (Linnaeus, 1758) | ✓ | ✓ | ✓ | ✓ | ✓ |
| Tetraodontidae | *T. lineatus* | (Linnaeus, 1758) | ✓ | ✓ | - | - | - |

✓ present at sampling location in both years
✓ Present at sampling location in only one year – absent

**Note**: Full genus names are on plates



**Plate I:** Lateral view of *Brachyalestes nurse*



**Plate II:** Lateral view of *Brycinus brevis*



**Plate III:** Lateral view of *Hydrocynus brevis*



**Plate IV:** Lateral view of *Hydrocynus vittatus*



**Plate V:** Lateral view of *Hydrocynus Forskahlii*



**Plat VI:** Late-ventral view of *Bagrus bajad*



**Plate VII:** Lateral view of *Parachana obscura*



**Plate VII:** Lateral view of *Coptodon zillii*



**Plate IX:** Lateral view of A tilapia



**Plate X:** Lateral view of *Oreochromis niloticus*



**Plate XI:** Lateral view of *Sarotheradon galilaeus*



**Plate XII:** Lateral view of *Citharanus citharus*



**Plate XIII:** Lateral view of *Citharanus latus*



**Plate XIV:** Dorso-lateral view of *Clarias gariepinus*

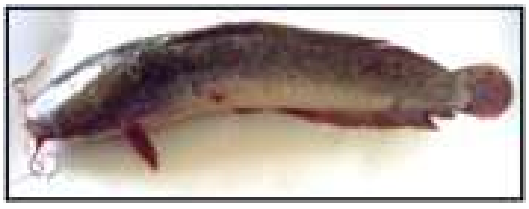


**Plate XV:** Lateral view of *Clarias anguillaris*

## CONCLUSION

The families caught in Kashimbila Reservoir include Cichlidae, Claroteidae, and Mormyridae notably with variation in species richness observed along the upstream-downstream gradient. This inventory contributes critical baseline data on the ichthyological structure of the Kashimbila Reservoir and supports future conservation and resource management initiatives in Nigeria's freshwater systems in the face of increasing anthropogenic pressures.

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# FISHERIES RESOURCES OF LAKE ALAU, NORTHEAST NIGERIA: A REVIEW

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**ABSTRACT**

*Lake Alau is located in the Northeastern Nigeria specifically in Maiduguri, the capital city of Borno state with important freshwater resource for irrigation, fishing and aquaculture purposes. This review aims at the provision of an extensive analysis of the fisheries resources of Lake Alau, with a special focus on its fish species composition, aquatic biodiversity, and ecological problems. The review documented 18 fish species from 12 families across 13 landing sites. Emphasis was placed on understanding the implications of fish community structures, their biological characteristics, and the environmental factors influencing fish productivity in the lake. The article also explores Lake Alau's role in local communities and its potential for sustainable management to support long-term fisheries viability.*

**Keywords**: Fisheries, Lake Alau, Biodiversity, Fish Species, Northeast Nigeria, Sustainable Management.

## INTRODUCTION

Nigeria is blessed with over 14 million freshwater bodies ranging from reservoirs, lakes, pond and Major Rivers (ha) that are capable of producing over 980,000 metric tons of fish annually (FDF 2007). However, most of these water bodies were built on seasonal rivers with paucity of fish species composition, resulting in low fish productivity (Mshelia *et al*., 2015). Statistics have shown that the demand for fish in the country exceeds the supply and also, the domestic production is over 980,000metric tonnes, considering the increasing human population. The annual fish consumption or demand in Nigeria has been estimated to be over 1.3 million metric tons and the total domestic production is just about 450,000 metric tons per annum. Lakes are invaluable ecological resources that serve many human needs and therefore, providing a lot of opportunities by improving human lives in many ways. This explains why a large proportion of Nigerian population live near water bodies such as lakes, reservoirs, rivers, swamps and coastal lagoons. Many riverine communities depend heavily on the resources of such water bodies as their main source of animal protein and family income (Haruna *et al*, 2006).

The significance understanding of the status of freshwater fisheries resources, notably focusing on Lake Alau, is underscored (Fierro *et al*., 2017). In recent decades, human activities such as agriculture, land use alterations, increased surface waterproofing resulting in amplified runoff and concentrated pollutants, unprocessed wastewater discharges, and the influence of climate change have collectively precipitated a widespread deterioration in the quality of surface waters. The degradation we observed underscores the critical importance of effective management practices includes: encompassing hygiene, environmental sanitation, storage, and disposal. These factors are pivotal in preserving our valuable water resources (Smith *et al*., 2020). The lakes fisheries productivity may not be optimized due to lack of ecological studies. For optimal management, providing information on fisheries resources is crucial. In view of the imperative roles of Lake Alau to Borno State and Nigeria in general, this work seeks to review the fisheries resources of the Lake.

## GEOGRAPHICAL AND ECOLOGICAL OVERVIEW OF LAKE ALAU

Lake Alau was created in 1987 on River Ngadda for the purpose of supplying portable water to Maiduguri metropolitan as well as for irrigating over 8,000 ha of farm lands in the catchment area of the reservoir Odunze *et al.,* (1995). Lake Alau is located on latitude 11° 41 N and longitude 13°16 E on the South Eastern (SE) part of Maiduguri (Fig. 1), capital of Borno State, Nigeria (Idakwo and Abu 2004; Google Earth 2008). The lake supplies the municipal water treatment plant, the major source of drinking water supply to the capital, apart from sporadic water obtained from boreholes. The lake also gives room to a significant number of agricultural activities for an estimated population of 521,492, 211,204 and 156,564 in Maiduguri, Jere and Konduga respectively (FRN 2007). The area is characterized by two distinct seasons, dry season (October to June) and wet season (July to September) with an average annual rainfall of 470 mm (for 1981 to 2010 weather data) as reported by Dammo *et al.,* (2015). The dry season is preceded by a period of harmattan (a dusty, dried, cool and windy breeze blown from the Sahara Desert from North Africa) between Novembers to February Umaru *et al.*, (2014). The lake has a relative humidity of 49% with temperature range of 28°C to 46°C for both seasons. It has a maximum storage capacity of 546,000,000r (CBDA, 1984). It has a mean depth of 9.5 m and total alkalinity of 38.4 mg/l (Idowu, 2004; Idowu *et al.*, 2004).

In Lake Alau, Temperature is low in December and January and high around April and May, with minimum and maximum values of 22 and 40°C respectively. The soil of the area is predominantly sandy loam (Arku, *et al.*, 2011). There are 16 species of fish in Lake Alau (Bankole and Mbagwu 2000) and farming of several fresh vegetables (Uwah *et al*. 2007) takes place all year around, thus making Lake Alau a very significant water body to Maiduguri and Nigeria.

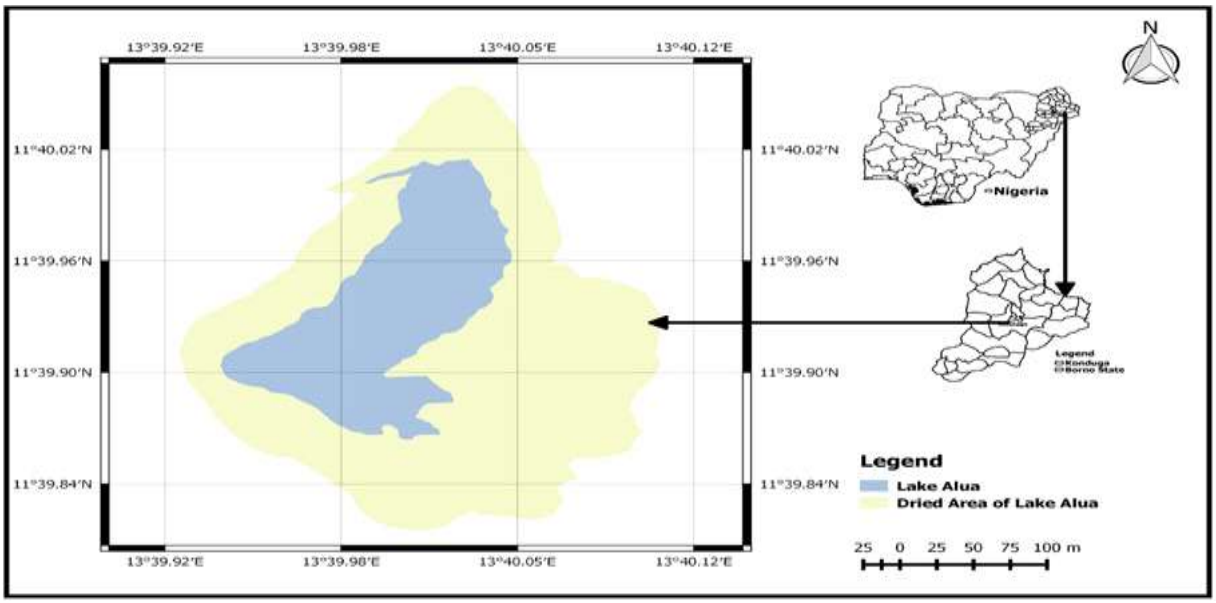



**Figure 1:** Map of Lake Alau, Borno state, Nigeria

Lake Alau has Thirteen (13) noticeable landing sites (Table 1) of which five landing sites are notable and used usually by scientist for sampling based on certain factors such as accessibility to the area, security and fishing activities. These stations are Abari fishing community, Daban Ali Zaki, automatic spillway, Gada and Musari landing sites. Abbari fishing community is about 500 m from the bank of the lake shore where students of the department of fisheries usually conduct their practical. It is one of the landing sites very close to main dam. Daban Ali Zaki is located closed to the community of Alau town. Low farming activities take place here the water is deep and flows faster. Automatic spillway is located 500 meters away to northward of Daban Ali Zaki; farming activities such as irrigation are carried out here at small scale level. Gada site is located close to one of the Large fishing camp of fishermen; a lot of human

activities are taking place in this station. Musari landing site is the largest landing side for canoe fishermen (Gwana *et al.*, 2017)

**Table 1:** Landing sites of Lake Alau

| S/N | Landing sites of Lake Alau |
|---|---|
| 1. | Abbari fishing community |
| 2. | Alau Ngaufate |
| 3. | Aliganari |
| 4. | Automatic spillway |
| 5. | Birmari |
| 6. | Burteri |
| 7. | Daban yerbirgi |
| 8. | Daban Ali Zaki |
| 9. | Gada |
| 10. | Kedari |
| 11. | Kulomari |
| 12. | Laujeri |
| 13. | Musari |

***Sources:*** *Bankole et al., 1995 and Mshelia et al., 2015*

## FISH SPECIES COMPOSITIONS OF LAKE ALAU

Odunze conducted the first species composition survey of lake Alau, three years after its formation and found 10 species representing 7 families, these includes *Oreochromis niloticus*, *Sarotherodoen galileus* and *Tilapia zilli* (Cichlidae) *Alestes nurse* (Characidae) *Schilbe mystus* (Schilbeidae) *Synodontis nigrita* (Mochokidae) *Clarias anguillaris* (Clariidae) *Marcusenius psittacus*, *Gnathonemus abadii* (Mormyridae) and *Protopterus annectens* (Lepidosirenidae). Although fishing is not the main reason why the lake was constructed but it serves as additional benefit for the nearby communities (Odunze *et al.*, (1995). The subsequent study carried out on the lake by Bankole *et al.*, (1994) was a survey of the catches obtained by fishermen. His studies revealed 16 species representing 9 families. An additional 2 species were recorded for the Mochokidae (*Synodontis batensoda* and S. *nigrita*) 1 additional species for the Characids (*Micralestes acutidens*).Two new families recorded were Polypteridae represented by *Polypterus senegalus* and Cyprinidae represented by *Labeo parvus*. Mshelia *et al.*, (2015) recorded seventeenth (17) fish species (table 2) of nine (9) families in eight (8) landing sides (table 1) of the same species mentioned in the lake. And he concluded that the fish species composition of the lake was declining in both quality and quantity.

Mshelia *et al.*, (2015) reported the estimate of fish caught in Lake Alau (Table 2) by which mean catch effort of fisher folk/trip varies from 1 kg to 12.5 kg/canoe with a total of seventeenth (17) different fish species, belonging to nine (9) different families. Cichlids dominated the catches in Lake Alau paticularly *Tillapia zillii*, *Oreochromis niloticus* and *sarotherodon galileus*. Although the catches of *clarias* reflected a promising size, but the catch in general showed a small sized fishes even though most of the species can attain sexual maturity. However, with the twelve (12) fish families and eighteen (18) fish species in lake Alau recorded by this present study, the lake is comparable with fish diversity in other small lakes, reservoir as reported by Balogun and Auta (2001), who reported nine (9) fish families and nineteen (19) fish species in Kingimi lake. They also reported that Cichlids dominated the catch. Ita (1984) reported a dominance of fish family cichlidae in Tiga Dam. Others who had similar reports were Balogun *et al.*, 2000 in Zaria reservoir; Kingimi Lake (Balogun and Auta, 2001) and ero reservoir (kester *et al.*, 2007). Mshelia *et al.*, (2015) reported 379 fisher folks, 254 canoes and 6 fishing gears in Lake Alau. However, Majority of this fisher folks are part time fishers who also engaged in farming activities. The fishing gears recorded includes gill net, cast net, traps, long line, baby hook and hook and line this differs with report by Bolagun

and Auta (2001) on lake Kangimi in which gear recorded includes cast net, gillnets, long line and dugout canoe for transportation system.

**Table 2:** Fish Species Composition of Lake Alau by different Authors

| S/N | Families | Species | Common Names |
|---|---|---|---|
| 1 | Cichlids | *Tillipia zillii*, *Oreochromis niloticus*, *Himechromis bimaculatus* | Red belly Tilapia, Nile Tilapia, Jewel cichlid |
| 2 | Characidae | *Alestes nurse* | African characin |
| 3 | Schilbeidae | *Schilbe intermedius*, *Saratherodan galileous* | Silver catfish, Galilee Tilapia |
| 4 | Mochokidae | *Synodontis nigrita Synodontis eupterus* | Black synodontis, Featherfin squeaker |
| 5 | Claridae | *Clarias gariepinus Clarias angularis* | African sharp tooth catfish, Mudfish |
| 6 | Mormyridae | *Hyperopsis bebe accidantalis Marcusenius Psitt acus* | Western electric fish, Parrot Momyrid |
| 7 | Lepidosirenidae | *Protepterus annectens* | African Lungfish |
| 8 | Cyprinidae | *Labeo sengalensis* | African bonytongue |
| 9 | Osteoglosisdae | *Heterotis niloticus* | African arowana |
| 10 | Centropomidae | *Lates niloticus* | Nile perche |
| 11 | Bagridae | *Bagrus bayad bayad* | Bayad catfish |
| 12 | Polypteridae | *Polypterus senegalus* | Senegal bichir |

*Sources: Bankole et al., 1994, Mshelia et al., 2015 Aliyu et al., 2018; Sabo et al., 2020; Ibrahim et al., 2021.*

## ENVIRONMENTAL FACTORS AFFECTING FISH PRODUCTION

Several environmental factors influence fish production in Lake Alau. According to Kavue *et al*., (2021), Water quality parameters such as temperature, pH, dissolved oxygen, and turbidity are critical determinants of fish health and productivity. During the rainy season, increased sedimentation and runoff can degrade water quality, leading to high temperature and low dissolved oxygen levels that adversely affect fish survival rates (Fisher *et al*., 2019).

Climate change is another significant factor influencing the lake's fisheries. Rising temperatures and altered rainfall patterns have the potential to change water quality issues, reduce fish spawning success, and alter the abundance and distribution of fish species in the lake (Ibrahim *et al*., 2021).

## ECONOMIC AND SOCIAL IMPORTANCE

Fishing and irrigation are the major economic activities in the region surrounding Lake Alau. The surrounding community relies on the lake for both subsistence and commercial fishing. According to Aliyu *et al*. (2018), the fisheries sector around Lake Alau provides employment for thousands of individuals, from fishermen to up takers, processors and marketers. The fish harvested provides a vital source of protein, contributing to food security and provide livelihood. Aquaculture is also growing in importance as a supplementary livelihood activity in the region. The introduction of species like *Oreochromis niloticus* and other foreign species has boosted aquaculture production, providing a sustainable source of fish for local markets (Agboola *et al*., 2022). However, despite the economic potentials, challenges such as overfishing, habitat degradation, and poor management practices threaten the long-term viability of the fisheries resources in Lake Alau, the lake contributing significantly to the economic activities of the region.

## CHALLENGES AND SUSTAINABLE MANAGEMENT

The sustainable management of Lake Alau's fisheries resources faces several challenges, including overfishing, pollution, and climate-induced stressors. Unregulated fishing, often involving destructive practices such as the use of small-mesh nets, has led to a decline in fish stocks in the lake, particularly of economically important species like O*reochromis niloticus*, *Sarotherodoen galileus*, *Tilapia zilli Clarias gariepinus* and *Synodontis* spp. (Ibrahim *et al*., 2021).

The implementation of effective fisheries management strategies, such as the establishment of fishing quotas, seasonal fishing restrictions, and the promotion of sustainable fishing methods such as the use of appropriate nets and mesh sizes, are essential to safeguard the future of the lake's fisheries. Additionally, improved monitoring of water quality and fish populations by government, as well as community involvement in fisheries management, can help enhance the resilience of Lake Alau's aquatic ecosystem (Sabo *et al*., 2020).

## CONCLUSION

Lake Alau is a vital resource with paramount opportunities for the local communities in Northeast Nigeria, providing a significant source of fish and supporting livelihoods through artisanal fisheries. The lake's diverse fish populations and ecological balance highlight its importance, demanding effective conservation measures. As environmental pressures and climatic changes mount, a collaborative approach to fisheries management, supported by science and community involvement, will be crucial to maintaining the fisheries resources of Lake Alau.

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# MONTHLY OCCURRENCE OF ZOOPLANKTON IN ST. NICHOLAS RIVER, BAYELSA STATE, NIGER DELTA, NIGERIA

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**ABSTRACT**
*Zooplankton which are microscopic animals that drift or float in aquatic environment, primarily in oceans, seas, and freshwater bodies like lakes and rivers are critical component of the aquatic food web, serving as a primary food source for many marine and freshwater organisms. The zooplankton occurrences in St. Nicholas River, Bayelsa State, Nigeria was studied for one year (October 2020 to September 2021) using a plankton net, which is a type of bolting cloth with a 20μm fine mesh aperture and a 30 cm long tiny bottle attached to its narrow end, was used to collect plankton samples. Before being sent to the laboratory for identification, the plankton samples were kept in a 4 to 5% formaldehyde solution. A key was used to identify the speces of zooplankton. A total of eighteen species of zooplankton, belonging to eleven different families, were documented during the study. The family of Cyclopidae recorded 6 species, while Cladocera and Rotifera recorded 2 species each, and Pontellidae, Centropagidae, Temoridae, Metridinidae, Acartiidae, Euchaetidae, Ameiridae, Clausocalanidae recorded one species each respectively. There is variation of phytoplankton distribution amongst the stations during the study, and there is seasonal distribution of phytoplankton in the St. Nicholas River.*

**Keywords:** Zooplankton, occurrence, St. Nicholas River, Bayelsa State, Niger Delta, Nigeria.

## INTRODUCTION

Zooplankton are vital to the aquatic ecosystems serving as key links in food web in the following ways: Zooplankton are critical for nutrient cycling and the biological carbon pump. It plays a significant role in carbon sequestration and nutrient cycling due to their high biomass and grazing activities. Johnston *et al.* (*2020*) emphasizes their contributions to the biological pump and ecosystem services like fisheries support and climate regulation, noting their sensitivity to ocean warming and acidification. Benedetti *et al.* (*2023*) highlight zooplanktons role in marine food webs, showing how climate-driven shifts favor carnivorous and gelatinous species (e.g., jellyfish, larvaceans), potentially reducing food quality for fish in tropical regions by 2100.

Climate change significantly impacts zooplankton dynamics. According to Record *et al.* (2023), ocean warming alters zooplankton phenology, distribution, and body size, affecting the biological carbon pump and trophic interactions. Botterell *et al.* (2020) demonstrate that microplastic ingestion by zooplankton, particularly copepods and jellyfish, disrupts feeding and reproduction, with implications for food web dynamics and human health via bioaccumulation.
Invasive zooplankton species are a growing concern, with Dexter and Bollens (2020) reporting 139 invasive taxa globally from 2000-2018, with significant ecological impacts in regions like the North American Great Lakes. Species like *Bythotrephes longimanus and Mnemiopsis leidyi* dominate research due to their disruptive effects on native communities. In freshwater ecosystems, Yang *et al.* (2020) emphasizes the challenges of monitoring micro-eukaryotes (e.g., rotifers, crustaceans) due to their high

diversity and small size, proposing DNA-based methods like metabarcoding to improve biodiversity assessments in polluted systems.

## MATERIALS AND METHODS

### Study Area

The St. Nicholas River is one of the major estuaries of the Niger River. It is situated between longitude 6° 27" 02" E and latitude 4° 18" 43"N. The Stretch of the river is about 17 km. and the average width of 0.6 km (Akani *et al.*, 2010). Anthropogenic activities such as sand mining, waste disposal, open defecation, pollution emanating from boat engine and so on are rampant in the river system. The vegetation is predominantly mangrove, *Rhizophora racemosa*, *Rhizophora mangle*, sparsely *Avicenia africana* and normal forest vegetation at the coastline.

### Sampling Technique and Identification

A plankton net, which is a type of bolting cloth with a 20$\mu$m fine mesh aperture and a 30 cm3 tiny bottle attached to its narrow end, was used to collect plankton samples. The water samples taken at the sites were transferred to a dark sample bottle with a capacity of around 100 ml. In between samples, the bottle was rinsed with distilled water. The sample was then preserved in 30 ml of 4% formalin and kept at room temperature and darkness in the laboratory. After settling for one to two days, the sedimentation process concentrated the sample to about 50 ml. We used a centrifuge set at 100 rev/min to further concentrate the material. After that, we transferred 1ml to a Sedgwick rafter cell and performed a preliminary microscopy scan. One millilitre of concentrate was mixed with nine millilitres of water for each sample. After the sample was well-mixed, five 1 ml sub-samples were used to identify marine invertebrates under the microscope using keys developed by Needham and Needham (1974) and Nwandiaro and Ezefili (1986). The samples were put on the Sedgwick rafter cell. The relationship was used to estimate the total number of cells per litre of the samples after counting plankton-identified cells;

$$N/L = C\ (1000mm^3) / SLDWS$$

Where C = Mean number of organisms or cell in the sample viewed
L = Length of Sedgwick rafter cell
D = Depth of Sedgwick rafter cell
W = width of strip viewed
S = Number of strips

## RESULTS

A total of eighteen taxa of zooplankton, which were classified into eight families was recorded during the study. The taxa are documented in Table 1.

**Table 1:** Monthly Occurrence of Zooplankton from October, 2020 to September, 2021 in St. Nicholas River, Bayelsa State Nigeria

| TAXONOMIC GROUP | Oct-20 | Nov-20 | Dec-20 | Jan-21 | Feb-21 | Mar-21 | Apr-21 | May-21 | Jun-21 | Jul-21 | Aug-21 | Sep-21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PONTELLIDAE** | | | | | | | | | | | | |
| *Anomalocera patersoni* | 25 | 34 | 36 | 32 | 24 | 29 | 35 | 23 | 26 | 32 | 24 | 30 |
| ***CYCLOPIDAE*** | | | | | | | | | | | | |
| *Paracyclops affini* | 33 | 32 | 38 | 50 | 25 | 28 | 24 | 31 | 29 | 25 | 24 | 23 |
| *Eucyclops maruroides* | 23 | 22 | 54 | 22 | 24 | 36 | 25 | 26 | 31 | 27 | 25 | 23 |
| *Macrocyclops distintus* | 26 | 34 | 37 | 50 | 21 | 21 | 25 | 32 | 32 | 25 | 24 | 27 |
| *Tropocyclops prasinus* | 27 | 51 | 50 | 66 | 26 | 28 | 22 | 31 | 25 | 25 | 27 | 31 |
| *Limnothoina sinensis* | 36 | 40 | 48 | 76 | 24 | 24 | 33 | 25 | 28 | 20 | 28 | 34 |
| *Paracyclops fimbriatus* | 25 | 26 | 32 | 34 | 26 | 45 | 36 | 45 | 25 | 35 | 23 | 33 |
| ***CENTROPAGIDAE*** | | | | | | | | | | | | |
| *Centropages typicus* | 54 | 61 | 69 | 66 | 14 | 35 | 30 | 29 | 29 | 24 | 28 | 28 |
| ***TEMORIDAE*** | | | | | | | | | | | | |
| *Temora longicornis* | 52 | 75 | 60 | 65 | 36 | 34 | 38 | 32 | 38 | 40 | 33 | 29 |
| ***METRIDINIDAE*** | | | | | | | | | | | | |
| *Metridia lucens* | 59 | 61 | 81 | 38 | 30 | 25 | 30 | 40 | 29 | 32 | 29 | 33 |
| ***ACARTIIDAE*** | | | | | | | | | | | | |
| *Acartia longiremis* | 18 | 12 | 12 | 24 | 31 | 32 | 33 | 31 | 34 | 28 | 31 | 28 |
| ***EUCHAETIDAE*** | | | | | | | | | | | | |
| *Pareuchaeta norvigica* | 24 | 30 | 36 | 30 | 32 | 25 | 38 | 33 | 31 | 25 | 30 | 34 |
| ***AMEIRIDAE*** | | | | | | | | | | | | |
| *Nitocra lacustris* | 24 | 33 | 32 | 26 | 32 | 24 | 31 | 28 | 27 | 27 | 28 | 28 |
| ***CLAUSOCALANIDAE*** | | | | | | | | | | | | |
| *Pseudocalanus elongatus* | 32 | 36 | 36 | 47 | 30 | 33 | 26 | 25 | 29 | 31 | 30 | 27 |
| ***CLADOCERA*** | | | | | | | | | | | | |
| *Penilia avirostris* | 6 | 3 | 6 | 11 | 13 | 7 | 6 | 9 | 7 | 14 | 5 | 6 |
| *Podon polyhemoides* | 4 | 6 | 6 | 4 | 4 | 7 | 2 | 12 | 6 | 6 | 5 | 5 |
| ***ROTIFERA*** | | | | | | | | | | | | |
| *Trichoceras longiseta* | 3 | 3 | 3 | 7 | 3 | 5 | 5 | 6 | 3 | 5 | 4 | 0 |
| *Filina longiseta* | 0 | 2 | 5 | 0 | 6 | 3 | 4 | 3 | 1 | 2 | 4 | 3 |

## DISCUSSION

The study found that *Cyclopidae* (copepods) were the most abundant zooplankton family in St. Nicholas River. In River Ossiomo at Ologbo, Niger Delta, Nigeria, 10 families and 18 species were identified, which were fewer than the 11 families and 22 genera reported by Ikhuoriah *et. al.* (2015). However, *Cyclopidae* remained the dominant family. Compared to Dimowo's (2013) findings, which documented 16 genera from 5 families in the Ogun River with Cladocera as the prevailing group, this study showed greater diversity. In contrast, Adesalu *et. al.* (2015) reported a limited zooplankton community in three rivers in Kogi State, North-Central Nigeria (lower River Niger, Okpo River, and Idebu River), recording only three families, with *Rotifera* as the dominant group.

## CONCLUSION

In conclusion, the findings of this study align with previous research in the Niger Delta, indicating limited zooplankton diversity which play an important role in the aquatic food web, thus reflecting a similar polluted aquatic environment.

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# PLANKTON DIVERSITY AND ABUNDANCE IN OBA FALLS: IMPLICATION FOR SUSTAINABLE AQUATIC FOOD WEBS

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**ABSTRACT**
*Phytoplankton accounts for up to half of global primary production, supporting aquatic food webs. This study investigated the plankton diversity and abundance in Kwa Falls for sustainable fish food production. Samples were collected and analysed, and the resulting data were statistically analysed using standard deviations and ANOVA. Results showed an abundance of phytoplankton in the upstream and downstream with three representatives from the Bacillariophyceae, Chlorophyceae, Volvocaceae and Cladophoraceae groups. Zooplankton abundance revealed four groups upstream and three groups downstream with Protozoa, Tintinnida, Rhizopoda and Rotifera groups present in varying abundance. Despite the intense human activity around the fall, the environment is rich in diverse planktonic content. A significant difference was observed in phytoplankton abundance between upstream (3.15±3.2) and downstream (8.85±8.90) locations, whereas zooplankton abundance did not differ significantly between upstream (7.17±4.60) and downstream (6.20±5.60) locations. These findings suggest that Kwa Falls has potential for supporting diverse fish species, and conservation efforts could focus on maintaining plankton diversity to promote increased and sustainable fish production.*

**Keywords**: Plankton abundance, Kwa falls, Upstream, Downstream, Fish production

## INTRODUCTION

The term phytoplankton encompasses all photoautotrophic micro-organisms in aquatic food webs. Phytoplankton serves as the base of the aquatic food web, providing an essential ecological function for all aquatic life. Zooplanktons are the intermediate link that transfer energy captured by phytoplankton to other piscivorous and carnivorous animals within the aquatic system. Diatoms are clearly the most diverse and abundant group of phytoplankton, with *Cyclotella* and smaller species of *Stephanodiscus* especially common in larger rivers worldwide. In some instances, poor preservation techniques may cause underreporting. The major limitations to survival and growth of river phytoplankton are the continuous removal of organisms by downstream flow (so-called washout) and mixing within the water column, which places cells in variable and often aphotic light fields. Hence, most studies conclude that riverine phytoplankton production is controlled by discharge (Reynolds and Descy, 1996). Assuming no other limiting resources, rivers must be sufficiently long and/or the flow rate sufficiently low for net positive algal growth rates.

However, human activities around the water body can contradict these conditions, potentially altering phytoplankton growth and abundance. As primary production increases, the quantity of food for zooplankton increases, as is observed for planktivorous fishes (*Olin et al., 2002*, and Mehner *et al., 2005)*. The species composition, diversity, biomass and season of maximum abundance of zooplankton organisms differ in water bodies (FAO, 2006). Commonly, in an aquatic system, Bacillariophyceae predominates where there is no heavy nutrient inputs possibly from run off or human inputs, whereas in the face of eutrophication Chlorophyceae may become more abundant (Ikhuoriah *et al.* (2015).

Phytoplankton communities in Mbo River and Ogun River with similar climatic and environmental characteristics as Oba Falls showed species richness containing five taxonomic groups (Essien *et al*. *2013;* Dimowo, 2013),

Since phytoplankton provide the primary food source for zooplankton, together with which form the base of the aquatic food chain, this study evaluates the abundance, diversity and the ecology of phytoplankton and zooplankton in, the Kwa Fall, a step towards ensuring food security. This is necessary because with aging, and changes in human activities and demand on water bodies, data on plankton composition ought to be updated.

## MATERIALS AND METHODS

### Study area

Kwa Falls is situated in a narrow, steep gorge on the Great Kwa River, within the Oban region of the Cross River National Park, between latitude $5^0$25'0"N/5.41667$^0$N, and longitude $8^0$35'0" E/8.58333$^0$E (CRNP, 2010). It is characterized by two seasons, wet and dry and mostly covered with lowland rainforest whose tree species include Umbrella tree, African mahogany etc. (CRNP, 2010).

### Duration of study and sampling regime

The study was conducted over a three-month period (August to October 2024), with sampling carried out in upstream and downstream sections of the main water fall. Samples were collected every two weeks (fortnightly).

### Collection, preparation and collation of plankton sample and data obtained

Plankton samples were collected using tow net dragged through the water for approximately 10 minutes. The collected samples were then emptied into labeled sampling bottles, preserved in 4% formalin and transported to Department of Zoology and Environmental Biology Laboratory, University of Calabar for analysis. Samples were identified using standard identification keys (Castro and Huber, 2005). The composition and abundance of various plankton taxa were recorded and presented for each sampling occasion.

### Statistical analysis

In addition to mean and standard deviations, ANOVA or Students t-test were used to analyze the data obtained using SPSS version 20.

## RESULTS AND DISCUSSION

A total of 20 plankton species were recorded during the study, comprising 14 phytoplankton species and 6 zooplankton species (Tables 1 and 2). The total species composition in the various stations on each sampling occasion is shown in table 3. The total number of plankton found in each sampling occasion varied, with 35,42, 37, 37, 39 and 40 individuals recorded in the 1$^{st}$, 2$^{nd}$, 3$^{rd}$, 4$^{th}$, 5$^{th}$ and 6$^{th}$ sampling occasions, respectively. Statistically, there was no significant difference ($p>0.05$) in the species composition between the sampling occasions (Table 3). Two (2) stations were sampled, in the upstream region, forty-one (41) phytoplankton and forty-three (43) zooplankton were found while in the downstream, one hundred and fifteen (115) phytoplankton were found and thirty-one (31) of zooplanktons were found.

**Table 1:** Phytoplankton groups sampled during the study

| S/N | Species | Genus | Family |
|---|---|---|---|
| 1. | *Coscinodiscus exentricus* | *Coscinodiscus* | *Bacillariophyceae* |
| 2. | *Coscinodiscus centralis* | *Coscinodiscus* | *Bacillariophyceae* |
| 3. | *Tabellaria fenestrate* | *Tabellaria* | *Bacillariophyceae* |
| 4. | *Surirella angusa* | *Surirella* | *Bacillariophyceae* |
| 5. | *Surirella elegans* | *Surirella* | *Bacillariophyceae* |
| 6. | *Surirella robusta var splendid* | *Surirella* | *Bacillariophyceae* |
| 7. | *Denticum thermalis* | *Denticum* | *Bacillariophyceae* |
| 8. | *Navicula placentula fo rostrata* | *Navicula* | *Bacillariophyceae* |
| 9. | *Eunatia pectiale* | *Eunatia* | *Bacillariophyceae* |
| 10. | *Pleurotaenium ehrenbergii* | *Pleurotaenium* | *Chlorophyceae* |
| 11. | *Zignema insigne* | *Zignema* | *Chlorophyceae* |
| 12. | Chlorophyceae *oligoclona* | *Chlorophyceae* | *Chlorophyceae* |
| 13. | *Eudorina elegans* | *Eudorina* | *Volvocaceae* |
| 14. | *Cladophora oliglona* | *Cladophora* | *Cladophoraceae* |

**Table 2:** Zooplankton groups sampled during the study

| S/N | Species | Genera | Phylum |
|---|---|---|---|
| 1. | *Centropysis aculeate* | *Centropysis* | *Protozoa* |
| 2. | *Centropysis contricta* | *Centropysis* | *Protozoa* |
| 3. | *Alona exima* | *Alona* | *Protozoa* |
| 4. | *Notholca acuminate* | *Notholca* | *Rotifera* |
| 5. | *Rugipes bilzi* | *Rugipes* | *Rhixopoda* |
| 6. | *Helicostomellasubulata* | *Helicostomella* | *Tintinnida* |

**Table 3:** T-test results of upstream and downstream abundance

| | Upstream | Downstream | $Tab_{t(a)}$ | $Cal_t$ |
|---|---|---|---|---|
| **Zooplankton** | 7.17±4.60 | 6.20±5.60 | 2.23 | 0.46 |
| **Phytopla nkyton** | 3.15±3.2 | 8.85±8.90 | 2.06 | 2.09 |

**Nb;** There is no significant difference between the abundance of zooplankton in upstream ($Cal_t < Tab_{t(a)}$)

There is significant difference between the abundance of phytoplankton in upstream ($Cal_t > Tab_{t(a)}$)

**Table 4:** Total abundance of phytoplankton families found in each station during the period of study

| Families | Upstream | Downstream | Total |
|---|---|---|---|
| *Bacillariophyceae* | 30 | 77 | 107 |
| *Chlorophyceae* | 9 | 25 | 34 |
| *Volvocaceae* | 0 | 13 | 13 |
| *Cladophoraceae* | 2 | 0 | 2 |
| **Total** | **41** | **115** | **156** |

**Table 5:** Total abundance of zooplankton phyla found in each station during the period of study

| Phylum | Upstream | Downstream | Total |
|---|---|---|---|
| *Protozoa* | 22 | 10 | 32 |
| *Rotifer* | 3 | 0 | 3 |
| *Rhizopoda* | 4 | 4 | 8 |
| *Tintinnida* | 14 | 17 | 31 |
| **Total** | **43** | **31** | **74** |

As reported by Brierley et al. (2007), phytoplanktons are used to measure the effectiveness of management or restoration programs or regulatory actions in aquatic environment. The phytoplankton community was dominated by *Bacillariophyceae*, which agrees with the findings of Victor *et al.* (2013) in the same location. *Diatom* dominance of the phytoplankton in waters within the Niger Delta region has been reported in other studies (Ekwu and Sikoki, 2006 and Essien-Ibok, 2013). Contrarily, the dominance of chlorophyta has been reported in Bonny River (Ajuonu *et al.*, 2011). Dimowo (2013) reported the dominance of cyanophyta and an absence of diatoms in River Ogun. Offem and Ikpi (2012) found that *Chlorophyceae* dominated the phytoplanktons community, with *Trachelomonas volzii* being the most abundant species within this group. The high abundance of diatoms in this study may be linked to high concentrations of silicate in the Cross River water system, which has been previously correlated with diatom growth (Antai *et al.*, 2015; Akpan, 1997). Additionally, the reduced impact of hunan activity or rapid water quality replenishment due to surrounding vegetation may also contribute to the high diatom abundance. The dominance of *Protozoa* in this study is contrary to the report of Agouru and Audu (2012) and Ajuonu *et al.*, (2011) who reported copepods as the most abundant zooplankton in Bonny River. Dimowo (2013) also reported the dominance of cladocera. Notably, previous study by Eyo and Paul (2015), found rotifera as dominant, contradicting our findings. These variations could be due to varying differences especially in period of study (FAO 2006). Offem and Ikpi (2012) reported that low density zooplanktons may be due to high discharge of water experienced in the fall. Discharge rate plays a crucial role in shaping plankton abundance and diversity both directly and indirectly, influencing environmental factors such as turbulence and turbidity.

## CONCLUSION

Kwa Fall is a diverse ecosystem with high plankton diversity that can sustain fishery development (Eyo and Paul, 2015). Despite its site which makes the river prone to serious pollution threat from human and industrial waste (Akpan et al., 2002), caused by increased human population within Calabar metropolis, this study recorded minimal zooplankton species belonging to 4 phyla groups and numerous phytoplankton species belonging to 4 families. The zooplankton and phytoplankton communities in the two sampling stations showed similar composition with minor variations that were not statistically significant. These findings indicate the unpolluted nature of Kwa Falls despite human activities around the fall. It also provides useful information on the composition and ecology of phytoplankton and zooplankton species within that aquatic community which could provide sufficient updated data for fishery managers for improving production and mitigating shortfalls in fish supplies.

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# PLANKTON ABUNDANCE AND CORRELATION EFFECTS OF WATER QUALITY PARAMETERS IN DOMA DAM NASARAWA STATE, NIGERIA

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**ABSTRACT**

*The study determined the plankton abundance and correlation effect of water quality parameters in Doma Dam Nasarawa State, Nigeria. Samples were collected during the early hours of the day (7:00 – 10:00 am) for three months between June and August 2024. Plankton net with 25 mm diameter and 50µm mesh size was used to collect plankton samples. The plankton net was towed horizontally at about 50 cm below the water surface for about 100 m distance. The result of the study revealed three families (Cladocera, Rotifera, and Copepoda) of zooplankton. Three species of zooplankton which are Daphnia pulex (6), Brachionus calyciflorus (4), and Cyclop nauphlii (2) were recorded. Nine species of phytoplankton (Gyrosigma attenuatum, Pediastrum duplex, Volvox carteri, Spirogyra spp, Microcystis flosaque, Eugleno gracilis, Anabaena spp, Nostoc spp, and Navicula spp) and their percentage abundance were recorded as 13.16%, 13.16%, 13.16%, 13.16%, 13.16%, 7.89%, 10.53%, 10.53%, and 5.26% respectively. Correlation analysis showed minimal effect of one parameter against the other therefore, normal mean values of water quality are within the range for freshwater fish production. Further study on plankton abundance and distribution should also be carried out in the dry season.*

**Keyword:** Zooplankton, Phytoplankton, water quality, correlation

## INTRODUCTION

Plankton is a collective term used to describe all those organisms whose powers of movement are insufficient to prevent them from being moved by water currents (Zira *et al.*, 2022). The term commonly refers to any drifting organisms that inhabit water bodies and serve as food base that supports aquatic life (Gogoi *et al.*, 2016). Plankton are mostly small organism, drifting along with the water currents and unable to swim against the water waves. They have been studied in a number of aquatic environments during the past several years in Nigeria including rivers, lakes, estuaries, seas, and the ocean.

Numerous researches on the species and abundance of plankton have demonstrated that variations in salinity, depth, and the spatial-temporal variation of physicochemical parameters, as well as the presence of predators, are the main causes of plankton population fluctuations (Zira *et al.*, 2022). Plankton plays a significant role in the energy transfer in aquatic environments, and understanding their ecology is crucial for determining the potential output of any given body of water (Kar *et al.*, 2018). In the aquatic environment, they make up the biggest group of species and are essential to the aquatic food chain. They serve as the conduit for the movement of energy in the aquatic environment between the lower and higher trophic levels (Iloba and Ruejoma, 2014).

Numerous researches on the fish abundance and distribution have been conducted in Doma Dam; however, the inadequate knowledge on the abundance of plankton in the same area has made it necessary to investigate the plankton community within the dam. The physical and chemical characteristics of the water can be changed by the use of pesticides by farmers releasing substances they may not be allowed to, which can have an impact on plankton reproduction and growth within the dam. The people who live near the dam wash their clothing and other household items in the dam's water. Seasonal farming practices,

particularly irrigation, may encourage the use of pesticides and fertilizers, which increases the likelihood that these materials may enter the dam through flooding thus, affecting the abundance of plankton in the study area. This study is aimed determining the abundance of phytoplankton and zooplankton and correlation analysis of water quality parameters in Doma Dam.

## MATERIALS AND METHODS

### Description of the Study Area

The study was conducted in Doma Local Government area of Nasarawa State. Doma is situated in the north central (middle belt of savannah ecological zone) of Nigeria. The studies area lies between latitude, $08^0$ 32E and approximately 181.53m above sea level. The mean temperature range" annual rainfall of 1288mm. the area has population of about 249,609 inhabitants. The major occupation of people is predominantly farming and fishing which few occupants are fish sellers. Doma Local Government Area consists of ten district area namely Madauchi, Rukubi, Sabon Gari, Galadima, Sarki, Dawaki, Dorka, Akpata, Madaki, Akpanaja, and Alagye. It shares boarder with River Benue which is the major sources of their fishing activities.

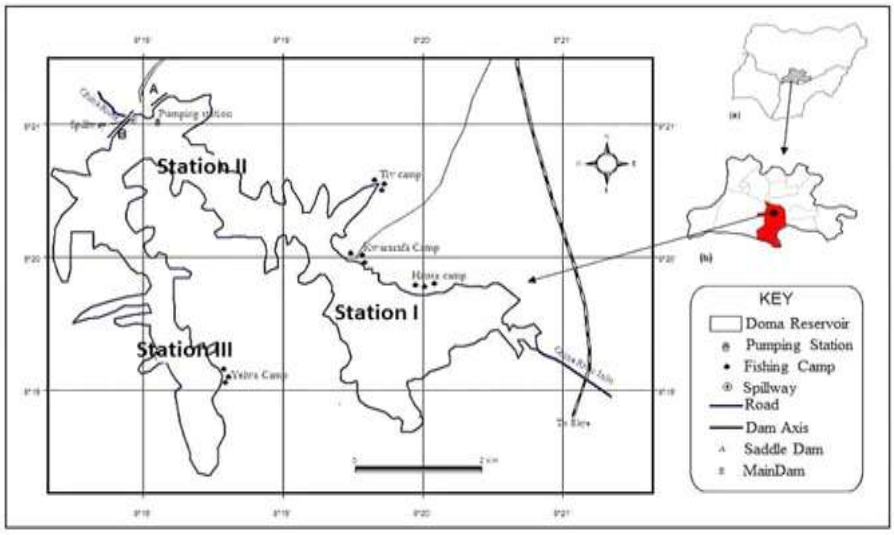



**Figure1:** Map of Nasarawa State, Showing the Study Area.

### Mapping and plankton Sampling

Monthly plankton samples were collected during the early hours of the day (7:00 – 10:00 am) with plankton net of 25 mm diameter and 50 µm mesh size. The plankton nets were towed horizontally at about 50 cm below the water surface for about 100 m distance. The content of the nets was emptied into a wide-mouthed plastic 50 ml storage bottle and preserved with 10% formalin on the field. The preserved samples were brought to the Fisheries Department Faculty of Agriculture Nasarawa State University Keffi. The plankton samples were allowed to settle and top cleared layer was decanted, then zooplankton concentration sample was obtained. The number of plankton in 1ml was calculated as: N = dp
Where: N = The number of plankton cells per litre; d = The number of concentrated drops that make 1ml (d = 28); p – The number of plankton cells per concentrated drop

### Measurements of the Physico-chemical parameters

Ten (10) physical parameters were evaluated including, water temperature, pH, total dissolved solids (TDS), conductivity, turbidity and dissolved oxygen (DO). Water temperature was measured using a mercury thermometer. The hydrogen ion (pH) will be determined by pH meter model HANNA. TDS and conductivity were measured by the Cole–Parmer model Check-mate 90 (CORNING). Turbidity was measured by secchi disc. Dissolved oxygen (DO) was measured by applying the titration method.

**Statistical Analysis**
The data obtained were subjected to descriptive and inferential statistical analysis using SPSS (Version 20.0) software to determine the abundance of zooplankton species

**RESULTS**
**Plankton Abundance Recorded at the Study Site**
Table 1 shows the result of zooplankton species identified at the study sites of Doma Dam.

**Table 1:** Phytoplankton Abundance Recorded at the Study Site

| Species | June | July | August | Total |
|---|---|---|---|---|
| **Zooplankton** | | | | |
| *Daphnia pulex* | 2 | 2 | 2 | 6 |
| *Brachionus calyciflorus* | 1 | 1 | 2 | 4 |
| *Cyclop nauphlii* | 1 | 1 | 0 | 2 |
| *Daphnia pulex* | 2 | 2 | 2 | 6 |
| **Phytoplankton** | | | | |
| *Gyrosigma attenuatum* | 2 | 1 | 2 | 5 |
| *Pediastrum duplex* | 2 | 2 | 1 | 5 |
| *Volvox carteri* | 2 | 1 | 2 | 5 |
| *Spirogyra spp* | 1 | 2 | 2 | 5 |
| *Microcystis flosaque* | 2 | 1 | 2 | 5 |
| *Eugleno gracilis* | 2 | 0 | 1 | 3 |
| *Anabaena spp* | 1 | 1 | 2 | 4 |
| *Nostoc spp* | 0 | 2 | 2 | 4 |
| *Navicula spp* | 0 | 2 | 0 | 2 |
| Total | 12 | 12 | 14 | 38 |

Three families **(**Cladocera, Rotifera, and Copepoda) of zooplankton were identified from the study. Three species of zooplankton (*Daphnia pulex* , *Brachionus calyciflorus* , and C*yclop nauphlii*) were recorded throughout the study. *Daphnia pulex* (6) was present in June (2), July (2) and August (2) respectively. *Brachionus calyciflorus* (4) was found in June (1), July (1) and August (2) while C*yclop nauphlii* (2) was present in June (1), July (1) but absent in August (0) respectively.
Nine species (*Gyrosigma attenuatum*, *Pediastrum duplex*, *Volvox carteri*, *Spirogyra spp*, *Microcystis flosaque*, *Eugleno gracilis*, *Anabaena spp*, *Nostoc spp*, and *Navicula spp*) and their percentage abundance are 13.16, 13.16, 13.16, 13.16, 13.16, 7.89, 10.53, 10.53, and 5.26% respectively.

**Occurrence of Phytoplankton Species recorded at Doma Dam**
The highest occurrence of phytoplankton species was found from five (5) species (*Gyrosigma attenuatum*, *Pediastrum duplex*, *Volvox carteri*, *Spirogyra spp* and *Microcystis flosaque*) followed by *Eugleno gracilis* and *Anabaena spp* while *Navicula spp* was the lowest.

**Physicochemical Parameters of Sampled Sites at Doma Dam**
Table 1 and Figure 1 shows the result of physicochemical parameters of water at Doma Dam Sampled sites. Therewere significant differences ($P<0.05$) recorded in all the water quality parameters.

**Pearson's Correlation Analysis of Water Quality Parameters**

The results for pearson's correlation of water quality parameters are shown in Table 2, 3 and 4 below. The pearsons' correlation analysis for water quality parameters in June showed significant correlation in three parameters which are TDS, Alkalinity and EC. The result showed that TDS correlating BOD was significant and negative ($r^2$ = -.999*, P<0.05), Alkalinity correlated with $NO_3$was positive and significant (0.999*, P<0.05) and EC correlated with Temperature was significant and negative (0.998*, P<0.05).

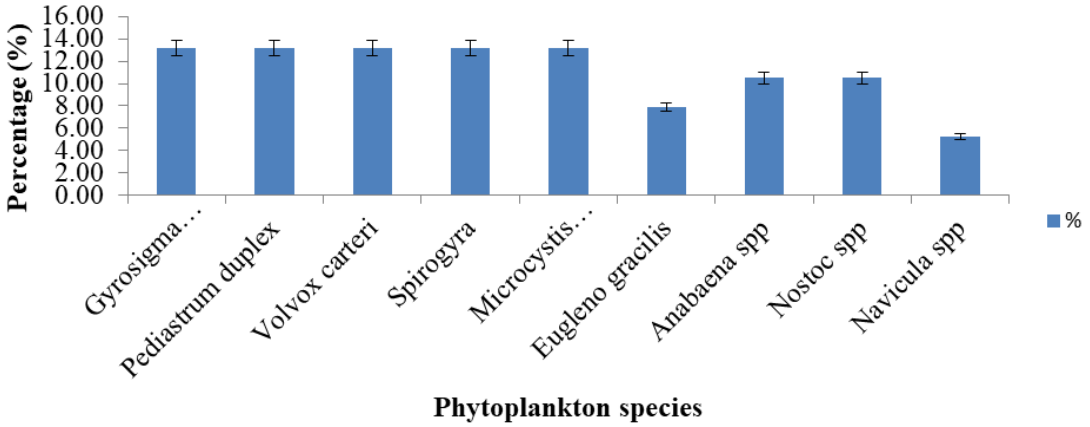



**Figure 1:** Percentage of Phytoplankton Species recorded at Doma Dam

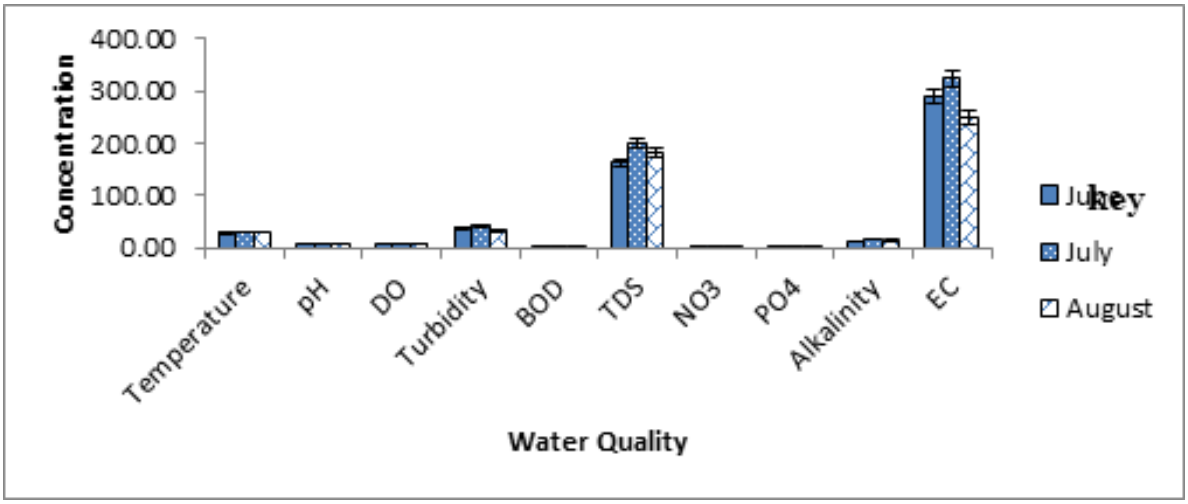



**Figure 2:** Monthly presentation of Water Quality Parameters

**Table 2:** Bivariate Correlation of Water Quality at Doma Dam Sampled Sites

| Parameters | Temperature | pH | DO | Turbidity | BOD | TDS | $NO_3$ | $PO_4$ | Alkalinity | EC |
|---|---|---|---|---|---|---|---|---|---|---|
| Temperature | 1 | | | | | | | | | |
| Ph | 0.912 | 1 | | | | | | | | |
| DO | -0.575 | -0.189 | 1 | | | | | | | |
| Turbidity | -0.961 | -0.99 | 0.327 | 1 | | | | | | |
| BOD | 0.421 | 0.756 | 0.5 | -0.655 | 1 | | | | | |
| TDS | -0.377 | -0.724 | -0.541 | 0.618 | -.999* | 1 | | | | |
| $NO_3$ | 0.764 | 0.432 | -0.967 | -0.556 | -0.264 | 0.31 | 1 | | | |
| $PO_4$ | 0.570 | 0.857 | 0.345 | -0.774 | 0.985 | -0.976 | -0.095 | 1 | | |
| Alkalinity | 0.785 | 0.462 | -0.958 | -0.584 | -0.231 | 0.278 | .999* | -0.062 | 1 | |
| EC | 0.998* | 0.937 | -0.519 | -0.978 | 0.481 | -0.438 | 0.719 | 0.623 | 0.742 | 1 |

*** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)*

## DISCUSSION

### Zooplankton Abundance Recorded at the Study Site

Phytoplanktons are microscopic aquatic plants, occurring as unicellular colonial or filamentous forms without any resistant to current and are freefloating or suspended in the open water (Ali *et al.,* 2013). They are important water quality indicators, because of the short life cycles and ability to respond to environmental changes. The current study identified three families of zooplankton (Cladocera, Rotifera, and Copepoda) and three species were recorded which are *Daphnia pulex, Brachionus calyciflorus,* and *Cyclop nauphlii*. The observation on the zooplankton composition in the study shows that the Dam sites are less productive in zooplankton species. The low occurrences is in line with the report of Tas and Gonolol (2007) who stated the amount of phytoplankton present in water depends on the light availability and the relative proportions of nutrients (nitrogen and phosphorous) and the temperature. The existence of phytoplankton in the waters can be seen on the basis of their abundance, influenced by several environmental and the physiological characteristics (Bellinger and Siege, 2010). The present of Rotifera in any water body indicate nutrients enrichment (Iloba and Ruejoma, 2014) but the low abundance and occurrence of this species in the current study is not a proof that the sampling sites are plankton productive. The number of Cladocera and copepod were relatively low; this may be attributed to the absence of aquatic macrophytes and it might have accelerated the rate of cannibalism by fish predation. Havens *et al.* (2002), suggested that fish prefer open waters to feed on zooplankton. Kemdirim, (2000) who observed low numbers of Copepoda as a result of the effects of fish predation, which was found to be the major factor structuring zooplankton assemblages in several studies.

### Phytoplankton Abundance Recorded at the Study Site

The most abundant of phytoplankton in the study belong to chlorophycaea and cyanophycaea. The dominating presence of Chlorophyta indicates gradual deterioration of the water quality. This could be as a result of anthropogenic activities, such as chemicals usage from agricultural activities, wastes released by community, washing of clothes and bathing sometimes around the Dam. This also agrees with Anago *et al.* (2013) who stated that, in any lotic system where domestic, agricultural and industrial pollution is accelerated, growth of Chlorophyta and Cyanophyta sets. Abubakar (2007) indicates the presence of Euglenophta in an environment indicates richness by decaying organic matter, and their large populations of Euglena could be favored by the presence of high levels of dissolved organic compounds and high temperatures. According to Tanimu *et al.* (2011) the increase in abundance of the Cyanophyta and Euglenophyta is an indication of organic pollution. The occurrence of *Eugleno gracilis* and *Nostoc spp* was an indication that the Dam had high level of dissolved organic matters.

### Physicochemical Parameters of Sampled Sites at Doma Dam

Water is one of the precious natural resources that living things consume and is necessary for life activities to continue (Butu *et al.,* 2019). Water quality is important not only for human consumption but for the health of the aquatic ecosystem where biotic and abiotic matrices interact and significantly affects each other (Imam *et al.,* 2011). Human alteration of the aquatic ecosystem environment such industrialization, fast urbanization, and agricultural inputs promote contamination of water bodies (Rabiu *et al.,* 2018). It was noted that during the study period, there were minor variations in the physicochemical parameter analysed of temperature, pH and turbidity, Dissolved Oxygen in the Dam water. This study is peculiar with the weather condition of makurdi since Doma Dam is sharing border with the River Benue Basin as stated in the research of Iliyasu *et al.* (2024). The findings of Rabiu *et al.* (2018) in Watari water body and Kefas *et al.* (2015) in Lake Geriyo, Adamawa State, are consistent with this trend of temperature variance. It was found that from June to August, the pH value that was recorded in this study increased somewhat. The water body's turbidity changed greatly depending on the season as well, ranging from 32.67 - 41.00cm in the raining season, respectively. Due to suspended

particle matter, turbidity in water may be correlated with cloudiness of the water body during the rainy season (Kutama *et al.*, 2013) as a result of frequent occurrence of rainfall.
The fluctuation in water pH of the river water reflects changes in the water chemistry due to the respiratory activities taking place in the water by the release of carbonic acid from respiration or decomposition of aquatic biota which tends to be alkaline. The pH range 0f 7.40-9.01 is suitable for physiological activities of aquatic animals. It is apparent that the pH of the water may be described as satisfactory as it was not impacted upon by compounds that could raise the pH to acidic or highly basic. This observation coincides with the work (Rabiu *et al.*, 2018).
Total Dissolved Solids is made up of disintegrated minerals and inorganic salts, and excessive TDS levels can alter water quality. The Dam water TDS readings is lower than the FAO/WHO (2018)'s maximum limit of 600 mg/L. According to Jaji *et al.* (2007), the current investigation's dissolved oxygen ranged from 4.6 to 6.9 mg/L, which is satisfactory to sustain aquatic life. This may be because of a high rate of aeration and photosynthetic activity, the present of riparian vegetations and trees could create more photosynthetic activities. Phosphate ranged from 2.0 to 7.8mg/L is suitable for freshwater organism. The study recorded the concentrations of phosphate above the FAO/WHO (2018) guidelines limit for fresh water.

**Pearson's correlation of Physicochemical Parameters**
Shinde *et al.* (2011) inferred from their research that positive correlation means that one parameter increases as other parameters also increase while a negative correlation means that as one parameter increases, the other parameters decrease. In this study, it was observed in July that Total Dissolved Solid correlated against BOD was significant, which mean that as the concentration of TDS increases in the sampled sites the concentration of Biological Oxygen Demand in the water becomes low. Alkalinity correlated with $NO_3$ was positive and significant (0.999*) which indicated that alkalinity increase with increase in nitrate. EC correlated with Temperature was significant and negative (0.998*). This shows that increase in electrical conductivity could occur as a result of an increase in temperature. In July, only one parameter which is EC correlated against $PO_4$ was positively significant (1.000*). In August, a similar trend as that which occurred in June was observed where three parameters which are TDS, Alkalinity and EC were correlated.

## CONCLUSION
The result of study on zooplankton in Doma Dam shows that the Dam sampling sites are partially devoid of species. There is indication of inadequate nutrients in the sampling sites during the time of study. Nine species of phytoplankton identified in the study indicate relatively low numbers. The results of plankton composition in the study sites shows that the Dam could be endangered by predatory organism (fish). The result of the study indicated the physicochemical parameters of Doma Dam are in good concentration and within the limit of organization and agencies. The ranges of water temperature, DO, Turbidity and pH prove the Dam to be less polluted. Correlation analysis showed minimal effect of one parameter against the other therefore, normal mean values of water quality are within the range for freshwater fish production.

## RECOMMENDATION
Further study on plankton abundance and distribution should also be carried out in the dry season

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# PHYSICO-CHEMICAL PARAMETERS AND MACRO INVERTEBRATE INDICES OF JABI LAKE, ABUJA.

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**ABSTRACT**
*This study assessed physicochemical parameters and macroinvertebrate assemblages in Jabi Lake, Abuja, to evaluate its ecological status. Dissolved oxygen, pH, conductivity, total dissolved solids, temperature, nitrate, phosphate, turbidity, and biochemical oxygen demand were determined across the Lake. Mean values showed slight variations but ANOVA revealed no significant differences ($p > 0.05$), indicating relatively uniform water quality. Dissolved oxygen (4.07–5.31 mg/L), pH (6.22–6.57), and BOD (1.33–3.10 mg/L) were within tolerable limits, suggesting moderate organic input. A total of 977 macroinvertebrates from 20 species were recorded, dominated by gastropods (Biomphalaria 31.9%, Melanoides tuberculata 26.8%). Odonata and Hemiptera were moderately represented. Diversity indices (Shannon H = 1.93–1.97; Simpson 1–D = 0.79–0.81) indicated moderate diversity. Findings suggest Jabi Lake is moderately disturbed but supports aquatic life.*

**Keywords**: Jabi Lake, Water Quality, Macroinvertebrates, Bioindicators, Diversity Indices.

## INTRODUCTION

Water is vital for human, agricultural, and industrial use, but pollution threatens freshwater ecosystems in developing nations like Nigeria (Garba *et al.*, 2010; Ikpeze and Aririguzoh, 2023). Lakes are particularly vulnerable due to their stagnant nature and ability to accumulate pollutants (Vadeboncoeur *et al.*, 2002). Jabi Lake, a man-made reservoir in Abuja, supports fisheries, recreation, and domestic use, but faces increasing anthropogenic pressure from urbanization and waste disposal (Daniel *et al.*, 2023). Biological monitoring using benthic macroinvertebrates offers a reliable approach to assess ecological status (Sharma *et al.*, 2013). This study therefore assessed the physicochemical and biological condition of Jabi Lake during the dry season.

## MATERIALS AND METHODS

### Study Area

The study was carried out in Jabi Lake (Lat 9°04′N; Long 7°25′E) which lies between Jabi and Kado districts, Abuja, with a surface area of 1,300 ha. It was created by damming the Katampe River and is used for fishing, recreation, and tourism.

### Sampling Stations and Sample collection

Three sampling sites (A, B and C) were selected after preliminary surveys of the Lake based on such factor as volume of water, accessibility, and the various activities taken place in and around the Lake. For water quality, Samples were collected monthly (Nov 2024–Mar 2025) at 20 cm depth. Temperature, pH, conductivity, TDS, turbidity, DO, BOD, nitrate, and phosphate were determined using standard methods (USEPA, 2014).

### Macroinvertebrates Collection

Macroinvertebrates were collected with a kick net (Barbour *et al.*, 1999), counted and identified to specie level using (Dickens and Graham, 2002) identification chart.

Analysis: ANOVA tested spatial variation (Minitab 23). Diversity indices (Shannon, Simpson, Margalef, Evenness) were calculated using PAST 6.0.

## RESULTS

**Table 1:** Variations in water quality across sampling points in Jabi Lake

| Parameters | Sampling points | | | p-value |
|---|---|---|---|---|
| | Point A | Point B | Point C | |
| Dissolved oxygen (mg/L) | 5.31±0.61 | 4.62±0.57 | 4.07±0.39 | 0.29 ns |
| Ph | 6.57±0.11 | 6.22±0.09 | 6.50±0.16 | 0.15 ns |
| Electrical conductivity (μS/ cm) | 270.80±21.30 | 190.50±62.70 | 236.30±18.40 | 0.38 nser4 |
| Total dissolved solids (mg/L) | 134.00±6.92 | 117.20±23.80 | 133.78±8.69 | 0.67 ns |
| Temperature ( °C) | 24.46±4.52 | 29.26±0.38 | 27.78±0.31 | 0.38 ns |
| Nitrate (mg/L) | 0.41±0.34 | 0.27±0.19 | 0.09±0.03 | 0.62 ns |
| Phosphate (mg/L ) | 0.14±0.09 | 0.38±1.83 | 0.27±0.14 | 0.27 ns |
| Turbidity (mg/L) | 7.42±2.70 | 10.94±1.99 | 12.52±1.07 | 0.22 ns |
| Biochemical oxygen demand (mg/L) | 3.10±0.29 | 2.37±0.36 | 1.33±0.81 | 0.36 ns |

*ns = means on the same row do not vary statistically (p<0.05)*

**Table 2:** Macroinvertebrates identified from Jabi Lake, Abuja

| Class/Order | Common Name | Scientific Name | A | B | C | Total | % Composition |
|---|---|---|---|---|---|---|---|
| Hemiptera | Water scorpion | *Nepa cinereal* | 6 | 1 | 3 | 10 | 1.02 |
| | Needle bug | *Ranatra linearis* | 6 | 1 | 0 | 7 | 0.72 |
| | Water bug | *Diplonychus rusticus* | 1 | 0 | 0 | 1 | 0.10 |
| | Creeping water bug | *Naucoris maculatus* | 2 | 1 | 0 | 3 | 0.31 |
| | Backswimmers | *Notonecta glauca* | 33 | 12 | 11 | 56 | 5.73 |
| | Giant water bug | *Belostoma flumineum* | 2 | 0 | 0 | 2 | 0.20 |
| Odonata | Dragonfly nymph | *Anax junius* | 36 | 16 | 7 | 59 | 6.04 |
| | Damselfly nymph | *Coenagrion puella* | 15 | 3 | 1 | 19 | 1.94 |
| Araneae | Fishing spider | *Dolomedes triton* | 1 | 2 | 3 | 6 | 0.61 |
| Coleoptera | Predacious diving beetle | *Dytiscus marginalis* | 0 | 1 | 0 | 1 | 0.10 |
| | Whirligig beetle | *Gyrinus natator* | 3 | 0 | 0 | 3 | 0.31 |
| | Water scavenger beetle | *Hydrophilus triangularis* | 1 | 1 | 0 | 2 | 0.20 |
| Gastropoda | Banded mystery snail | *Viviparus georgianus* | 15 | 6 | 3 | 24 | 2.46 |
| | Red-rimmed melania | *Melanoides tuberculata* | 159 | 60 | 43 | 262 | 26.82 |
| | Ram's horn snail | *Biomphalaria pfeifferi* | 231 | 54 | 27 | 312 | 31.93 |
| | Bladder snail | *Physa acuta* | 16 | 3 | 0 | 19 | 1.94 |
| | River snail | *Viviparus viviparus* | 9 | 4 | 6 | 19 | 1.94 |
| Bivalvia | Clam | *Corbicula fluminea* | 109 | 16 | 16 | 141 | 14.43 |
| | Mussel | *Unio pictorum* | 2 | 0 | 1 | 3 | 0.31 |
| Ephemeroptera | Mayfly nymph | *Baetis rhodani* | 16 | 4 | 4 | 24 | 2.46 |
| Clitellata | Leech | *Hirudo medicinalis* | 2 | 1 | 1 | 4 | 0.41 |
| TOTAL | | | 665 | 186 | 126 | 977 | 100 |

### Physicochemical Parameters:

No significant differences ($p > 0.05$) were found across sites. DO ranged 4.07–5.31 mg/L, pH 6.22–6.57, BOD 1.33–3.10 mg/L. TDS (117–134 mg/L), turbidity (7.42–12.52 NTU), nitrate (0.09–0.41 mg/L), and phosphate (0.14–0.38 mg/L) were within acceptable ranges, reflecting moderate organic input.

### Macroinvertebrates

A total of 977 macroinvertebrate comprising of 20 species were recorded. Gastropods dominated: *Biomphalaria pfeifferi* (31.9%) and *Melanoides tuberculata* (26.8%). Clams contributed 14.4%, while

Odonates (6.0%) and Hemipterans (5.7%) indicated moderate habitat disturbance. Shannon H = 1.93–1.97 Simpson 1–D = 0.79–0.81 Margalef = 2.48–3.06 Evenness = 0.34–0.55

## DISCUSSION

Uniform physicochemical conditions across stations suggest mixing within the lake, consistent with earlier findings (Daniel *et al.,* 2023) who reported no significant special variation in physicochemical parameters across different stations in Jabi Lake indicating that water quality is relatively uniform within the system despite localized influences. Composition and abundance of macroinvertebrates observed in this study revealed that gastropods were the most dominant taxa, particularly *Biomphalaria pfeifferi* (31.9%) and *Melanoides tuberculata* (26.8%). This dominance suggests that the lake provides favorable conditions for mollusks, including abundant organic matter and soft sediments, which are known to enhance gastropod colonization (Adewumi and Ajani, 2021). Similar mollusk dominance has been reported in Jabi Lake, Abuja (Chia *et al.,* 2009) and in Asejire Lake, Oyo State (Oyediran and Egbebiyi, 2018), Adewumi and Ajani, 2021). The combined analysis of physico-chemical parameters and macroinvertebrate community structure indicates that Jabi Lake is under moderate pollution stress since water quality remained largely within permissible limits.

## CONCLUSION

Jabi Lake exhibits moderate disturbance, with uniform water quality and macroinvertebrate assemblages dominated by gastropods. The system retains functional integrity but requires monitoring to prevent further degradation. it is therefore recommended that routine monitoring be sustained and anthropogenic activities within the lake be minimized to preserve ecological integrity.

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# FISH WELFARE – INTERCONNECTIONS AMONG STRESS, HEALTH, ENVIRONMENT AND DIVERSITY

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**ABSTRACT**
*The welfare of fish in aquaculture is of increasing public concern in the world and thus of growing importance for fish farmers. Although the topic can be regarded as controversial, due in particular to the lack of available knowledge, there is nevertheless an urgent need for fish farmers, authorities and scientists to develop criteria, approaches and practices to monitor and safeguard the welfare of cultured fish.*

**Keywords:** Fish welfare, Pain, Stress, Suffering, Welfare management

## INTRODUCTION

Aquaculture is an important source of animal protein, and the sector is expected to grow further in order to satisfy the protein demand of an increasing human population. As this production grows, the interest of the public on the husbandry and processing practices used in aquaculture and their associated welfare issues is increasing too, stimulating the demand for high-welfare fish products. The increasing importance of fish welfare in aquaculture comes from ethical considerations as well as from the perspective of improving standards and quality of fish production technologies and aquaculture products. The welfare status of the fish has direct implications for their production and for the sustainability of the industry as a whole. Fish kept under good welfare conditions are less stressed and less susceptible to diseases and therefore they require less medication and treatment, show better growth rates and food conversion and ultimately provide a better-quality product. Finally, the economic benefits are obvious. There is growing evidence that fish, like other vertebrate animals, are sentient beings, and that they can experience pain and distress (OIE, 2008). Sentience is usually seen as a prerequisite when considering welfare and the public, especially in the industrialized world, is increasingly considering that fish are entitled to good welfare. Thus, the interest of consumers, as well as policy makers and scientists, for husbandry practices used in aquaculture and their associated welfare issues is growing. As consumers begin to enquire about welfare in fish farming, the production sector cannot ignore this issue so as to avoid negative impacts on sales (Broom, 2007). In this framework, the prioritization and coordination of research as well as an enhanced dialogue among stakeholders are essential to ensure improvement of fish welfare in practice. The aim of this study was to investigate the main research gaps on fish welfare, and to reach consensus between the aquaculture industry and researchers in setting future research priorities.

## WELFARE CONCEPTS

Fish welfare is important in two main contexts: laboratory research and aquaculture farms. Despite some common elements, these two contexts differ at the level of the dimensional scale, objectives, husbandry conditions, species and number of captive fish maintained. The welfare of an animal is its state as regards its attempts to cope with its environment," the key challenge is how to translate such a principal statement into welfare concepts of practical relevance within the farm environment. Defining and legislating a welfare concept will have direct implications on the production of aquaculture animals and on how animal welfare is assessed and measured. Also, by which parameters can we measure that cultured fishes are able to cope with their environment? Can we reduce welfare to the absence of negative

factors such as injury and disease, or does welfare, as formulated in the principles of the "Five Freedoms," (Fife-Cook and Franks, 2019). also include positive measures such as the freedom to express normal behaviour? This debate is further complicated by the still-unresolved question of whether fishes are sentient animals. What is a proven fact is that fish do experience stress and fight-or-flight responses, as can be seen through hormonal changes. What is discussed controversially, however, is whether fish experience feelings and emotions and is conscious of pain and fear, although there exists substantial neuroanatomical, physiological and ethological evidence that fish are sentient. Therefore, the concept of welfare is wider than the simple concept of 'wellness', which refers more to physical health and the avoidance of prolonged stress.

## FISH ARE SENTIENT BEINGS

Research into consciousness and pain in fishes has lagged behind studies of birds and mammals, but there is now good evidence that fish are conscious, sentient beings with the capacity to feel pain (Fife-Cook and Franks, 2019). They possess nociceptors, respond to noxious/painful events, react positively to analgesics, and show avoidance learning (Sneddon, 2003) which is indicative of a conscious avoidance of suffering. They also have many cognitive abilities that help them in adverse situations and can show physiological and behavioural stress responses similar to mammals when subdued to pain or handling. Many fish species have been shown to have long-term memory, social learning, conditioned suppression, and problem-solving ability (Yue *et.al*, 2008) all of which are used as indicators of sentience and cognitive capacity in other animal species.

## STRESS, WELFARE AND HEALTH

Welfare is a concept with many connections with the health concept. Although we normally associate health in animals with the lack of disease or the lack of pathogen input, it is normally true that healthy animals correspond well with animals in good welfare, i. e. without significant functional alterations and developing a rather normal life. It is true that some aspects of welfare associated to the development of natural behaviour may not appear into this health/welfare concept, but it is also true that episodes of discomfort, heavy stress or disease can appear in natural conditions. These concepts can also be applied to farm animals including fishes, thus approaching even more closely the health and the welfare features. As an example, some episodes of sudden death in Sea bass during the nineties decade in South Mediterranean Sea cages could have been clearly associated to non-pathogenic sources like fatty diets and reduced exercise as a result of pressure for fast growth and higher culture densities (Parpoura, *et.al.*, 2001). This situation involved reduced welfare as a result of the lack of healthy habits infringed to fish.
Welfare in animals including fishes has been most often associated to the lack of suffering and to the association with the Five Freedoms (Huntingford and Kadri 2008) and particularly to episodes of euthanasia and anaesthesia in aquaculture harvesting or fish transport with trading fish in aquariology. Nonetheless, when it comes to measure welfare and determine suitable indicators, the welfare criteria use to match with the lack of stress, as stress includes most of the situations in which fishes' experiences significant altered status, from mild alarm to eventual suffering. When fishes are stressed, as it happens with most vertebrates, there is an increase of susceptibility to pathogens, there is an increase of disease incidence and consequently, loss of welfare (Yada and Tort, 2016).

## PERCEIVING STRESS

How fishes perceive stressors is very relevant in terms of developing a response, for reacting in a particular direction and for the recovery of a welfare status, physiological balance and maintain overall health. Fishes are animals intensively connected with the environment with many receptors associated with the changes in biotic and abiotic features of the water and the characteristics of the organisms living in it. Therefore, temperature, ionic and osmotic components, currents, but also all types of pathogenic and non-pathogenic microorganisms are in constant interaction with the fish, and in particular to external fish

sensors and mucosal surfaces. In recent years it has been shown that mucosae (skin, gut, gills and nasal) are key sites for fish-environment interaction and therefore relevant actors in the modulation of the transitions between welfare and health status and stressed and pathological. The assessment of selected indicators obtained from specific sensors of these mucosal surfaces can be also indicators of welfare and even predictors of welfare alteration (Kulczykowska, 2019). However, a main drawback for describing a unified and integrated physiological stress response in fishes relate to their extreme diversity of lifestyles and ecotypes. Fishes can live under extreme conditions including freezing waters, dry ponds or huge pressures in deep waters; fishes are able to adapt to changing conditions such as freshwater-seawater transitions, low oxygen waters or temperature changes; fishes have adapted also to all types of feed resources; fishes can show sophisticated predatory activity or efficient mimetic strategies. Some fishes, such as African killifish, live only a few months during the wet season in dry climates (Harel and Brunet, 2015), whereas other species may live centuries in Greenland cold waters. This adaptive ability has resulted in the fact that almost half of the existing vertebrate species are fishes. This fact also shows that the ability of fishes to overcome stressors has been quite successful. As recently pointed out (Balasch and Tort, 2019) when defining stress responses in fishes we should analyse the stressotope, an adaptive niche-related scenario subjected to environmental selective pressures that elicit multilevel responses and produce a measurable allostatic load in every organism. When this coping is successful, fishes are able to retain welfare

**RESPONDING TO STRESS**

One of the main descriptors of a stress situation is the energetic component (as it is for other basic functions or organismic performance such as growth, disease resistance or reproduction). Thus, any situation of stress, discomfort or lack of welfare can be translated in terms of the energetic component. Since all animals and plants follow the homeostatic rule, (i. e., to react to any challenge in order to recover the balance of internal variables and adapt to the environmental inputs), such reaction always involve minute or longer term reorganization of resources and therefore changes in the allocation of available energy. Therefore, significant alterations of the energetic balance as a result from stressors such as heavy space restrictions, flying from predators, aggression, injuries, pathogens, or those resulting from discomfort or mild stressors, can indicate changes in welfare. In this way, performance functions like growth, disease resistance or reproductive capacity will receive less resources, with the consequent impairment or alteration of the degree of such performance. Another aspect of fish diversity that is relevant to the response to stressors and challenges and therefore to the maintenance of welfare is the individual variability. This feature, that is common to most vertebrates, is also observed in fishes (Harel and Brunet, 2015).

Some authors name it personality, although a better word could be individuality, as personality refers too directly to human features (Castanheira *et. al.* 2013). Whether a fish behaves proactively/aggressively or reactive in front of a challenge depends on the individual coping strategy, life-story experiences, evolutionary constrictions, behavioural plasticity, and social context, provided that there is competition for space, resources or reproductive partnership (Vargas *et.al.* 2018). Such diverted behaviour is much associated to the ability of fishes to maintain or recover welfare. Reactive fishes, more plastic to confront novel environments, may become inactive or shy thus avoiding injuries and heavy stress when facing a possible episode of aggression, whereas proactive fishes may take much more risk but having the opportunity to increase welfare through abundant feeding or effective reproductive success (Kulczykowska, 2019) Fishes also indulge in a panoply of reproductive modes, ranging from gonochorism (separate sexes) to sequential or simultaneous hermaphroditism, with few species being true parthenogenetic (Harel and Brunet, 2015). This diversity also influences the onset of physiological responses to environmental stressors (Vargas *et.al.*,2018).

**Processes and Factors in Aquaculture that can be Critical for Fish Welfare**

**Staff (education, training, responsibility)**

Fish reared in aquaculture eventually depend completely on man. Hence, well-trained staff are a critical factor in supporting the good welfare status of the fish. "Trained" means that the personnel responsible for the fish are educated in welfare-related issues, including knowledge in the biological requirements of fish in general as well as in the specific requirements of the particular species cultivated and in considerate handling. The personnel know the normal behaviour of the fish species cultivated and are aware of their environmental requirements. The staff are trained in detecting abnormalities in fish behaviour and in fish health that possibly indicate a welfare problem. Training also involves technical knowledge in the overall functioning of the rearing system and how to react if problems show up.

**Fish (species, life stage and domestication)**

According to (Kulczykowska, 2019) more than 350 finfish species are cultivated in aquaculture. Many of these species evolved in a variety of entirely different habitats and adapted to different environmental conditions and thus developed highly diverse biological traits. Consequently, each species and each stage of life has its own specific requirements from the rearing environment. Importantly, strains of a species may vary in their adaptation to environmental conditions. This is especially true for some species that have been subjected to domestication and intensive genetic selection, such as rainbow trout, carp, or Atlantic salmon. Through domestication, ranges in behaviour and tolerance may be changed compared to the respective undomesticated species.

**Husbandry techniques**

A number of husbandry factors and practices can impact the welfare status of the cultured fish, they include water quality (physical, chemical parameters), stocking density and rearing environment

**Fish Health and Welfare Management**

Since many fishes are subjected to anthropogenic sources of potential stress (fisheries, aquaculture, fish trading, aquariology, and research), the issue of fish health management and welfare management is increasingly becoming a priority for those involved in these activities? In this way, indicators of both welfare and health management have been developed (Carbajal *et. al.* 2019) and are still being developed for fishes for the objectives of maintenance of good health and disease prevention and to obtain a welfare standard or even a welfare certification. When it comes to assessing operational welfare or health, the indicators used become more and more very similar.

## CONCLUSION

As we dive deeper into the world of fish welfare, it becomes clear that their wellbeing is a delicate balance of stress, health, environment and diversity. Whether we're working in conservation or aquaculture, it is crucial that we take holistic approach to promoting the welfare of these excellent animals. By recognizing the impacts of stress on their health, the role of environment in shaping their lives and the importance of diversity in thriving ecosystems. We can more compassionate and sustainable practice.

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# ASSESSMENT OF WATER QUALITY PARAMETERS, COMPOSITION OF PLANKTON AND MACROPHYTE IN RIVER AMBA, LAFIA NASARAWA STATE, NIGERIA

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**ABSTRACT**
*The study assessed the physicochemical parameters, abundance of zooplankton, phytoplankton and macrophyte in River Amba. Samples were collected from three sampling stations (upstream, midstream and downstream) as stations A, B, and C respectively. The ranges of mean values of physicochemical parameters were Temperature (27.19°C – 27.44°C); Turbidity (19.88cm – 27.20cm); Dissolved Oxygen (4.49mg/L – 4.81mg/L); Biochemical Oxygen Demand (1.84mg/L – 2.17mg/L); pH (6.63 – 6.75) and Alkalinity (36.86mg/L – 45.25mg/L). Phytoplankton recorded three families (Cyanophyceae, Chlorophyceas and Euglenophycea) and four species; the most abundant was Chlorella ellipsoidea (76.3%) in station A while the least was Spirulina substilissina (7.1%) in station C, eleven zooplankton species belonging to three groups: Rotifera, Copepoda and Cladocera were found. The most abundant zooplankton was Cyclops nauplii (36.0%) in station C while the lowest was Moina spp. (1.6%) in station A. The macrophytes species identified were fourteen belonging to eleven families; the most abundant macrophytes was Hyrolea glahra (28.8%) while the least was Fuirena ciliaris (1.6%) both were in station A. Conclusively, the overall assessment elucidated that most of the physicochemical parameters were within the ranges of unpolluted water bodies and different levels of anthropogenic inputs have caused wide variations in plankton and aquatic macrophyte composition in different stations.*

**Keywords:** Zooplankton, Phytoplankton, Macrophyte, River Amba, Physicochemical Parameters

## INTRODUCTION

Rivers support diverse and large numbers of flora and fauna, making it one of the most productive ecosystems on the earth. Freshwater bodies across the world are subjected to intense human activities which have degraded the quality and utility of the water (Amah-Jerry *et al.*, 2017). Researchers have predicted the quality of the aquatic ecosystem and ecological effects of human activities by the assessment of its biological communities (Aliu *et al.*, 2020). Planktons are one of the essential biological communities found in lotic freshwater ecosystems (Sharma, 2018). The existence and distribution of plankton across the aquatic ecosystem depend on several factors such as water quality, climatic factors, grazing intensity and competition (Ojelade *et al.*, 2021). Zooplanktons as free-floating, aquatic invertebrates, often described as microscopic because of their normal small sizes that range from few to several micrometers and are not often exceeding a millimeter and consists of protozoans, rotifers and crustaceans and others. Zooplanktons constitute an important source of natural food resources for aquatic organisms, therefore occupied a strategic trophic level as primary consumers (Ja'faru *et al.*, 2015), they respond strongly to environmental change, often used as indicators to assess the condition and change of the freshwater environment or the conditions in aquatic ecosystems (Primo *et al.*, 2015; Schmidt *et al.*, 2020). Zooplankton assemblages of freshwater ecosystems vary in space and time (Kar *et al.*, 2018). It is thus important to look at the composition, abundance and diversity of the zooplanktons and how environmental conditions impact the trophic level in the lake. (Ojelade *et al.*, 2021). Aquatic

macrophytes are plants that are larger than most algae. They characteristically grow in water or in wet areas and are quite a diverse group. Some are rooted in the sediment while others float on the water surface and are rooted to the bottom, including largely flowering plants (angiosperms), some (pteridophytes) and ferns and microscopic mosses algae (storwort for insatance chara and alga cladophora) (Lacoul and Freedman, 2006; Akomolafe and Nkwocha 2017). Amba River is subjected to number of anthropogenic activities such as agricultural activities, car washing and washing of cloth and refuge dump. The resultant activities can constitute heavy aquatic pollution which in turn can change the water quality, affect the biota population (plankton and macrophyte) within the aquatic communities. Hence there is a need to assess the aquatic environment. This study was aimed at assessing the water physicochemical parameters, composition and relative abundance of zooplankton, phytoplankton and macrophyte of River Amba.

## MATERIALS AND METHODS

### Study Area

River Amba lies at a longitude of $08^0$.30 East and latitude $08^0$.32 North, is in the middle climatic belt that is generally very warm and humid in both dry and rainy seasons. It has a mean range of temperature $26^0$C to $30^0$C, rainfall 1120 mm to 1500 mm, relative humidity 60 – 80 %. This falls within the Guinea Savannah kind of vegetation. River Amba lies within the River Amba Basin. The catchment is situated within the capital city of Lafia, Nasarawa State, 90 km North of Makurdi, capital of Benue State. The perennial River has a catchment area of 115 square kilometers. The Amba River system rises as small tributaries from Dutse, Bukan Kwatu, and Angogo springs, from the Eastern Agyaragu-Obi minor highland areas. The rivulets join the mainstream of the River Amba which flows roughly East-West to the West where it joins other tributaries, it empties through the major River Oriye, into the River Mada. (Aho, *et al*., 2018).

### Sampling Stations

Three sampling stations were chosen based on upstream (Station A), midstream (Station B) and downstream (Station C) respectively. The sampling stations were chosen one thousand meters apart from the last site. The samples (Water, Plankton and Aquatic macrophyte) were collected twice monthly (after two weeks) at 6 – 8am to reduce the impact of diurnal variation at each station, since planktons undergoes vertical migration), for the period of 4 months (July to October 2024).

### Sample Collection and Physicochemical Parameter Analysis

Water samples for physicochemical analysis were collected from each sampling stations (A, B, and C) in triplicate and analyzed using Freshwater Aquaculture Test kit/model AQ2/CODE 3633-04, Temperature was determined using Mercury Glass Thermometer and turbidity using Secchi disc. Some of the water quality parameters were determined in-situ (temperature, turbidity, $P^H$, dissolved oxygen and alkalinity). Biological Oxygen Demand (BOD) samples were transported to the Department of Fisheries and Aquaculture College of Agriculture Science and Technology Laboratory, Lafia Nasarawa State for analysis using standard method described by American public health Association (APHA) (2012).

### Field Plankton collection (Sampling)

Plankton (zooplankton and phytoplankton) samples were collected from the three sampling stations (A, B and C) using a plankton net with a standard mesh size of 55µm. Plankton net is a conical device made of fine nylon mesh which was used to sweep across the water column horizontally for a known distance of five meters. Plankton (zooplankton and phytoplankton) were captured into the vial at the bottom of the net and the resultant concentrated plankton (zooplankton and phytoplankton) samples were transferred into the storage bottle. The samples were preserved with 4% formalin solution. then transported to the

laboratory for analysis. at the Department of Fisheries and Aquaculture College of Agriculture Science and Technology Laboratory, Lafia Nasarawa State.

**Plankton Laboratory Analysis**
The Samples were homogenized by inverting the containers few times. With a wide-mouth pipette, 1ml of the plankton subsample were withdrawn from the field samples, placed on a Sedge-wick rafter-counting chamber and observed by direct microscopy. Plankton (zooplankton and phytoplankton) were identified to the species level and enumerated using a microscope fit with a camera (Premier equipped model) at x400 and x1000 magnification. was used for species identifications. Counts were made in triplicates and their averages taken and expressed in cells/ml for (phytoplankton) and organisms/ml (zooplankton) of water.

**Plankton Sample Identification**
The identification of the plankton species was carried out using a combination of identification keys and field guides by Needham and Needham (1975), Jeje and Fernando (1986), APHA (2005). The organisms in the concentrated samples were counted in a counting chamber. Pictures of the planktons were taken using digital camera.

**Aquatic Macrophytes Collection**
The matured aquatic macrophytes were collected from each station (A, B and C). Photographs of each aquatic species were taken using a digital camera. The collected aquatic macrophyte was pressed, dried and mounted on the standard herbarium sheet as described by Akomolafe and Nkwocha 2017).
The identification was made using a handbook of common aquatic plant of the kainji Lake, Nigeria (Obot and Ayeni 1987) in the Department of plant Science and Biotechnology, Federal University of Lafia. The collected aquatic macrophyte species were mounted on the standard herbarium sheet

## RESULTS AND DISCUSSION
Physicochemical parameters of Amba river Lafia Nasarawa State. The mean result of physicochemical parameters, Water temperature showed station C had the highest (27.44°C), while the lowest was recorded in station A (27.19°C), Dissolved Oxygen (DO) the lowest value (4.49mg/L) at station C and the highest mean at station B (4.81mg/L), Biochemical Oxygen Demand (BOD) the lowest means was obtained at station C (1.84mg/L) and B recorded the highest value of (2.17mg/L) and The mean pH value range respectively from the lowest (6.63) recorded at station C and station A recorded the highest (6.75) all show no significant difference ($P>0.05$) across all the stations. The mean result of transparency revealed that station C had the lowest (19.88cm) and B recorded the highest (27.20cm) and the lowest mean of alkalinity (36.86mg/L) recorded in station B and highest (45.25mg/L) recorded station at C respectively.

**Table 1:** Mean Physicochemical Parameter of River Amba

| Parameters | A<br>Mean ± SD | B<br>Mean ± SD | C<br>Mean ± SD | F | *P* |
|---|---|---|---|---|---|
| N | 16 | 16 | 16 | - | - |
| Temperature ( ℃) | 27.19 ± 1.05 | 27.38 ± 1.15 | 27.44 ± 1.15 | 0.217 | 0.806 |
| pH | 6.75 ± 0.71 | 6.72 ± 0.41 | 6.63 ± 0.47 | 0.23 | 0.795 |
| DO (mg/L) | 4.72 ± 0.63 | 4.81 ± 0.71 | 4.49 ± 0.40 | 1.25 | 0.297 |
| BOD (mg/L) | 2.15 ± 0.51 | 2.17 ± 0.56 | 1.84 ± 0.46 | 2.13 | 0.131 |
| Alkalinity (mg/L) | 40.31 ± 7.13 | 36.86 ± 4.75 | 45.25 ± 5.29 | 8.41 | <0.001 |
| Transparency | 21.38 ± 1.87 | 27.20 ± 5.91 | 19.88 ± 2.27 | 16.51 | <0.001 |

**Table 2:** Phytoplankton Composition of River Amba

| Family | Species | A | %Composition | B | %Composition | C | %Composition |
|---|---|---|---|---|---|---|---|
| Cyanophyceae | *Anabaena spiroides* | 18 | 23.7 | 17 | 45.9 | 16 | 19.0 |
| Chlorophyceas | *Chlorella ellipsoidea* | 58 | 76.3 | 14 | 37.8 | 47 | 56.0 |
| Euglenophycea | *Euglena convolute* | 0 | 0 | 6 | 16.2 | 15 | 17.9 |
| | *Spirulina substilissina* | 0 | 0 | 0 | 0 | 6 | 7.1 |
| **Total** | | **76** | **100** | **37** | **100** | **84** | **100** |

Phytoplankton species belonging to three families were recorded during the study period. one species of Chlorophyceae, two species of Cyanophyceae and one species of Euglenophyceae. The highest abundance for phytoplankton was recorded in station A, C*hlorella ellipsoidea* (76.3%) while, the lowest abundance *Spirulina substilissina* (7.0%) was recorded in station C.

**Table 3**: Zooplanktons Composition of River Amba

| Group | Species | A | % Composition | B | % Composition | C | % Composition |
|---|---|---|---|---|---|---|---|
| Copepoda | *Cyclops nauplii* | 22 | 35.5 | 17 | 31.5 | 9 | 36.0 |
| | *Neuplius spp.* | 4 | 6.5 | 5 | 9.3 | 1 | 4.0 |
| Cladocera | *Daphnia rosea* | 6 | 9.7 | 3 | 5.6 | 2 | 8.0 |
| | *Daphnia spp.* | 7 | 11.3 | 6 | 11.1 | 3 | 12.0 |
| | *Moinamicrura* | 3 | 4.8 | 9 | 16.7 | 4 | 16.0 |
| | *Moina spp.* | 1 | 1.6 | 2 | 3.7 | 3 | 12.0 |
| | *Keretella spp.* | 10 | 16.1 | 4 | 7.4 | 0 | - |
| Rotifera | *Brachionus spp.* | 9 | 14.5 | 8 | 14.8 | 3 | 12.0 |
| **Total** | | **62** | **100** | **54** | **100** | **25** | **100** |

The zooplankton species encountered were eleven species belonging to three groups; Rotifera, Copepoda and Cladocera. The Rotifera is two species, five species of Copepoda and three species of Cladocera. The highest abundance for zooplankton was recorded in station C. C*yclops nauplii* (36.0%), while the lowest was *Neuplius spp* (4.0%) recorded in station C. The macrophytes species identified in Amba River were fourteen species belonging to eleven families, Cyperaceae, Asteraceae, Onagraceae, Typhaceae, Poaceae, Hydrophyllaceae, Fabaceae, Azollaceae, Araceae,Amaranthaceae and Haloragaceae. The highest (%) composition of macrophytes was recorded in station A *Hyrolea glahra.* (28.8%), while the lowest was *Fuirena ciliaris* (1.6%) recorded in station A.

**Table 4:** Aquatic macrophytes River Amba

| Family | Species | Station / (%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | A | | B | | C | |
| | | N | % | N | % | N | % |
| Cyperaceae | *Fuirena ciliaris* | 1 | 1.6 | 11 | 6.4 | 5 | 5.6 |
| Asteraceae | *Edipta prostrate* | 0 | 0 | 21 | 12.1 | 9 | 10.1 |
| | *Emilia coccinea* | 4 | 6.7 | 6 | 3.5 | 0 | 0 |
| Onagraceae | *Ludwigia abyssinica* | 0 | 0 | 16 | 9.2 | 17 | 19.1 |
| Typhaceae | *Typha austratis* | 2 | 3.4 | 9 | 5.2 | 3 | 3.4 |
| Poaceae | *Phragmites australis* | 4 | 6.7 | 6 | 3.5 | 8 | 9.0 |
| " | *Echinochloa Africana* | 6 | 10.2 | 12 | 6.9 | 4 | 4.5 |
| | *Oryza* | 3 | 3.4 | 7 | 4.0 | 5 | 5.6 |
| Hydrophyllaceae | *Hyrolea glahra.* | 17 | 28.8 | 21 | 12.1 | 11 | 12.4 |
| Fabaceae | *Mimosa pendica* | 3 | 3.4 | 11 | 6.4 | 7 | 7.9 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Azollaceae | *Azolla Africana* | 5 | 8.5 | 8 | 4.6 | 4 | 4.5 |
| Araceae | *Pistia stratiotes* | 4 | 6.7 | 8 | 4.6 | 2 | 2.2 |
| Amaranthaceae | *Alternanthera nodiflora* | 4 | 6.7 | 14 | 8.1 | 6 | 6.7 |
| Haloragaceae | *Proserpina capalustris* | 6 | 10.2 | 23 | 13.3 | 8 | 9.0 |
| **TOTAL** | | **59** | **96.2** | **173** | **99.9** | **89** | **100** |

## DISCUSION

Water temperature is one of the most critical water quality parameters that directly influenced the growth, food intake, reproduction and other biological activities of aquatic organisms (Halim *et al*., 2018). (Dugdale *et al*., 2018) reported water temperature as a critical factor in biotic and abiotic processes; capable of affecting the amount of dissolved matter, organic/inorganic pollutants, nutrients, micro bacterial concentrations, the behaviour of fish and invertebrates in the aquatic environment. The mean water temperature of Amba River during the study period fell within the normal temperature range (20-33°C) as suitable for aquatic life in the tropical region (WHO, 2011 and NESREA, 2011). The standard limit for transparency was exceeded in the values recorded in all the stations during the period of studies which could be attributed to agriculture activities and anthropogenic activities. Swimming by large number of children, bathing, washing and extraction of water for drinking were higher during the season and affected transparency in Station B. However, Stations A and C had relatively high values because of agricultural activities which increased with the rains (Anyanwu and Umeham 2020). Dissolved oxygen (DO) is one of the major parameters used in the determination of water quality, it critical to support aquatic biodiversity (Aydin *et al*., 2021), the DO values reported in this study periods were within the W.H.O (2011) and NESREA (2011) threshold for aquatic life. The mean BOD in this study was below the 4.0 mg/L limit recommended as suitable for aquatic life by NESREA (2011). The higher BOD in station could be attributed to the different organic wastes received from the residents. High BOD level is a pointer to' potential pollution problems because it is capable of adversely depleting dissolved oxygen to the detriment of aquatic biota (Al-Sulaiman *et al*., 2018). The mean pH fell within the acceptable limit (6.0-9.0) recommended by NESREA (2011) for aquatic life. Water bodies in the tropics usually show a wide range of fluctuations in total alkalinity, the values depending on the location, season, plankton population and nature of the bottom deposits. However, the mean alkalinity recorded in this study was within the 20-200mg/L optimal range for fish production as classified by Boyd (1982).

The phytoplankton assemblages from these studies, had been previously identified from different Nigerian rivers Esenowo and Ugwumba (2010) recorded 50 species of phytoplankton in Majidun River in Lagos State and Ogbuagu and Ayoade (2012) recorded a total of (6) phytoplankton in Imo River. The low phytoplankton from Amba River could be due to low nutrient availability and high turbidity in the water body. The phytoplankton was dominated by Chlorophyceae followed by Bacillariophyceae as reported by Bwala, (2019). River Kaduna in North Central Nigeria by (Arimoro *et al*., 2018) and Orashi River, South-South Nigeria by (Davies *et al*., 2019) The observation of Chlorophyceae as the most abundant phytoplankton in this study is similar to the finding of (Solomon *et al*., 2011) that Chlorophyceae are more obvious representative of the phytoplankton in the tropics that the euglenoids are not only planktonic but good indicators of pollution in freshwater bodies. This study recorded 8 species of zooplankton, 19 species recorded by (Ogbuagu and Ayoade, 2012) in Imo River; 30 species reported by (Nkwoji *et al*., 2010) in Lagos Lagoon. This present observation of low zooplankton species possibly indicates low presence of organic wastes deposition in Amba River, which results in decrease in phytoplankton production, consequently, zooplankton productivity. The Copepoda generally is adapted to warm water, occurring mostly in tropical bodies, with high temperatures. The composition of the

zooplankton group was dominated by Rotifer followed by Cladocera, Protozoa and Copepod as observed by (Kamboj and Kamboj, 2020) in the mining-impacted stretch of Ganga River, India.
The Aquatic macrophytes identified from Amba River agreed with the research reported from different Nigerian Rivers (Ladipo *et al*., 2011) the high macrophytes taxa (11) in Amba River could be as a result of nutrient availability in the water body and application of inorganic fertilizer during dry season farming. This results in high growth of *Hyroleaglahra*. occurring in a solid mass over Amba River is in credence with (Okayi and Abe 2001).

## CONCLUSION

From the results of the studies conducted, the overall assessment elucidated that most of the physicochemical parameters were within the observed ranges of unpolluted water bodies and different levels of anthropogenic inputs have caused wide variations in plankton and aquatic macrophyte composition in different stations of River Amba. Proper monitoring and sensitization could be recommended to prevent degradation of the aquatic biota and its ecosystem over time.

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# BIOACCUMULATION OF HEAVY METAL CONCENTRATION IN NILE TILAPIA (*Oreochromis niloticus*) IN DOMA DAM, NASARAWA STATE, NIGERIA

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**ABSTRACT**
*This study investigated heavy metal bioaccumulation (Pb, Cd, Fe, Cu, Cr, Zn) in gill, liver, and muscle tissues of Oreochromis niloticus from Doma Dam, Nasarawa State, Nigeria. Fish samples were collected monthly (June-November 2024) from three stations and analyzed using Atomic Absorption Spectrometry. Results showed muscle tissue accumulated highest concentrations of most metals. Chromium peaked in liver (1.90±0.14 mg/kg) and gills (1.50±0.16 mg/kg), while iron was highest in muscle (2.35±0.32 mg/kg). Cadmium in liver (0.33±0.03 mg/kg) exceeded WHO/FAO standards (0.20 mg/kg). Peak accumulation occurred during August-September rainy season. The study confirms potential health risks from consuming contaminated fish and recommends regular monitoring and pollution control measures.*

**Keywords:**
Bioaccumulation, Heavy metals, O*reochromis niloticus*, Concentration

## INTRODUCTION

Heavy metal pollution in aquatic ecosystems represents a significant environmental concern due to the persistence, bioaccumulation, and toxic effects of metals such as cadmium, lead, copper, chromium, iron, and zinc. These pollutants originate from industrial runoff, mining activities, agricultural practices, and urbanization, ultimately accumulating in sediments and aquatic organisms, leading to biodiversity loss and ecosystem degradation (El-Sharkawy *et al*., 2025).

Nile tilapia (O*reochromis niloticus*) is widely recognized as an effective bioindicator for heavy metal contamination in aquatic environments due to its adaptability, feeding habits, and ability to bioaccumulate pollutants in tissues. Studies have demonstrated that heavy metals accumulate in O. *niloticus* tissues, particularly in the liver, gills, and muscles, making it an effective sentinel species (El-Shafei, 2015). Research in various freshwater systems has found elevated heavy metal concentrations in fish muscles, with levels often surpassing permissible limits, posing potential human health risks (Mohamed *et al*., 2020).

Doma Dam, a crucial water source in Nasarawa State, Nigeria, is potentially exposed to heavy metal contamination from several anthropogenic sources, including agrochemical-intensive agriculture, mineral processing, small-scale mining, and food processing industries. These industries release pollutants through agricultural runoff, industrial effluents, and untreated domestic sewage, which eventually accumulate in water bodies (Olalekan *et al*., 2019). Despite the importance of Doma Dam as a source of fish and livelihood for the local population, there is a lack of comprehensive studies on heavy metal levels and their bioaccumulation in O. *niloticus*.

The bioaccumulation of heavy metals in aquatic organisms poses serious health risks to both wildlife and human consumers. Metals such as lead, cadmium, chromium, copper, iron, and zinc accumulate in fish through bioaccumulation and biomagnification, leading to toxic effects at higher trophic levels. In

humans, consumption of contaminated seafood can cause neurotoxicity, kidney damage, cardiovascular disorders, and developmental issues, particularly in children and pregnant women (Almashhadany *et al.*, 2024).

This study aims to assess the bioaccumulation of heavy metals in O*reochromis niloticus* from Doma Dam Reservoir, providing critical information for environmental monitoring, food safety regulations, and public health policies. The findings will contribute to existing knowledge on heavy metal pollution in freshwater ecosystems and support the development of strategies for monitoring and controlling pollution in Nigerian water bodies.

## MATERIALS AND METHODS

### Study Area and Sampling

The study was conducted at Doma Dam, Nasarawa State, Nigeria Located between latitude 7°45'-9°25°N, and longitude 7°C-9°37'E. Three strategic sampling locations were selected: Yelwa (minimal human interference), Kwararafa Fishing Activity Area (heavily populated with fishing activities), and Doma main Dam (water treatment and irrigation activities).

### Sample Collection and Analysis

Fresh O. *niloticus* samples were collected monthly from June to November 2024. Fish were dissected to obtain liver, gill, and muscle tissues, oven-dried at 105°C for 24 hours, and homogenized. Heavy metal analysis was performed using Atomic Absorption Spectrometry after acid digestion with aqua regia ($HCl+HNO_3$, 3:1 ratio). Water quality parameters were also monitored.

### Statistical Analysis

Data were analyzed using SPSS version 20.0. Duncan's multiple range test ($P<0.05$) was used to assess variability between stations and organs. Results were expressed as mean ± standard error.

## RESULTS AND DISCUSSION

### Heavy Metal Concentrations in Fish Organs

The concentration of heavy metals in different organs of O. *niloticus* showed significant variations ($P<0.05$) as presented in Table 1. Muscle tissue accumulated the highest concentrations of most heavy metals compared to liver and gills.

Zinc concentration was significantly higher in muscle tissue (1.13±0.12 mg/kg) compared to gills and liver. This pattern aligns with findings by Ibrahim and Sa'id (2010) who recorded highest zinc concentrations in tilapia muscles. Chromium showed the highest bioaccumulation levels, with liver recording 1.90±0.14 mg/kg, exceeding WHO/FAO standards. The high chromium concentration in liver suggests its role as a detoxification organ, consistent with research showing that liver tissue preferentially accumulates certain heavy metals (Kumar *et al.*, 2011).

Iron concentrations were highest in muscle tissue (2.35±0.32 mg/kg), followed by liver (1.07±0.08 mg/kg) and gills (0.28±0.05 mg/kg). Although iron is essential for biological functions, elevated concentrations can cause oxidative stress and cellular damage in both fish and human consumers (Jaishankar *et al.*, 2014). Cadmium levels in liver (0.33±0.03 mg/kg) exceeded WHO/FAO standards of 0.20 mg/kg, indicating potential health risks. This is particularly concerning as cadmium is a non-essential metal with no biological function and can cause significant liver damage and toxic effects even at low concentrations (El-Ghasham *et al.*, 2008). Lead concentration was highest in muscle tissue (0.24±0.02 mg/kg), which was below the WHO/FAO standard but still represents a potential health concern due to lead's ability to substitute calcium in biological systems. Copper showed the lowest accumulation across all organs.

The result in figure 1-3 show the concentration of heavy metals in the liver, gill, and tissue of O.*niloticus* analyzed from Doma Dam during the study period the result show significant variation between the months among the heavy metals.
Table 2 show the monthly variation of water quality parameter monitor during the study period. Water quality parameter like Ph and temperature where not significant different ($P<0.05$)
Between the month but EC, TDS, DO and BOD shows significant different ($P>0.05$) among the months. Monthly analysis revealed that heavy metal concentrations peaked during August and September 2024, corresponding to the height of the rainy season. Table 1 shows the monthly variation of heavy metals across all organs.

his pattern can be attributed to increased surface runoff carrying pollutants from agricultural activities, domestic waste, and industrial sources during heavy rainfall. The trend contradicts some studies that reported lower concentrations during rainy seasons due to dilution effects (James *et al*., 2017), suggesting that pollution input exceeded dilution capacity in Doma Dam. Chromium accumulation peaked in August (2.614±0.001 mg/kg) and September (2.602±0.027 mg/kg) in liver tissue, while iron concentrations in muscle tissue reached maximum levels in August (2.958±0.011 mg/kg), indicating substantial contamination during this period. This temporal variation aligns with findings by Rajeshkumar and Li (2018) who reported seasonal fluctuations in heavy metal bioaccumulation due to environmental factors.

**Water Quality and Heavy Metal Distribution**
Water quality parameters and heavy metal concentrations varied significantly across sampling sites and months. Table 3 presents heavy metal concentrations in water samples from different sampling stations during the peak contamination period (August).

**Effect of Heavy Metal on Fish Organs**
Kwararafa Fishing Activity Area consistently recorded higher concentrations of cadmium and chromium, while chromium levels exceeded WHO standards across all sites. Iron concentrations also exceeded WHO standards (0.3 mg/L) at all sampling locations. These findings are consistent with studies by Ikponmwen and Tukura (2024) who reported higher metal concentrations in sediments than water in Nigerian rivers. The detected heavy metal concentrations, particularly chromium and cadmium levels exceeding WHO/FAO standards, pose potential health risks to consumers. Chronic consumption of contaminated fish may lead to organ damage, neurotoxicity, and developmental disorders, especially in vulnerable populations such as children and pregnant women (Okoye *et al*., 2022). The high chromium levels are particularly concerning given its carcinogenic potential and ability to cause oxidative stress (Sharma *et al*., 2021). Similar health concerns have been reported in other Nigerian freshwater systems where fish consumption poses risks due to heavy metal bioaccumulation (Tamunosa *et al*., 2025). The results indicate that Doma Dam is experiencing significant heavy metal contamination from multiple anthropogenic sources. The higher concentrations during the rainy season suggest that surface runoff from agricultural activities, domestic waste, and industrial sources contributes substantially to pollution loading (Olalekan *et al*., 2019). This contamination pattern threatens not only fish populations but also the broader aquatic ecosystem and human communities dependent on the dam for water and fish resources. The bioaccumulation patterns observed align with global research indicating that predatory and bottom-feeding fish species tend to accumulate higher metal concentrations due to biomagnification processes (Yang *et al*., 2021).

The detected heavy metal concentrations, particularly chromium and cadmium levels exceeding WHO/FAO standards, pose potential health risks to consumers. Chronic consumption of contaminated fish may lead to organ damage, neurotoxicity, and developmental disorders, especially in vulnerable

populations such as children and pregnant women. The high chromium levels are particularly concerning given its carcinogenic potential and ability to cause oxidative stress. The results indicate that Doma Dam is experiencing significant heavy metal contamination from multiple anthropogenic sources. The higher concentrations during the rainy season suggest that surface runoff from agricultural activities, domestic waste, and industrial sources contributes substantially to pollution loading. This contamination pattern threatens not only fish populations but also the broader aquatic ecosystem and human communities dependent on the dam for water and fish resources.

**Table 1:** Heavy Metal Concentrations in O. *niloticus* Organs (mg/kg)

| Elements | Liver | Gill | Muscle | WHO/FAO Standard (2021) |
|---|---|---|---|---|
| **Zn** | 0.25±0.04 $^{b}$ | 0.32±0.01 $^{b}$ | 1.13±0.12 $^{a}$ | - |
| **Cu** | 0.06±0.00 $^{a}$ | 0.02±0.00 $^{a}$ | 0.05±0.00 $^{a}$ | - |
| **Cr** | 1.90±0.14 $^{a}$ | 1.50±0.16 $^{b}$ | 0.89±0.00 $^{b}$ | 1.00 |
| **Cd** | 0.33±0.03 $^{a}$ | 0.10±0.00 $^{b}$ | 0.09±0.00 $^{b}$ | 0.20 |
| **Pb** | 0.09±0.00 $^{c}$ | 0.11±0.00 $^{b}$ | 0.24±0.02 $^{a}$ | 1.00 |
| **Fe** | 1.07±0.08 $^{b}$ | 0.28±0.05 $^{c}$ | 2.35±0.32 $^{a}$ | - |

*Note: Different superscripts in same column indicate significant differences (P<0.05)*
*Zn-Zinc,Cu-Copper,Cr- chromium, Cd-cadmium, Pb-Lead, F- iron.*

**Table 2:** Monthly Variations of Water Quality Parameters recorded during the Study

| Parameters | June | July | August | Sept | Oct | Nov | Pvalue |
|---|---|---|---|---|---|---|---|
| pH | 5.13 $^{a}$ | 5.13 $^{a}$ | 5.47 $^{a}$ | 5.40 $^{a}$ | 5.47 $^{a}$ | 5.40 $^{a}$ | 0.577 |
| EC ($\mu$ms $^{-1}$) | 45.33 $^{b}$ | 42.6 7 $^{c}$ | 46.33 $^{ab}$ | 47.33 $^{a}$ | 44.00 $^{b}$ | 47.33 $^{a}$ | 0.031 |
| TDS (mg/l) | 26.67 $^{b}$ | 26.00 $^{b}$ | 29.33 $^{a}$ | 25.00 $^{c}$ | 28.33 $^{ab}$ | 25.00 $^{c}$ | 0.000 |
| DO (mg/l) | 5.40 $^{a}$ | 4.97 $^{b}$ | 5.47 $^{a}$ | 4.07 $^{c}$ | 4.13 $^{c}$ | 6.10 $^{a}$ | 0.001 |
| BOD (mg/l) | 2.43 $^{a}$ | 2.43 $^{a}$ | 2.27 $^{ab}$ | 1.77 $^{b}$ | 2.27 $^{ab}$ | 1.77 $^{b}$ | 0.000 |
| Tempt ( $^{o}$C) | 28.56 $^{a}$ | 28.67 $^{a}$ | 28.87 $^{a}$ | 28.43 $^{a}$ | 28.87 $^{a}$ | 28.43 $^{a}$ | 0.500 |

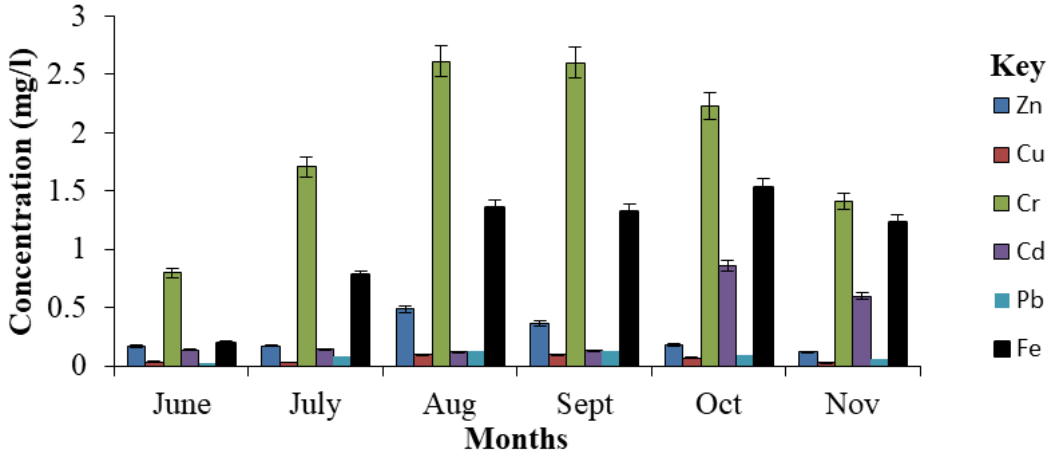



**Figure 1:** Heavy Metals Concentration in the Liver of O*reochromis niloticus*

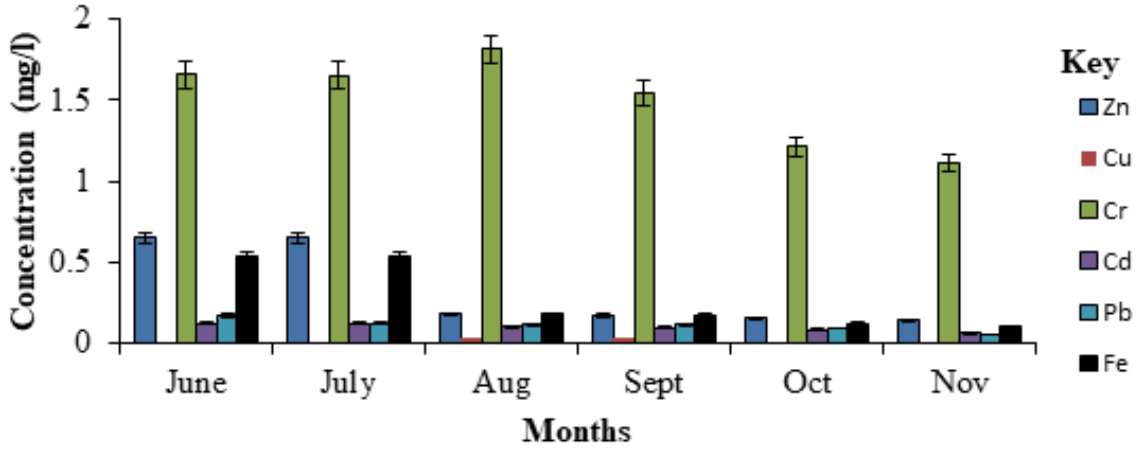



**Figure 2:** Heavy Metals Concentration in the Gill of O*reochromis niloticus*

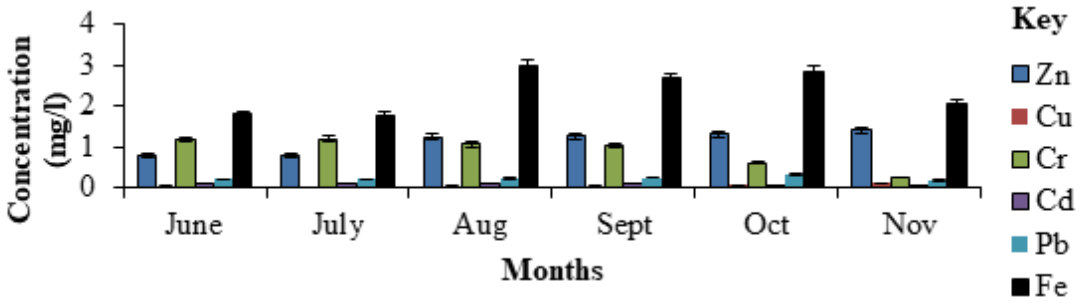



**Figure 3:** Heavy Metals Concentration in the Tissue of O*reochromis niloticus*

## CONCLUSION

This study demonstrated significant heavy metal bioaccumulation in O. *niloticus* from Doma Dam, with muscle tissue showing highest accumulation. Chromium and cadmium levels exceeded WHO/FAO standards, while temporal analysis revealed peak contamination during rainy season, indicating surface runoff as a major pollution source.

## RECOMMENDATIONS

Recommendations include establishing **regular monitoring** programs for heavy metal levels in water, sediment, and fish tissues to track pollution trends. **Pollution source control** should be implemented through strict regulations on industrial discharge and agricultural runoff, while **water treatment enhancement** must include heavy metal removal technologies, particularly for chromium and cadmium.

The study confirms O. *niloticus* as an effective bioindicator and highlights urgent need for environmental management interventions to protect ecosystem and human health.

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# AQUATIC ECOTOXICOLOGY AND WATER QUALITY MANAGEMENT - AEWQ

# WATER QUALITY CHARACTERIZATION AND HEAVY METAL CONCENTRATIONS IN WATER AND SEDIMENT FROM LITTORAL ZONE AXIS OF EPE LAGOON

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**ABSTRACT**

*Lagoon littoral zone is an essential part of lagoon ecosystem and it plays an important role in the sustainability of lagoon's organisms. This study was conducted to investigate the influence of coastal community on water quality and heavy metals concentrations in lagoon water and sediments from the littoral zone. The site was mapped out and divided into 10 sampling stations water and sediments samples were taken from these sampling stations once in a month for three consecutive months. The water quality from the results shows that there is a negative significant difference (P<0.05) in Temperature, D.O, pH, BOD, $NO_3$, and $NO_2$ while the Salinity, E.C, TDS, COD, and $NH_3$ show a positive significant difference (P<0.05) between the sampling months. However, all the investigated heavy metals concentrations in water are significant (P<0.05) while the concentrations of heavy metals in the sediment shows that the month of October significantly (P<0.05) had the highest concentrations of heavy metals with the exception of iron and zinc and November had the lowest concentrations. The spatial distribution of water quality characteristics and heavy metal concentrations in the water and sediment from the littoral zone revealed that the lagoon littoral zone is moderately polluted. The sources of pollution are presumed to be from the combination of the textural nature of lagoon sediment and the coastal community's poor attitude towards the environmental sanitation. It is therefore, recommended that public enlightenment programs be conducted for the coastal community by the environmental protection agencies on environmental sanitation.*

**Keywords:** Littoral Zone, Water Quality, Heavy Metal

The *in-situ* measurements taken were temperature and dissolved oxygen with the aid of hand-held well calibrated probe meters while *ex-situ* were carried out in the laboratory (Nigerian Institute for Oceanography and Marine Research (NIOMR), Victoria Island, Lagos) using Atomic Absorption Spectrophotometer and Complexation Titrations Procedures respectively. Statistical significance of water quality characteristics and heavy metal concentrations in water and sediments from littoral zone of Agbowa-Ikosi axis of Epe Lagoon, were assessed using a one-way analysis of variance (ANOVA) and the software used is SPSS version 20. The correlation coefficient and differences between groups were considered significant when $p = .05$ (two tailed).

## RESULTS AND DISCUSSION

Water quality characteristics from littoral zone of Agbowa-Ikosi for the months of October, November and December sampling periods. The statistical results from data collected shows the heterogeneous

distributions of water quality characteristics during the study periods. The highest mean data values of temperature, electrical conductivity, salinity, nitrate, nitrite and ammonia were recorded in December while dissolved oxygen, pH and Total dissolved solids had the highest means in October. Similarly, the highest means of chemical oxygen demand was recorded in November. However, temperature, electrical conductivity, and nitrite had the lowest means in November while BOD lowest means was recorded in December. All these implies negative significant difference (p=.05) in Temperature, Dissolved oxygen, pH, BOD, $NO_3$ and $NO_2$ while the Salinity, E.C, TDS, COD and $NH_3$ shows positive significant difference ($P<0.05$) between the sampling months.

The monthly mean value concentrations and variations in the water quality characteristics from the littoral zone of the lagoon between October and December shows the effect of seasons on assay of water quality characteristics conducted. All the investigated water quality parameters were above standard regulatory limits. This occurrence could be associated with the influence of hydrological patterns on the environment (World Bank Group, 2021), uncontrolled discharge of waste water directly into the Lagoon water body, and the open defecation by the host community (Babalola and Fiogbe, 2017).
The numerical analysis of heavy metals in water from littoral zone of Agbowa-Ikosi axis of Epe shows that Cadmium, Cobalt, Lead, Manganese, Nickel, and Zinc had their highest concentrations in October while Iron and copper had their highest concentrations in December while Chromium had the highest concentration in November but Vanadium concentrations were the same throughout the sampling months. Additionally, the concentrations of all the investigated heavy metals from the study site are significant ($P<0.05$).

The monthly mean values concentration of heavy metals in water from the littoral zone of the lagoon during the sampling periods shows the effect of hydrological patterns and correlations between water quality characteristics and heavy metal concentrations in the Lagoon environment (Babalola and Fiogbe, 2017). The categories of heavy metals that were detected in the environment are Essential and Non-essential metal elements. The non-essential metal elements such as cadmium, (Cd), Lead (Pb), Chromium (Cr), and vanadium (Va) finds their ways into the lagoon environment by natural occurrence and or by anthropogenic from the host community via indiscriminate disposal of household unserviceable items and industrial effluents discharge (Martinez-Finley *et al.*, 2012). The Essential elements such as Iron (Fe), Manganese (Mn), Cobalt (Co), Copper (Cu), Nickel (Ni), and Zinc (Zn) are group of essential metal elements. They are known for their range of uses from household equipment to medicament (Klaudia *et al.*, 2022). These essential metal elements occur naturally in the earth's crust and also spread into the environment through the natural occurrences, industrial and anthropogenic activities (Lenntech, 2023).

The mean data values of the heavy metals collected on the sediments from the littoral zone showed that different month and nature of the heavy metals significantly affects their concentrations in the lagoon environment with the exception of Vanadium that had similar concentrations all through the sampling months. The month of October significantly ($P<0.05$) had the highest heavy metals in the sediments while November had significantly (p=.05) the lowest except Iron and Zinc which had the lowest concentrations of 40.93mg/kg and 2.45mg/kg respectively in October and highest concentrations of 68.35mg/kg and 4.44mg/kg separately in November. All the investigated heavy metals concentrations in the sediments from the study site are significant ($P<0.05$).

The anthropogenic sources of these heavy metals found in the littoral zone of Agbowa-Ikosi lagoon axis's sediment are assumed to be from the protective metal coatings and paint pigments of fishing craft docked at the lagoon coastal areas. Such fishing crafts are dug-out wooden canoe, in-board and out-board

motorized engines used by the fisher folks for fishing activities and transportation, wood preservatives from the wood used in the local fabrication of dug-out wooden canoe. These protective metal coatings and paint pigments are used to prevent rusting and decaying of the fishing crafts respectively. Similarly, spilled gasoline and engine oil from automobile canoe engines use for fishing and transportation, spilled engine oil and fuel oil from electricity power generating set use by community's households during power outage, and used spilled engine oil and fuel from automobile servicing shed in the community, and the use of charcoal from the local smoking kilns by fish mongers (Awan *et al.*, 2021). This could similarly complement the elevated concentrations of these heavy metals that have their natural source of occurrence in the Agbowa-Ikosi lagoon environment (Hazrat *et al.*, 2019).

## CONCLUSION

The presence of pollutants in the lagoon environment poses a potential ecological risk and its associated health challenges in human from physiological complications in aquatic organisms to carcinogenic and neurological effect in human (Alkesh, 2023). The pollution and the spatial distribution of water quality characteristics, and heavy metal concentrations in the water and sediment from the littoral zone of Agbowa-ikosi lagoon axis of Epe are majorly influenced by the hydrological pattern, the coastal community's unorthodox disposers of waste and unserviceable materials and uncut attitude towards environmental sanitation. It is therefore, recommended that a public enlightenment programs on the benefits of environmental sanitation, the implication of polluting the environment, and the associated health risks to it be conducted by the regulatory agencies on environmental protection for the inhabitants of Agbowa-ikosi coastal community. Also, it is pertinent to educate the Agbowa-Ikosi coastal community residents on the proper ways of disposing wastes and unserviceable that contains organic matters and elemental materials. Lastly, government should improve on the social amenities in this coastal community to ward off the incident of coastal environmental pollution by the inhabitants.

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# SEASONAL VARIATION IN PHYSICOCHEMICAL PARAMETERS AND HEAVY METAL CONCENTRATION IN WATER ALONG RIVER YOBE IN GASHUA

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**ABSTRACT**

*The physicochemical properties and heavy metal concentrations of water from three sampling sites were analyzed using standard methods and Atomic Absorption Spectrophotometry (AAS). The pH values ranged from 7.10 to 7.77, falling within acceptable limits. Electrical conductivity was higher in the dry season (0.56±0.00, 0.59±0.003, 0.58±0.003 µS) than in the wet season (0.46±0.01, 0.48±0.01, 0.47±0.03 µS). Dissolved oxygen generally met WHO and USEPA standards, although temperature was elevated during the dry season, and dissolved oxygen peaked above guideline limits in the wet season. Analysis of variance ($P < 0.05$) indicated significant seasonal differences in measured parameters. AAS results showed spatial variation in heavy metal concentrations across the sites. Most metals were higher during the dry season, except arsenic (As), cadmium (Cd), and lead (Pb), which were consistently low in both seasons. Zinc (Zn), chromium (Cr), arsenic (As), iron (Fe), and nickel (Ni) levels exceeded USEPA safe limits for drinking water (0.01, 0.01, and 0.001 mg/L, respectively). Overall, some metals remained relatively high across all sites and seasons, indicating potential contamination risks.*

**Keywords**: Metal concentration, Seasonal variability, anthropogenic activities.

## INTRODUCTION

Aquatic Pollution can be defined as the introduction of contaminants into the natural environment that causes adverse change (Merriam-Webster, 2010). In 2015, pollution killed 9 million people in the world *(*Beil and Carrington, *2017)*. The many parts of the heavy metals released into the earth discover their way into the freshwater and marine environment as by many ways as input of direct air deposition, climatic, and disintegration due to rainwater. The levels of heavy metals are too high, in the area where domestic activities, mining activities, mechanical and cultivating activities are across the natural areas (Suleiman and Suleiman 2019)

The bioaccumulation of heavy metals widely varies among aquatic species, which is mainly due to specific physiological processes, metabolic activities, feeding strategies, and living habits (Baki *et al.* 2018; Liu *et al*. 2019). Moreover, some metabolically active organs, such as gills and the liver, generally accumulate high levels of heavy metals (Subotić *et al.*, 2013; Djikanović *et al.* 2018).Recent development in the agricultural sector, industrialization, and urbanization have contributed substantially to elevated heavy metal pollution in freshwater and marine environments. Anthropogenic activities such as mining and smelting (Chen *et al*. 2015), combustion of fossil fuel refining (Muradoglu *et al*., 2015), discharge and disposal of domestic and municipal wastes (Khan *et al*., 2016), using pesticides in agricultural sector (Ogunlade and Agbeniyi 2011), sewage irrigation in some countries (Sun *et al*., 2013), fertilizer and urea application (Atafar *et al*., 2010), dust (Chen *et al*., 2011) contribute to the spread of dangerous heavy metals in aquatic environments. Different parts of fish such as gills, liver, kidneys and muscles have been widely investigated for heavy metals (Oguzie and Izevbigie, 2009). Fish have been considered as one of

the most significant indicators in water systems for the estimation of metal pollution level (Oguzie and Izevbigie, 2009).

The people of Gashua town in Yobe State, Nigeria, including high and low-income groups utilized a considerable quantity of fish. Other sources generated by agricultural technologies such as: irrigation with wastewater, the administration of organic and mineral fertilizers with the load of heavy metals, or application of pesticides, which contain in their structure such chemical elements (Singh *et al*., 2004; Sharma *et al*., 2006).Chronic Kidney Disease (CKD), also known as chronic renal disease, is a condition that is characterized by a gradual loss of kidney function over time, and when it progresses can lead to kidney failure (NKF, 2013). CKD is a quiet disease because it does not have noticeable signs and symptoms that are apparent to the patient at the early stage of the disease. Studies in some parts of Nigeria indicated that 10 people out of every 100 will have CKD, and in some parts, one out of every five people will have CKD at some point in life, according to Bamgboye (2013). The rate of CKD prevalence in Nigeria is between 8% and 45%, depending on the region and population that was studied (Alebiosu and Ayodele, 2005). In addition, the number of environmental risk factors has been recognized globally as probable causes of CKD, namely exposure to heavy metals (Arsenic (As), Cadmium (Cd), chromium (Cr), copper (Cu), and lead (Pb), agrochemicals, and nephrotoxic substances.

## MATERIALS AND METHODS

### Study Area

The Yobe River, also known as the Komadougou located on latitude 10°22'E and longititude 12°46'N covering about 3500 $km^2$ is a river in West Africa that flows into Lake Chad through Nigeria and Niger. Its tributaries are the Hadejia River, the Jama'are River and the KomaduguGana River. River Yobe is situated in the Sudan Sahel zone of the Northeast of Nigeria. The average annual temperature of the Gashua ranges from $38^0$C to $40^0$C with a mean maximum temperature of 39.8°C between March to April and mean minimum temperatures of 28.1°C between June to September. Gashua falls within the vegetation zone of Sudan Savannah usually dominated by shrubs and short tress with a yearly rainfall of 500 to 1000mm that lasts for about 120 days.

### Sample collection and determination

The samples were collected from the three-sampling station and taken to the laboratory for the analysis. Heavy metals Pb, Cd, As, Fe, Ni and Zn in the water samples were determined using AAS as described by APHA (2005), using a Buck Scientific 200A model, Atomic Absorption Spectrophotometer (AAS) and the values obtained were expressed in milligram per litre (mg/l) (APHA 1995). Procedural blanks were prepared and aspirated along with the analytical samples in order to correct for background absorption and the values obtained were expressed in milligram per litre (mg/) (APHA 1995).

### Seasonal Variability in Physicochemical Parameters and Heavy Metals in Water

Seasonal variability of Heavy metals in Water and Sediments were determined by comparing levels obtained in Wetseason with the level obtained in Dry season.

### Data Analysis

Data obtained in this study were subjected to descriptive statistics to establish means, standard errors and one way analysis of variance (ANOVA) was used to determine the mean significant variation ($P<0.05$) in physicochemical parameters and heavy metals in the sampling stations using Statistical Package for Scientists and Engineers (Statistix 9.0).

## RESULTS

### Water Quality parameters

The results of the selected physiochemical parameters are analysed in both dry and wet season from the various sampling site. The pH of all the water samples of the three locations are within the permissible limit; this is because it ranged between 7.10 and 7.77. Statistical analysis of variance conducted on the data revealed that there was no significant difference between the interactions of locations. The maximum pH value recorded in this study is lower than 8.22, and 8.1 reported in similar water bodies in Nigeria (Arimoro, *et al*., 2008; and Davies *et al*., 2006). However, values recorded in this study which ranged between 7.10 and 7.77 are comparable to the work of Adeyeye and Abulude (2005) with a pH range between 5.90 and 7.60 when studying the assessment of some surface ground water resources in Ile-Ife, Nigeria. The pH of all the locations was within the 6.0 and 9.5 WHO and USEPA standard limits for drinking water. The pH values of this study were in concordance with the findings of Badejo *et al.*, (2017), Nazir *et al.*, (2015) and Seiyaboh *et al.*, (2016) with the values of 7.49 – 7.66, 7.22 – 8.32 and 6.73 – 6.87$\mu$ respectively. The obtained results indicate that the water sample from S1 is slightly acidic. The of the EC results in dry season was also found to be higher compared to the wet season as identified from the data 0.56±0.00, 0.59±0.003 and 0.58±0.003($\mu$S) at dry season and 0.46±0.01, 0.48±0.01and 0.47±0.03 ($\mu$S) at wet seasons as presented in the Table 4.1. The observed variations of these values however may be accounted for the changes in the water level as a result of high rate of sunlight and lowering of the amount of drainage water pouring into the water by dry season. The lower values are due to conductivity is proportional to salinity. Surface water temperature from the sampling periods for the two seasons are 29.93±0.07, 30.00±0.00 and 29.31±0.03°C dry and 26.93±0.067, 27.31±0.01 and 28.01±0.00°C in wet seasons as presented. The period of greatest light penetration was in dry season. This may be as a result of sedimentation due to high evaporation as reported by Ude (2012). A decrease in water transparency increases water temperature because suspended particles absorb more heat. As presented, the variations dissolved oxygen was 7.17±0.43, 7.02±0.12 and 8.02±1.05mg/L at wet season and 4.2±1.3, 3.2±0.01 and 3.4±0.02 at dry season. Dissolve oxygen at sampling site of wet was relatively highest and it is above the permissible limit. This might be because of relatively lower temperature of the water. Thus, as temperature increases, the amount of dissolved oxygen decreases. As it is indicated, DO in the wet season was found to be high due to the movement of the water and increase due to rainfall.

**Table 1:** Physicochemical Parameters in dry and wet season mean±SD

| Stations | pH | Conductivity ($\mu$S) | Temperature ($^0$C) | DO mg/l |
|---|---|---|---|---|
| S1DS | 7.10 ± 0.00 | 0.56 ± 0.00 | 29.93 ± 0.07 | 4.2±1.3 |
| S1WS | 7.73 ± 0.03 | 0.46 ± 0.01 | 29.00 ± 0.00 | 7.17±0.43 |
| S2DS | 7.13 ± 0.03 | 0.59 ± 0.003 | 30.00 ± 0.00 | 3.4±0.02 |
| S2WS | 7.73 ± 0.07 | 0.48 ± 0.01 | 29.31 ± 0.01 | 7.02±.012 |
| S3DS | 7.13 ± 0.03 | 0.58 ± 0.003 | 29.97 ± 0.03 | 3.4±0.02 |
| S3WS | 7.77 ± 0.03 | 0.47 ± 0.01 | 29.03 ± 0.09 | 8.02±1.05 |
| **WHO/USEPA Limit** | **6.0–9.5** | **≤1.0** | **≤35** | **≥5** |

### WATER

Heavy metal concentrations in the water increase in the sequence of Ni>Zn>Cd>Cr>Fe>As>Pb. The distribution pattern of Pb concentration in the river sample ranged from0.168±0.055 to 0.106±0.048, 0.020±0.054 to 0.194±0.047, and0.399±0.213 to 0.676±0.361 $\mu$g mL$^{-1}$ in wet and dry season respectively. A significant high concentration of Pb was recorded at S3 0.676±0.361 which is high compared to WHO (2008) stipulated standards of 0.1 $\mu$g mL$^{-1}$. The wet season had the highest

concentration of Pb, these values could be attributed to the fact that the major sources of Pb in the environment are automobile exhaust, industrial wastewater, wastewater sludge and pesticides Ahmad *et al.* (2019). The results show that the mean concentration of Cd in the river water was 0.359±0.316 to 0.201±0.190 $\mu$g mL$^{-1}$ in dry and wet seasons respectively as presented. Higher concentration of Cd was recorded at point S3 for both wet and dry season. The concentration exceeded the admissible limit (0.05 $\mu$g mL$^{-1}$) set by WHO (2008). And the lowest concentration of Cd (0.027±0.036$\mu$g mL$^{-1}$) was recorded at point S2, for dry season. The difference may be due to the high agricultural activity around the river in wet season. This was similar to a research conducted by Belay and Eshete (2014). It could be possible that the high level of Cd contamination is because of organic fertilizer and environmental pollution in the study area. Previously, studies have shown that the concentration of metals in water body were higher than the recommended concentrations (Davies *et al.,* 2009; Rauf*et al.,* 2009; Vicente-Martorell *et al.*, 2009). Furthermore, Table 4.6 shows that the mean concentration of Cr varies from 0.375±0.092 to 0.055±0.006 S1, 0.462±0.167 to 0.055±0.006 and 0.313±0.125 to 0.138±0.139 $\mu$g mL$^{-1}$ for wet and dry seasons, respectively. The highest concentration of Cr (0.462±0.167 $\mu$g mL$^{-1}$) was observed at point S2 for wet season, which was found above WHO (2008) standards of 0.1$\mu$g mL$^{-1}$. The study revealed that the river water is been contaminated with heavy metals, and this might be of artificial origin due mainly to agricultural influx, wastes from farms or sewage via surrounding cultivated lands (Saleh and Ahmad, 2019)

**Table 2:** Shows the means on seasonal variation on water in both dry and wet season

| Site | Pb | Cd | Cr | As | Fe | Ni | Zn |
|---|---|---|---|---|---|---|---|
| **Site1 WS1** | 0.168±0.055 | 0.234±0.046 | 0.375±0.092 | 0.444±0.262 | 0.107±0.123 | 0.099±0.078 | 0.174±0.086 |
| **Site1 DS1** | 0.106±0.048 | 0.067±0.052 | 0.119±0.041 | 0.029±0.049 | 0.130±0.076 | 0.015±0.006 | 0.066±0.013 |
| **Site2 WS2** | 0.194±0.047 | 0.302±0.156 | 0.462±0.167 | 0.958±0.566 | 0.557±0.321 | 0.157±0.049 | 0.461±0.536 |
| **Site2 DS2** | 0.020±0.054 | 0.027±0.036 | 0.055±0.006 | 0.035±0.028 | 0.083±0.064 | 0.041±0.030 | 0.123±0.100 |
| **Site3 WS3** | 0.676±0.361 | 0.359±0.316 | 0.313±0.125 | 0.354±0.149 | 0.301±0.444 | 0.085±0064 | 0.208±0.089 |
| **Site3 DS3** | 0.399±0.213 | 0.201±0.190 | 0.138±0.139 | 0.011±0.020 | 0.189±0.101 | 0.018±0.009 | 0.101±0.045 |
| **WHO (2022)** | 0.01 | 0.003 | 0.05 | 0.01 | 0.3 | 0.01 | 5 |
| **USEPA (2023)** | 0.015 | 0.005 | 0.1 | 0.01 | 0.3 | 0.02 | 5 |
| **FAO (2022)** | 0.05 | 0.01 | 0.1 | 0.05 | 1.0 | 0.02 | 3.0 |

*1W1, S2W2, S3W3 represent the three sample sites on wet season, DS1, DS2 and DS3 represent dry season*

## CONCLUSION

the results shows that some metals especially Pb, Cd, Cr, As, and Ni exceed FAO/WHO/USEPA standards, while Zn and Fe are within acceptable limits. The results also show that the seasonal variations show higher pollution during the wet season.

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# OCCURANCE OF HEAVY METALS IN INLAND WATER BODIES OF KATSINA STATE: A REVIEW

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**ABSTRACT**
*Heavy metals are persistent and highly toxic pollutants that threaten aquatic ecosystems, food safety, and public health. This review examined the occurrence, sources, and implications of heavy metal contamination in inland water bodies of Katsina State, Nigeria. The Water bodies such as the Zobe, Jibia Lake, Ajiwa Reservoir, and others have shown elevated levels of lead, cadmium, chromium, copper, and mercury, exceeding World Health Organisation (WHO) and Nigerian standards. Major contaminants include mining, agricultural runoff, industrial effluents, and urban activities, which introduces heavy metals which accumulate in aquatic organisms posing risks to aquaculture operations, and human consumers. The toxic effects range from neurotoxicity and organ damage in fish to human health hazards like neurological, cardiovascular, and renal diseases. The review shows the urgent need for continuous monitoring, stricter regulation, public awareness, and mitigation strategies such as phytoremediation and improved water management to safeguard biodiversity of inland waters and public health in Katsina State.*

**Keywords:** Inland water bodies, Katsina State, Aquatic pollution

## INTRODUCTION

Heavy metals, defined as metallic elements with high densities and toxic characteristics, pose significant risks to environmental health, aquatic ecosystems, and human health (Lenntech, 2022). Heavy metals, which are harmful to humans generally include cadmium, chromium, copper, mercury, lead, zinc, iron, arsenic, cobalt, and nickel except copper, zinc and iron when found in excess. These are found naturally in the soil in minute amounts, and in industrial wastewater due to different chemical processes such as precipitation, filtration, and ion exchange. These metals are normally found in limited amounts or above the permissible limit, which causes few problems (Halnor, 2015). The environmental problems due to globalization and speedy industrialization are becoming disadvantageous to human beings due to increase in pollution (Oladimeji *et al*., 2024). They are generally considered as those metals whose density exceeds 5g/cm$^3$ (Gunatilake, 2015).

Problems associated with metal (embracing metalloids) contamination are of great concern, particularly in agricultural production systems (Kachenko and Singh, 2006) due to their increasing trends in human foods and the environment. These metals pose a significant health risk to humans, particularly in elevated concentrations above the very low body requirements (Gupta *et al*., 2008). Hence, the metals must be controlled in food sources in order to assure public health safety (WHO, 1995). Excessive concentration of heavy metals in food can cause a number of diseases, such as cardiovascular, renal, neurological, and bone diseases (Chailapakul *et al*., 2007). Under certain environmental conditions, these metals may accumulate in the fish organs that leads to toxic concentration and can cause ecological damages (Muhammad *et al*., 2019).

In Nigeria, issues surrounding heavy metal contamination in inland water bodies, such as rivers, lakes, and reservoirs, have gained increasing attention. This review focuses on the occurrence, sources, and implications of heavy metals in various water bodies in Katsina State, and its influence on fish and Aquaculture.

**Heavy Metals found in Water Bodies**

**Cadmium** is an extremely toxic metal commonly found in industrial workplaces, particularly where ores are being processed or smelted. Several deaths from acute exposure have occurred among welders who have unsuspectingly welded on cadmium-containing alloys or with bead or silver solders (Valkovic, 1975).**Lead**: Occupational exposure to lead is one of the most prevalent over exposures. Industries with high potential exposures include construction work, most smelter operations, radiator repair shops, firing ranges and electrical gadgets repair shops (Hervy *et al.*, 2015). Lead-based paint and its dust, usually found in older buildings, are common sources of exposure. Young children are especially at risk. Occupational exposure, such as welding, is a common cause for adults.

**Iron**: Iron is an essential element in the formation of red blood cells, the liver and the spleen. The normal human body contains 60 – 70 mg/kg of iron. Deficiency of iron causes anaemia, while its excessive intake causes haemochromatosis and siderosis (Valkovic, 1975).

**Copper**: It is an essential element for living organisms, including humans, and in small amounts is necessary in our diet to ensure good health. However, too much copper can cause adverse health effects, including vomiting, diarrhea, stomach cramps, and nausea. It has also been associated with liver damage and kidney disease (Minnesota Department of Health, 2016). **Chromium**: Chromium is an important environmental pollutant, particularly in areas with high anthropogenic activities. Their presence in the atmosphere, soil and water, even in traces can cause serious problems to living organisms. Compounds of chromium, such as calcium chromate, chromium trioxide, lead chromate, strontium chromate, and zinc chromate are known human carcinogens. An increase in the incidence of lung cancer has been observed among workers in industries that produce chromate and manufactured pigments containing chromate ions. (Sobukola *et.al*, 2010).

**Sources of Heavy Metals in Katsina State Water Bodies**

**Mining Activities**

Katsina is home to various mineral deposits, including gold, limestone, and kaolin, prompting a surge in mining operations. These activities often lead to the leaching of heavy metals such as lead (Pb), mercury (Hg), and cadmium (Cd) into water bodies, either directly through runoff or indirectly via soil erosion (Babalola *et al.*, 2021). Artisanal and small-scale mining can introduce heavy metals from the soil into water sources (Nwankwoala and Chukwuma, 2020).

**Agricultural Runoff**

The heavy use of fertilizers and pesticides in agricultural practices introduces metals like copper (Cu) and zinc (Zn) into the aquatic environment through runoff (Mokgolodi *et al.*, 2013). This pollution is particularly pronounced during the rainy season when surface runoff increases. Pesticides and fertilizers can leach heavy metals into water bodies (Ogunfowokan *et al.*, 2020). These toxic metals can be absorbed through the water or soil or may be deposited on the vegetable surfaces during their production, transport or marketing (Sobukola, *et al.*, 2010; Sharma *et al.*, 2009). Furthermore, due to the persistent nature and cumulative behavior of heavy metals, they have the ability to concentrate through the food chains and cause toxic effects to humans (Sharma *et al.*, 2009). Heavy metals also find their ways into the food chain in the form of environmental contaminants through the application of agricultural inputs, such as

pesticides, insecticides, herbicides and fertilizers. Hence, there is need to continuously monitor and analyse the levels of toxic metals in the water and food items to ensure that the levels of these elements comply with permissible limits specified by local and international health agencies.

**Industrial Effluents**

Although Katsina State has scarce industrial activities compared to other Nigerian states, existing small-scale industries and artisanal workshops still emit waste containing heavy metals (Abubakar *et al*., 2020). Poorly managed effluents can contaminate nearby water bodies. Local industries discharge untreated waste, contributing to elevated metal levels (Adesanya *et al*., 2021). An environment that is heavily polluted with heavy metal effluents is unsafe for human life. Rapid industrialization and urbanization have caused significant increase in traffic activities in and around our capital cities which subsequently contributed to substantial release and accumulation of heavy metals in roadside environments (air, water and soil). In addition, wide range of small-scale industries including textile, battery production and charging, metallurgical and cable coating industries, brick kilns, diesel generators, re-suspended road dust etc, have also contributed to the heavy metal accumulation in the environments.

**Urban Runoff**

Urbanization leads to increased surface run-off that can carry metals from roadways, construction sites, and other urban surfaces into water bodies. Road traffic contributes to the accumulation of heavy metals like lead and cadmium in urban waterways (Bello *et al*., 2021).

**Heavy Metal Contamination in Key Water Bodies**

**1. Zobe Dam**

Research has indicated elevated levels of heavy metals, such as lead, arsenic (As), and mercury, in Zobe Dam's water and sediments (Garba *et al*., 2021). These metals derive not only from mining operations but also from agricultural runoff in the surrounding areas. Such contamination threatens fish populations, potentially leading to bioaccumulation in aquatic organisms.

**2. Jibia Lake**

Jibia Lake, primarily used for fishing and local agriculture, has shown alarming levels of metals (Ogundele *et al*., 2019). Fish from this lake are consumed by local communities, raising concerns about health implications, including neurotoxic effects from mercury.

**3. Kaita River and Other Smaller Bodies**

Preliminary assessments reveal the presence of metals in Kaita River, which serves as a water source for many rural communities (Ibrahim and Balogun, 2020). These findings highlight a pressing need for comprehensive monitoring and management strategies to safeguard public health.

The table 1 below presents the concentration levels of various heavy metals in notable water bodies of Katsina State, Nigeria, compiled from multiple studies. For each metal, concentration levels from four (4) different sources are compared. These studies give insight into the range of heavy metal contamination and the extent to which it exceeds the permissible standards of WHO and Nigerian regulations:

**Table 1:** Heavy Metals Concentration of various water bodies in Katsina State

| Water Body | Heavy Metal | Concentration (mg/L) (From four (4) sources) | WHO/Nigerian Standards (mg/L) |
|---|---|---|---|
| Kwanar-Are Dam | Lead (Pb) | 0.017, 0.012, 0.014, | 0.01 |
| | Cadmium (Cd) | 0.010 | 0.003 |
| | Chromium (Cr) | 0.013, 0.008, 0.009, 0.010 | 0.05 |
| | Zinc (Zn) | 0.002, 0.0015, 0.004, 0.003 | 3.0 |
| Ajiwa Reservoir | Copper (Cu) | 1.40, 1.50, 1.45, 1.42 | |
| | Nickel (Ni) | 0.85, 1.2, 0.9, 0.88 | 2.0 |
| Zobe Dam | Manganese (Mn) | 0.015, 0.020, 0.018, 0.016 | 0.07 |
| Sabke Dam | Chromium (Cr) | 0.22, 0.18, 0.20, 0.21 | 0.5 |
| | Cadmium (Cd) | 0.0015, 0.0018, 0.002, 0.0016 | 0.05 |
| Katsina River | Zinc (Zn) | 0.008, 0.009, 0.007, 0.006 | 0.003 |
| Gwaigwaye River | Lead (Pb) | 1.50, 1.60, 1.55, 1.52 | 3.0 |
| | Copper (Cu) | 0.018, 0.015, 0.016, 0.014 | 0.01 |
| Jibia Reservoir | Nickel (Ni) | 1.2, 1.3, 1.1, 1.05 | 2.0 |
| | | 0.023, 0.021, 0.020, 0.019 | 0.07 |

**Implications of Heavy Metals on Fish and Aquaculture**

Heavy metals, such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As), are persistent pollutants that can have profound impacts on aquatic ecosystems, including fish populations and aquaculture operations. Due to their toxic nature and the tendency to bio accumulate, these metals pose serious risks to the health of fish and other aquatic organisms, as well as to humans who consume contaminated fish. In aquaculture, the presence of heavy metals in the water bodies, can lead to reduced productivity, health complications in cultured species, and economic losses. (WHO, 2017)

**1. Bioaccumulation and Biomagnification in Aquatic Food Chains**

Once in the water, these metals are absorbed by aquatic plants and animals, leading to bioaccumulation, where the concentration of metals in the tissues of organisms exceeds their concentration in the water. Furthermore, as fish and other organisms are consumed by predators, the metals move up the food chain in a process called biomagnification, where top predators, including humans, may experience even higher concentrations of toxic metals than are present in the environment (UNEP, 2021).

**2. Physiological Impacts on Fish Health**

The accumulation of heavy metals in fish can have a wide range of physiological effects, many of which are detrimental to their health and survival:

**Neurotoxicity**: Heavy metals such as mercury (Hg) and lead (Pb) are neurotoxic, affecting the central nervous system of some fish species especially *clarias spp* and O. *niloicus*. Studies have shown that mercury exposure can impair the swimming ability and predator avoidance behavior of fish, making them more susceptible to predation (Mohammed *et al.*, 2023). Heavy metal exposure has been linked to compromised immune function in fish, making them more vulnerable to diseases and infections. Arsenic (As) and cadmium (Cd), in particular, have been shown to reduce the activity of immune cells in fish, leading to increased mortality rates (Kumar *et al.*, 2021).

**Reproductive Disorders:** Heavy metals disrupt endocrine function in fish, leading to reproductive problems. For instance, exposure to cadmium (Cd) has been associated with reduced spawning success, lower egg quality, and abnormal larval development in several commercially fish species (Rahman *et al*., 2022). Heavy metals induce the production of reactive oxygen species (ROS), leading to oxidative stress in fish tissues. This results in damage to cellular components such as lipids, proteins, and DNA, ultimately impairing fish health and growth (Atobatele and Ugwa, 2022). Heavy metals are known to accumulate in the liver, kidneys, and gills of fish. Chronic exposure to lead (Pb) and mercury (Hg) can result in liver and kidney damage, impeding the ability of fish to detoxify and excrete harmful substances (Oliveira *et al*., 2021). In addition, gill damage can impair respiration, leading to reduced oxygen uptake and metabolic stress.

**3. Impacts on Fish Growth and Development**

Heavy metal contamination affects the growth and development of fish at different life stages. Elevated levels of mercury (Hg) and lead (Pb) have been linked to delayed growth, skeletal deformities, and higher mortality rates in fish fry and juveniles (Palaniappan *et al*., 2022). These developmental abnormalities can significantly reduce the overall productivity of fish populations and aquaculture systems.

**4. Economic Implications for Aquaculture**

The contamination of water sources by heavy metals presents serious economic challenges for aquaculture operations. The implications include:

**Reduced Productivity**: Heavy metal contamination can lead to lower survival and growth rates of farmed fish, reducing the overall yield of aquaculture systems. This is particularly problematic in areas where water quality monitoring and treatment are inadequate (Anonymous, 202).

**Health Risks and Marketability**: Fish contaminated with heavy metals pose health risks to consumers, leading to restrictions on their sale and export. International guidelines, such as those from the World Health Organization (WHO) and Codex Alimentarius, set maximum allowable levels of heavy metals in fish products. Aquaculture farms found to exceed these limits may face economic losses due to product rejection and reduced consumer confidence (FAO, 2023).

**5. Human Health Risks through Fish Consumption**

One of the most significant implications of heavy metal contamination in aquaculture is the potential risk to human health through the consumption of contaminated fish. Heavy metals, particularly mercury (Hg), lead (Pb), cadmium (Cd), and arsenic (As), can accumulate in the tissues of fish at concentrations that pose risks to consumers.

**Mercury**: Methylmercury, the organic form of mercury, is highly toxic and can cause neurological damage in humans. Consuming fish with elevated mercury levels can lead to developmental delays in children and cognitive impairments in adults (WHO, 2021).

**Lead and Cadmium**: Long-term exposure to lead (Pb) through fish consumption can cause cardiovascular and kidney diseases, while cadmium (Cd) is linked to bone demineralization and cancer (FAO/WHO, 2022).

**6. Mitigation Strategies in Aquaculture**

To address heavy metal contamination in aquaculture, several mitigation strategies can be implemented:

**Water Quality Monitoring**: Regular testing of water sources for heavy metal contamination is crucial to ensure that aquaculture environments remain safe for fish farming. This includes monitoring both surface and groundwater sources used in aquaculture (FAO, 2023).

**Phytoremediation**: Some aquatic plants, such as *Eichhornia crassipes* (water hyacinth), have been used to remove heavy metals from contaminated water through a process known as phytoremediation. These plants absorb metals through their roots, reducing the overall metal concentrations in aquaculture ponds (Alhassan *et al*., 2022).

**Use of Chelating Agents**: Chelating agents can be added to aquaculture systems to bind with heavy metals, reducing their bioavailability to fish. This approach helps prevent the accumulation of metals in fish tissues (Kumar *et al*., 2021).

**Alternative Water Sources**: In areas where surface water is heavily contaminated, switching to alternative water sources, such as rainwater harvesting or treated groundwater, can help reduce the risk of heavy metal contamination in aquaculture operations (Adesuyi *et al.*, 2022).

## CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the findings have shown that the in the inland water bodies of Katsina State, have some metals that shown above permissible limit posing significant risks to aquatic ecosystems and human health. Comprehensive monitoring programs and strict regulations on industrial and agricultural practices in Katsina are essential to reduce pollution. Furthermore, public awareness campaigns targeting the health risks associated with consuming contaminated fish should be prioritized. Active collaboration between government agencies, local communities, and researchers will be crucial in developing effective mitigation strategies and improving water quality for the people of Katsina State.

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# PHYSICOCHEMICAL PROPERTIES, ABUNDANCE AND DISTRIBUTION OF MACROINVERTEBRATE IN CALABAR RIVER, SOUTH-EASTERN, NIGERIA

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**ABSTRACT**
*Macro-invertebrates play a crucial role as bio-indicator in assessing water quality. The Calabar River was studied over a 4 months period (September- December, 2024). Macro-invertebrates were collected, labelled and preserved in 5% formaldehyde, before identification using the relevant identification keys. The physico-chemical parameters of water were also measured. A total of 2357 macro-invertebrate individuals, made up of 32 species, and belonging to 3 Phyla and 6 classes were observed in the study. Macro-invertebrates were represented by Phylum Arthropoda, Mollusca and Annelida. The classes of macro-invertebrate recorded were crustacean, insecta, gastropoda, bivalvia, polychaeta and oligochaete phyla. The most abundant macro-invertebrate species was Tubifex tubifex (281 individuals), class Crustacean was more in number (857 individuals). Arthropoda were the most abundant Phylum (1106 individuals). The physico-chemical parameters value varied across sampling stations. The mean physico-chemical parameters values were; 6.988 ± 0.557 (pH), 109.044 ± 21.907 us/cm (conductivity), 0.022 ± 0.012 mg/1 (TSS), 70.827 ± 24.604 mg/1 (TDS), 3.743 ± 1.221 mg/1 (DO), 11.411 ± 2.842 mg/1 (BOD) and 30.057 ± 2.567 °C (temperature). All physicochemical parameters were within the WHO acceptable limit except DO, TSS and BOD which were slightly higher. The physico-chemical parameters of water had significant influence on the abundance and distribution of macro-invertebrates due to their various relationship strength (r).*

**Keywords**:
Macro-invertebrates, Physico-chemical Parameters, Abundance, Distribution, Calabar River

## INTRODUCTION

Macroinvertebrates play a crucial role as bioindicators in assessing the quality of the aquatic ecosystem (Andem *et al.*, 2013). Aquatic macro-invertebrates form a rather large group of organisms which include insect larvae, annelids (leeches), Oligochaetes (worms), Crustaceans (crayfish and shrimp), Molluscs (clams and mussels), and Gastropods (snails). The aquatic arthropods when considering fresh water species comprised of multiple orders of insect's spiders and crustaceans (Edward and Ugwumba, 2011, Okorafor *et al.*, 2012, USEPA, 2014). These organisms play a vital role in the circulation and recirculation of nutrients in aquatic environments and are very sensitive to changes in their environment, making them ideal indicators of river health (Agi and Okwuosa, 2011, Shailendra *et al*, 2013, Andem *et al.*, 2013). Several benthic species are relatively long lived, with life spans ranging from weeks for some opportunistic worms to months or years for larger taxa (Bamikole *et al*, 2009). As benthic macroinvertebrates tend to remain in their original habitat, they are affected by local changes in water quality (Andem *et al.*, 2012). Macro-invertebrates are useful bio-indicators providing a more accurate understanding of changing aquatic conditions. Absence of sensitive species and presence of tolerant ones indicate water quality deterioration (Andem *et al.*, 2013, Ojija *et al., 2016*). Also, understanding the structure of the benthic faunal communities with regards to the impacts of pollution is an important part of monitoring changes in river ecosystems in Nigeria. Their diversity, abundance and composition at a particular time can give a picture of the nature of disturbance in the system (Andem *et al.*, 2013).

Inhabitants of the Calabar River depend on this important river for both fin, shell fishes and water for domestic purposes. This indicates the need for a routine investigation of the pollution status of this river especially with the nature of anthropogenic activities in the River area. It is against this background that this study was carried out to evaluate macro-invertebrate community as bio-indicators of pollution in Calabar River, South-Eastern Nigeria, other specific objectives include to assess the physic-chemical parameters of Calabar (surface water temperature, pH, conductivity, total dissolved solid, total suspended solid, dissolved oxygen and biochemical oxygen demand), determine the seasonal variations in the abundance of benthic macro-invertebrates.

## MATERIALS AND METHODS

### Study Area

The study area is located at Calabar River between Latitude N40 57' 326" and Latitude E80 18' 557" at 26 feet altitude (Fig 1). The climate of the area is characterized by a long-wet season from the months of April to October and a dry season between November to March (Akpan, 2000). A short period of drought occurs in the wet season around August and September which is called August break, and a cold, dry and dusty period between December and January usually referred to as harmattan season (Ama-Abasi *et al*, 2004). Calabar river has its downstream or lower reaches influenced by semi-diurnal ocean tides (Akpan, 2000).

### Sampling stations and sample collections

This study was carried out at three stations along Calabar River in order to provide a more comprehensive data about macroinvertebrate in the river, the coordinates and appropriate distances of each station were taken using Geographic Positioning System (GPS). Station 1 (Adiabo bridge), is located between Latitude 4° 3' 27.23° N and Longitude 8° 18° 23.53° E, station 2 is located between Latitude 4 ° 57'26.76 ° N and Longitude 8 ° 18'40.02 ° E. and station 3 (Nsidung beach) is located between Latitude 4° 55'26. 76 N and Longitude 8° 18'40.02"E. The common features of all the stations is the presence of Nypa palms and shrubs along its shores.

Water temperature, pH, dissolve oxygen (DO), biochemical oxygen demand (BOD), conductivity, total dissolved solids (TDS) and total suspended solids (TSS) were measured using the ex-situ method from September to December 2024, on a monthly basis.

Benthic organisms were collected very month; from September to December, 2024. For each sampling station, a measurement of 10m by 10m was taken to avoid bias and 3 or 4 hauls were made by sending the grab down into the bottom. Also, hand trowel, sweeping net and hand picking were also used for sampling. The sweeping net was used in collecting aquatic insects. Hand picking method and hand trowel was used at low tide. Sediments were also collected from the study area. The sediment collected was poured into polythene bags, labelled and taken to the laboratory for analysis. The sediments were passed through 3 sieves of 2mm, 1mm and 0.5mm mesh sizes to collect the benthos. The benthos was poured into a white enamel tray, stained with Rose Bengal Solution and sorted using forceps (EPA 1998, Andem *et al.*, 2012). They were sorted out into different groups and preserved in 4% formalin. They were then identified using identification guides namely; Merritt and Cummings (1996); Thorpe and Covich (1991); Voshell (2002), then counted and recorded.

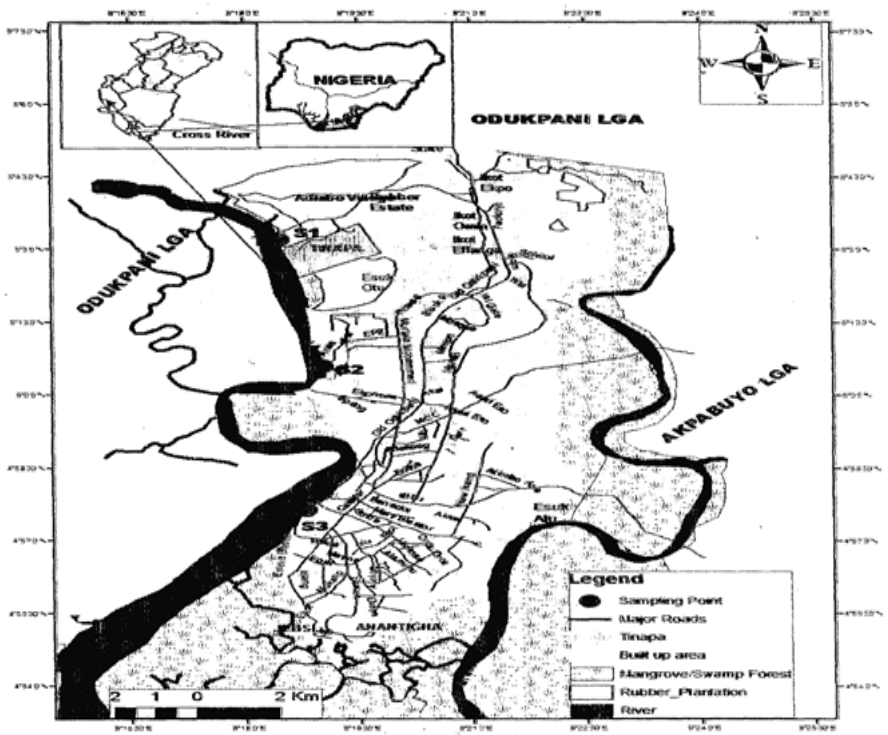



Figure 1: Map of Calabar River showing the sampling stations

**Determination of numerical and relative abundance**

Macro-invertebrate species were identified, sorted and counted individually. The sum of each individual macro-invertebrates from each sampling station for the four sampling months were added together in order to determine the total abundance of each species in each of the station (Eyo *et al.*, 2013).

The Relative abundance (%) of macro-invertebrate species from Calabar River was calculated according to Eyo *et al.*, (2013) as follows:

$$\%RA = n(100)/N \quad \text{----------(1)}$$

Where; n - the total number of individuals in each macro-invertebrate taxonomic group.

N = the total number of individuals in the entire macro-invertebrates taxonomic.

**Ecological diversity indices**

The occurrence and relative numerical abundance of macro-invertebrates was calculated using biotic indices such as Margalef's index, Equitability and Shannon and Weiner's index in order to determine abundance and diversity of species.

**Margalefs index (d)**: is a measure of species richness (Margalef, 1949) and expressed as;

$$\frac{S-1}{d=\ln(N)} \quad \text{---------- (2)}$$

Where:

S = number of species in samples.

N = total number of individuals in the sample and *In* is the natural logarithm

**Shannon and Weiner's index (H):** is a measure of species abundance and evenness (Shannon and Weiner, 1949) and expressed as:

$$H = \Sigma \frac{H}{\ln S} \quad \text{---------- (3)}$$

Where
H = Shannon and Wieners index, S = Number of species in samples, N = total number of individuals in the sample
Ni = total number of individuals of species *ith* in the sample

**Statistical analysis**
Data obtained was subjected to descriptive statistics for mean, standard deviation and ranges of water physico-chemical parameters. Analysis of variance (ANOVA) was used to test for significant difference in the results obtained from the three sampled stations. Co-relation analysis was carried out between water physico-chemical parameters and macro-invertebrates' abundance. All analysis was carried out using predictive analytical software version 20 at 0.05 level of significance and at their relevant degree of freedom.

## RESULTS AND DISCUSSIONS

**Macro-invertebrate composition, abundance and distribution**
A total of 2357 macro-invertebrate individuals, which was made up of thirty-two species, and belonging to three (3) Phylum and six classes (6) were recorded during the study (table 1). Macro-invertebrates were represented by Phylum Arthropoda, Mollusca and Annelida. Phylum Arthropoda were represented by Class Malacostraca (Crustaceans) and Insecta. The most abundant Crustacean species was *Uca tangeri* which had 235 individuals and a percentage abundance of 9.38%, while the least abundant Crustacean was *Macrobrachium felicium*, having 6 individuals and a percentage abundance of 0.23%. The most abundant Insecta species was *Stenonema species* which had 83 individuals and a percentage abundance of 3.31%, while the least abundant Insecta was *Similium species*, having 6 individuals and a percentage abundance of 0.23%. Phylum Mollusca were represented by Class Gastropoda and Bivalvia. The most abundant Gastropoda species was *Tympanotonus fuscatus* with 212 individuals and a percentage abundance of 8.99%, while the least abundant Gastropoda was *Neritina adansoninna*, having 4 individuals and a percentage abundance of 0.16%. The most abundant Bivalvia species was C*ardium costatum* with 55 individuals and a percentage abundance of 2.33%, while the least abundant Bivalvia species was O*strea tulipa*, having 25 individuals and a percentage abundance of 1.06%. Phylum Annelida were represented by Class Polychaeta and Ologochaeta. Polychaeta and Oligochaeta classes were represented by C*apitella species* having 153 individuals and a percentage abundance of 6.49% and *Tubifex tubifex* having 281 individuals and a percentage abundance of 11.92%, respectively. *Tubifex tubifex* was the most abundant macro-invertebrate species with a numerical abundance of 281 individuals and a relative abundance of 11.92%, while the least abundant macro-invertebrate species was *Neritina adansoninna* having a numerical abundance of 4 and a relative abundance of 0.16%. Nsidung beach (Station 3) had the highest number of species (32 species), while Adiabor beach had the least number of species (28 species). Adiabo, Esuk Utan and Nsidung beach had a numerical abundance of 540, 928 and 889 macro-invertebrate respectively (Table 1). Findings of this study is lower than the 78 and 36 macro-invertebrate species reported respectively by Arimoro *et al* (2007a). Similarly, macro-invertebrate individuals recorded is by far higher than the 1859 macro-invertebrate individuals reported by Odo *et al.* (2007). The differences in the number of species and numerical abundance recorded during this study with that of the other reported findings could be as a result of the difference in study area, duration of study, and level of human activities.

Class Crustacean was the most dominant during the study (33.76%), which did not corroborate with the findings of Andem *et al.* (2012), who reported Chironomous larvae in the class insecta as the most dominant species and class in Ona rover, South-West, Nigeria.

**Table 1:** Macro-Invertebrate Species Sampled in Calabar River through-Out the Study Period

| S/N | MACROINVERTEBRATE SPECIES | SI | % | S2 | % | S3 | % | TOTAL | % |
|---|---|---|---|---|---|---|---|---|---|
| | **ARTHROPODA** | | | | | | | | |
| | **Malacostraca (crustaceans)** | | | | | | | | |
| | **Decapoda** | | | | | | | | |
| 1 | *Uca tangeri* | 86 | 15.92 | 80 | 8.62 | 69 | 7.76 | 235 | 9.97 |
| 2 | *Callinectes amnicola* | 68 | 11.48 | 79 | 8.51 | 57 | 6.41 | 204 | 8.65 |
| 3 | *Macrobrachium vollenhovenii* | 63 | 11.66 | 39 | 4.20 | 32 | 3.59 | 134 | 5.69 |
| 4. | *Pinaeus notialis* | 30 | 5.55 | 24 | 2.58 | 20 | 2.25 | 74 | 3.13 |
| 5 | *Cronius ruber* | 2 | 0.37 | 8 | 0.86 | 15 | 1.68 | 25 | 1.06 |
| 6. | *Nemalecarcinus africanus* | 3 | 0.55 | 22 | 2.37 | 3 | 0.33 | 28 | 1.18 |
| 7. | *Pachygrapsus transversus* | 32 | 5.92 | 23 | 2.47 | 21 | 2.36 | 76 | 3.22 |
| 8. | *Ocypode cursor* | 12 | *2.22 | 22 | 2.37 | 8 | 0.89 | 42 | 1.78 |
| 9 | *Sesarma angolense* | 0 | 0.00 | 8 | 0.86 | 25 | 2.81 | 33 | 1.39 |
| 10 | *Macrobrachium felicium* | 2 | 0.3? | 0 | 0.00 | 4 | 0.44 | 6 | 0.25 |
| | **Insecta** | | | | | | | | |
| | **Diptera** | | | | | | | | |
| 11. | *Chironomus larvae* | 28 | 5.18 | 3 | 0.32 | 1 | 0.11 | 32 | 1.35 |
| 12. | *Tabanus species* | 19 | 3.51 | 4 | 0.43 | 4 | 0.44 | 27 | 1.14 |
| 13. | *Psychoda larvae* | 16 | 2.96 | 5 | 0.53 | 2 | 0.22 | 23 | 0.97 |
| 14. | *Similium species* | 5 | 0.92 | 1 | 0.10 | 0 | 0.00 | 6 | 0.25 |
| | **Ephemeroptera** | | | | | | | | |
| 15 | *Stenonema species* | 69 | 12.77 | 11 | 1.18 | 3 | 0.34 | 83 | 3.52 |
| 16. | *Atractomorph acutipennis* | 12 | 13.33 | 2 | 0.21 | 4 | 0.44 | 78 | 3.30 |
| | **MOLLUSCA** | | | | | | | | |
| | **Gastropoda** | | | | | | | | |
| 17 | *Pachymelaniafusca* | 3 | 0.55 | 14 | 1.50 | 23 | 2.58 | 40 | 1.69 |
| 18 | *Pachymelania byronensis* | 4 | 0.74 | 40 | 4.31 | 70 | 7.87 | 114 | 4.83 |
| 19 | *Turritella annulata* | 1 | 0.18 | 22 | 2.37 | 21 | 2.36 | 44 | 1.86 |
| 20 | *Tympanotonus fuscatus* | 4 | 0.74 | 113 | 12.17 | 95 | 10.68 | 212 | 8.99 |
| 21 | *Thais callifera* | 1 | 0.18 | 5 | 0.53 | 21 | 2.36 | 27 | 1.14 |
| 22 | *Semifusus morio* | 1 | 0.18 | 4 | 0.43 | 8 | 0.89 | 13 | 0.55 |
| 23 | *Pachymelania aurita* | 6 | 1.11 | 40 | 4.31 | 58 | 6.52 | 104 | 4.41 |
| 24 | *Thais nodosa* | 2 | 0.37 | 46 | 4.95 | 28 | 3.14 | 76 | 3.22 |
| 25 | *Triphora species* | 0 | 0.00 | 23 | 2.47 | 2 | 0.22 | 25 | 1.06 |
| 26 | *Neritina qfra* | 1 | 0.18 | 12 | 1.29 | 35 | 3.93 | 48 | 2.03 |
| 27 | *Neritina rubricata* | 0 | 0.00 | 6 | 0.64 | 24 | 2.69 | 30 | 1.27 |
| 28 | *Neritina adansoninna* | 3 | 0.55 | 1 | 0.10 | 0 | 0.00 | 4 | 0.16 |
| | **Bivalvia** | | | | | | | | |
| 29. | *Cardium costatum* | 3 | 0.55 | 27 | 2.90 | 25 | 2.81 | 55 | 2.33 |
| 30. | *Ostrea tuli pa* | 3 | 0.55 | 14 | 1.51 | 8 | 0.89 | 25 | 1.06 |
| | **ANNELIDA** | | | | | | | | |
| | **Polychaeta** | | | | | | | | |
| 31 | *Capitella species* | 1 | 0.18 | 88 | 9.48 | 64 | 7.19 | 153 | 6.49 |
| | **Oligochaeta** | | | | | | | | |
| 32 | *Tubifex tubifex* | 0 | 0 | 142 | 15.30 | 139 | 15.63 | 281 | 11.92 |
| | **Total number of species** | 28 | | 31 | | 32 | | | |

Where S1 = Adiabo Beach, S2 = Esuk Utan, S3 = Nsidung Beach

Gastropoda, Insecta, Polychaeta and Oligochaeta had a relative abundance percent of (33.84%), (10.1%), (6.15%) and (11.35%) respectively (Figure 2). Arthropoda were the most abundant Phyla through-out the study, having a numerical abundance of 1106 and relative abundance of 44.17%, while the least abundant Phylum was Annelida, having a numerical abundance of 434 and relative abundance of 17.49 % (Figure 3).

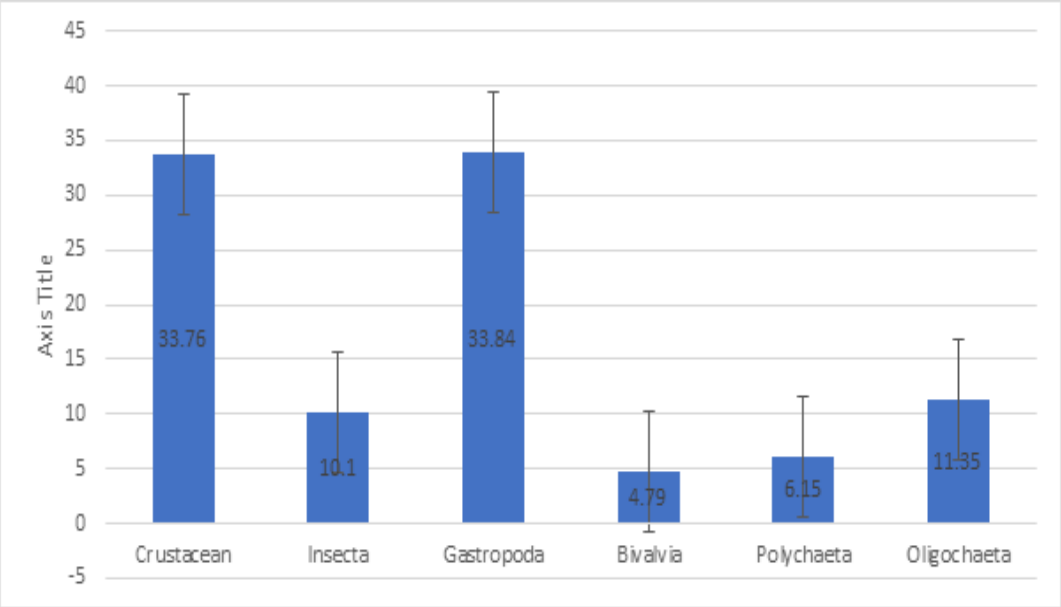



**Figure 2:** The numerical abundance and relative abundance of the macro-invertebrate classes from Calabar River

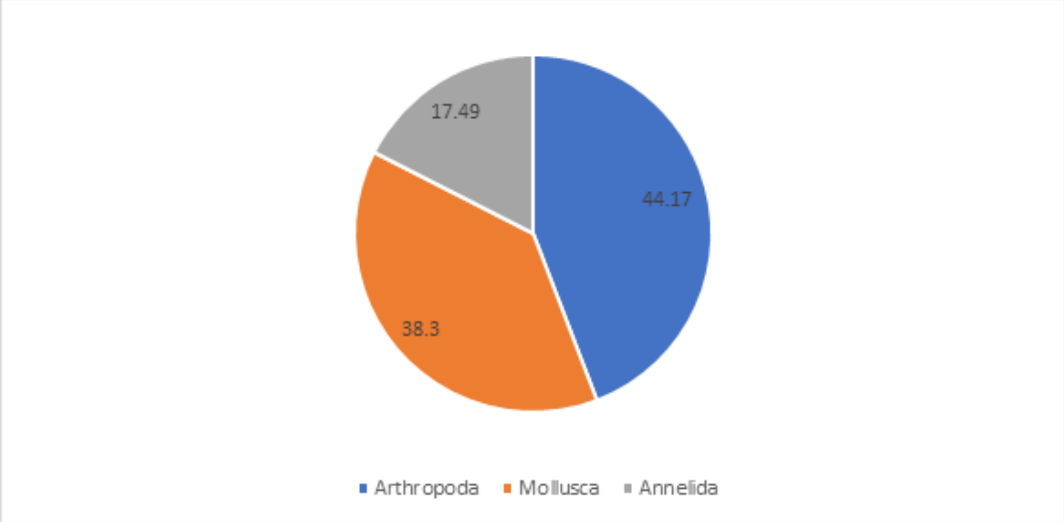



**Figure 3:** The numerical abundance and relative abundance of the macro-invertebrate phyla from Calabar River

**Diversity indices and seasonal variations in the abundance of macro-invertebrates**

Adiabo Beach had the highest Shannon Weinner diversity index value (2.912), while Nsidung Beach had the lowest value (2.333) Table 2. Adiabo Beach recorded the highest Margalef diversity index (4.647), while Nsidung Beach had the lowest value (4.080). Esuk Utan had the highest equitability index (0.845), while Nsidung Beach had the lowest equitability index value (0.821) (Table 2). The high diversity indices found at Adiabo Beach indicated a greater diversity of macro-invertebrates. Additionally, Esuk Utan's macro-invertebrate distribution was more even than that of the two other sampling sites, according to the

Equitability Index.
The results of this study's diversity analysis are different from those of Andem *et al.*'s (2012) investigation of the diversity, distribution, and composition of benthic macroinvertebrates in the Ona River in southwest Nigeria. The degree of anthropogenic disturbance and ecological variations in the study sites could be the cause of this. The considerable species variety may be partially attributed to favorable physicochemical circumstances that support the macroinvertebrates' survival and influence their reproductive phases.

**Table 2:** Diversity Indices of Benthic Macro-invertebrates of Calabar River during the Study Period

| Stations | SI | S2 | S3 |
|---|---|---|---|
| Shannon Index | 2.912 | 2.658 | 2.333 |
| Margalef's Index | 4.647 | 4.200 | 4.080 |
| Equitability | 0.832 | 0.845 | 0.821 |
| **Taxa** | **28** | **31** | **32** |
| **Individual** | **540** | **928** | **889** |

Where; S1 - Adiabo Beach, S2 = Esuk Utan, S3 = Nsidung Beach

**Physico-chemical Parameters of water**
Table 3 displays the ranges and means of each physicochemical parameter. Station 3 (Nsidung Beach) had the greatest mean pH value (7.496 ± 0.452 mg/L), while station 1 (Adiabo) had the lowest mean pH value (6.458 ± 0.412 mg/L). Adiabo beach had the lowest conductivity value (97.016 p,s/cm), whereas Nsidung beach had the greatest conductivity value (122.833 us/cm). The highest total suspended solid value was recorded in Adiabo beach (0.031 mg/1), while the lowest total suspended solid value was observed in Nsidung beach (0.014 mg/1). The mean total suspended solid value was lower than the WHO acceptable range of > 10 mg/1. The highest total dissolved solid value was recorded in Nsidung beach (91.866 mg/1), while the lowest total dissolved solid value was recorded in Adiabo beach (55.066 mg/1). The highest dissolved oxygen value was observed in Adiabo beach (6.116 mg/1), while the lowest dissolved oxygen value was observed in Nsidung beach (2.230 mg/1). Biochemical oxygen demand was highest in Nsidung beach (14.366 mg/1), while the lowest bio-chemical oxygen demand value was recorded in Adiabo beach (14.366 mg/1). Though, the mean bio-chemical oxygen demand values was above the WHO acceptable limit of < 10 mg/1. Surface water temperature value was recorded to be highest in Nsidung beach (30.350±3.110°C), while the lowest water temperature value was observed in Adiabo beach (29.575 ± 2.524°C). Analysis of variance (ANOVA) reveals that pH (mg/l), conductivity (s/cm), and surface water temperature (°C) were not significantly different between the 3 stations ($p>0.05$), while Total suspended solid (mg/l), Total dissolve solid (mg/l), dissolve oxygen (mg/l) and biochemical oxygen demand were significantly different between the stations ($p<0.05$). According to the data, biological oxygen demand exceeded the WHO acceptable limit, total suspended solid and dissolved oxygen fell below the WHO acceptable limit, and the mean values of pH, conductivity, total dissolved solid, and surface water temperature were all within the WHO acceptable limits.

**Table 3:** Mean Physico-chemical Parameters of Water from Calabar River during the Study

| Water Parameters | S1 (Adiabo beach) | S2(Esuk Utan) | S3 (Nsidung beach) | Mean | WHO Limit |
|---|---|---|---|---|---|
| pH (mg/L) | 6.458±0.412[a] (5.94-6.90) | 7.010±0.180[a] (6.80-7.24) | 7.496 ±0.452[a] (7.08-8.12) | 6.988±0.557 (5.94-8.12) | 6.0-8.5 |
| Conductivity µs/cm | 97.016 ± 14.685[a] (81.30-118.00) | 107.283 ± 19.913[a] (85.20 -129.60) | 112.833 ± 24.778[a] (96.80-154.50) | 109.044 ±21.907 (81.30-154.50) | 400 |
| Total Suspended Solid (TSS) mg/l | 0.031±0.012[a] (0.02-0.05) | 0.024±0.011[b] (0.01-0.03)c | 0.014 ±0.004[C] (0.01-0.02) | 0.022±0.012 (0.01-0.05) | >10 |
| Total Dissolved Solid (TDS) mg/l | 55.066±10.939[a] (40.70 - 69.70) | 65.550 ±[c] 21.633[b] (37.90-91.20) | 91.866±24.655[c] (58.20-121.60) | 70.827 ± 24.604 (37.90 -121.60) | 500 |
| Dissolved Oxygen (DO) mg/l | 6.116±0.321[a] (45.20-78.90) | 2.883 ± 1.283[b] (40.90-65.10) | 2.230 ±2.059[c] (35.00-53.60) | 51.438± 1.221 (35.00-78.90) | >6 |
| Biochemical Oxygen Demand (BOD) mg/l | 8. 883 ±1.327[a] (7.40-10.80) | 10.983±1.838 (8.50-13.60) | 14.366±1.989[b] (11.70-17.10) | 11.411±2.842 (7.40-17.10) | <10 |
| Surface water temperature (°C) | 29.575 ± 2.524[a] (27.50-32.10) | 30.247±2.95l[a] (28.50-32.30) | 30.350±3.110[a] (27.60-32.40) | 30.057±2.567 (27.50 -32.40) | <40 |

Values are in Mean ± Standard deviation (Ranges in Parenthesis),
*Means with Different Superscript are Significantly Different (P<.05)

Differences in the severity of environmental disruptions caused by human activity along the river and effluent released into the waters at the various stations may be the cause of variations in the physicochemical parameters. The current study's pH and dissolved oxygen values are marginally higher than the 6.526±0.104 mg/l and 1.474±0.135 mg/l, respectively, reported by Andem *et al.* (2019) in their investigation of the ecological approach of plankton responses to water quality variables of a tropical river (Idundu river), South Eastern Nigeria.

This study's conductivity value was more than that of Atobatele *et al.* (2008). While the BOD value obtained during the study was higher than that published by Andem *et al*. (2013), the TSS and TDS recorded during the study were lower than those reported by Andem *et al.* (2012). The variations in the study area, study time, geographical area, and degree of human activity among the study locations may be the cause of the discrepancies between the values of these physico-chemical parameters and those of other comparable discoveries.

The relationship strength (r) between the water physico-chemical parameters and macro-invertebrate abundance in Calabar River is shown in Table 4. Crustaceans and Oligochaeta had a strong positive significant relationship with pH, having r-value of 0.95 and 0.83 respectively at P<0.05. Crustaceans and Oligochaeta had a strong negative relationship with conductivity, having r-value of -0.91 and -0.92 respectively at P>0.05. Crustaceans and Oligochaeta had a strong negative relationship with total suspended solid, having r-value of-0.88 and -0.95 respectively at P>0.05. Crustaceans and Qligochaeta had a strong negative relationship with total dissolved solid, having r-value of -0.85 and -0.89 respectively at P>0.05. Crustaceans, Gastropoda and Oligochaeta had a strong negative relationship with dissolved oxygen, having r-value of -0.93, -0.80 and -0.95 respectively at P>0.05. The Crustaceans had a strong

positive significant relationship with bio-chemical oxygen demand, having r-value of 0.82 at P<0.05. Crustaceans, Gastropoda and Oligochaeta had a strong negative relationship with temperature, having r-value of-0.91, -0.90 and -0.96 respectively at P>0.05.

The distribution of macro-invertebrates was influenced by physico-chemical factors, which is consistent with the findings of Sharifinia *et al.* (2012). According to Teferi *et al.* (2013), there is a strong positive correlation between Oligichaeta and pH as well as between Crustaceans and BOD. There was a substantial negative correlation between temperature and crustaceans, gastropoda, and oligochaeta, suggesting that an increase in temperature could result in a decrease in their abundance. The results of this study are different from those of Yakub and Ugwumba (2022), who found that the macroinvertebrate richness decreased with lotic water body size. The low level of dissolved oxygen observed could possibly be explained by the high level of human activity around the sampling stations, which discharged trash into the river. According to Ogbeibu and Egborge (1995), environments free of major human effects should have high biodiversity.

**Table 4:** Relationship (r) between Physico-chemical Parameters and Benthic Macro-invertebrates Abundance of Calabar River

| Soil/Water Parameters | pH | Conductivity | TSS | TDS | DO | BOD | Temperature |
|---|---|---|---|---|---|---|---|
| **Macro-invertebrates** | | | | | | | |
| Crustaceans | 0.95* | -0.91 | -0.88 | -0.85 | -0.93 | 0.82* | -0.91 |
| Insecta | 0.55 | -0.73 | -0.65 | -0.78 | -0.71 | 0.35 | ' -0.68 |
| Gastropoda | 0.78 | -0.70 | -0.73 | -0.65 | -0.80 | 0.54 | -0.90 |
| Bivalvia | 0.54 | -0.65 | -0.65 | -0.45 | -0.63 | 0.47 | -0.66 |
| Polychaeta | 0.37 | -0.35 | 0.38 | -0.14 | -0.35 | 0.31 | -0.35 |
| Oligochaeta | 0.83* | -0.92 | -0.95 | -0.89 | -0.95 | 0.64 | -0.96 |

** Correlation is significant at p<0.05,* ***Relationship Strength:*** *0.80 - 0.99 Strong Relationship*
*0.50 - 0.79 Slightly Strong Relationship, 0.10 - 0.49 Weak relationship, 0.00 - 0.09 No relationship*

## CONCLUSION

Even though the Calabar River Water is contaminated with organic pollutants from anthropogenic sources, such as the nearby industries and waterfront residents releasing raw human excrement, detergents, wastewater, cleaning agents from the industries, and plastic waste, the high number of macroinvertebrate fauna recorded indicates that the water is less stressed. In order to minimize the amount of contaminants released into the river, the government should create and implement policies and laws regarding the indiscriminate discharges of waste into the water by humans living along the waterfront. Additionally, the government should monitor the level of activities surrounding the river.

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# METAL CONTENTS IN COMMERCIALLY IMPORTANT FROZEN FISH SPECIES IN DUTSIN-MA COMMUNITY, KATSINA STATE, NIGERIA

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**ABSTRACT**
*The study evaluated the concentration of selected metals in the flesh of Scomber scombrus and Sardinella maderensis samples collected from frozen fish stores in Dutsin-Ma community, Katsina State, Nigeria. Duplicates samples of S. scombrus and S. maderensis were obtained monthly from four prominent retail frozen fish outlets within Dutsin-Ma community over a period of four months. The samples were gutted, cleaned, oven-dried and digested using standard methods while the concentration of lead, zinc, copper and iron in the digested samples were determined spectrophotometrically. All the metals analysed for in the samples were present in both fish species across the sampling locations. The lead content in S. scombrus was significantly highest (4.253±1.264 mg/kg) and lowest (2.977±0.796 mg/kg) in locations D and C, respectively, while the other metals varied insignificantly. Furthermore, there were insignificant variations in the concentration of all the metals in S. maderensis. It is noteworthy that concentrations of most of the metals were relatively higher in S. scombrus than those observed in S. maderensis while the order of occurrence of the metals were similar in both fish species, Although the lead contents in both fish species was slightly higher than the allowable metal limits, the other metals were within the recommended levels of the local and international standards. Therefore, the flesh of the two fish species can be regarded as safe for human consumption.*

**Keyword:**
Bioaccumulation, Dutsin-Ma, food safety, frozen fish

## INTRODUCTION

Fish importation has been a culture in Nigeria, aimed at bridging the gap between the domestic demand and local fish production. Over several decades, Nigeria has enjoyed the importation of fish products, which are largely marine species. These imported fish commands varying commercial values based on preference and socio-economic status of Nigerians. These fish products are mainly imported in frozen forms which allows for longevity of the shelf life of the fresh fish (Olaoye *et al.*, 2022). The importance of frozen fish to Nigerian fisheries sector is enormous, as it is one of the most acceptable forms of distributing fish products in the country, in addition to providing jobs and supporting livelihood (Olaoye *et al.*, 2022).

However, the safety of the frozen fish products has been a source of concern considering Nigeria's epileptic power supply and the highly perishable nature of fish especially in the fresh form. Dutsin-Ma community, like many Nigerian communities, is not spared of these problems. The community has witnessed upsurge in human population over the last decade especially with the establishment of the Take-off campus of the Federal University Dustin-Ma in the community, in addition to the existing Isa Kaita College of Education. As the host community of two tertiary institutions, Dutsin-Ma has attracted many business enterprises including frozen fish outlets established to cater for the community's demand for fish products. There are four notable frozen fish outlets in the community where fish species such as Atlantic mackerel (*Scomber scombrus*), Short body sardine (*Sardinella maderensis*) Atlantic herrings

(*Clupea harengus*) and Horse mackerel (*Trachurus trachurus*) are commonly sold. Among these fish species, the Atlantic mackerel (*S. scombrus*) and Madeiran sardinella (*S. maderensis*) were selected for this study due to their readily availability and fast rate of sales due high demand and patronage by residents of Dutsin-Ma community.

However, some of the challenges facing frozen fish outlets in Dutsin-Ma community include the economic hardship and rising cost of fish products. These factors have contributed to reduction in patronage and long duration of fish storage in the frozen fish outlets. Although, poor storage may reduce the nutritional quality of frozen fish, presence of metals in the fish flesh beyond the recommended levels may pose health challenges to fish consumers (Jaishankar *et al*., 2014). The beneficial and toxic importance of metals to humans have been documented (Jaishankar *et al*., 2014; Ayanda *et al*. 2020; Sani *et al*., 2022). Despite the nutritional importance of the trace metals such as zinc, copper, iron and manganese, among others, their availability in concentrations above the essential limits have been reported to cause cellular, tissue, organ and system damages (Sani *et al*., 2022). Some metals, which include lead, cadmium, chromium and mercury, have been reported to be of no known physiological importance to man. Therefore, their availability in toxic concentrations could cause diseases in various parts of human body (Duruibe *et al*., 2007). These toxic attributes of the metals have formed the basis for metal evaluation in food products. The study evaluated the concentration of selected metals in the flesh of *Scomber scombrus* and *Sardinella maderensis* samples collected from frozen fish stores in Dutsin-Ma community, Katsina State.

## MATERIALS AND METHOD

This study was carried out in Dutsin-Ma community, the headquarters of Dutsin-Ma Local Government Area (LGA) in Katsina State. The LGA is located between latitude 12°27'14.11" North and longitude 7°29'50.03" East. Duplicates samples of *S. scombrus* and *S. maderensis* were obtained from the four retail frozen fish outlets located in the community and were labelled as locations A, B, C and D. The frozen samples were collected on a monthly basis for a period of four months, and transported in cold packs to the Laboratory where they were allowed to thaw separately, gutted and rinsed of blood and other body fluid before being over-dried to a constant weight at 105°C.

The dried flesh of each of the samples was ground into powdery form; digestion of the powdery samples was carried out using the method of Abou El-Anwar (2019), before the concentration of metals (Pb, Zn, Cu and Fe) were determined using the atomic absorption spectrometer (AAS). Data obtained from the metal content determination were analysed using mean and standard deviation; one-way Analysis of Variance (ANOVA) was used to test the differences in metal content among the sampling locations while the Tukey HSD test was used to separate the means at $P<0.05$.

## RESULTS AND DISCUSSION

The metal contents in the flesh of *S. scombrus* and *S. maderensis* are presented in Tables 1 and 2, respectively. These tables revealed that all the metals evaluated were present in the fish samples in varying levels. This could be attributed to the roles of the fish species as bioindicators of metals in aquatic environments (Oladele *et al*., 2019; Okoli *et al*., 2022). In specifics, Table 1 shows that the lead content in *S. scombrus* were significantly ($P<0.05$) highest ($4.253\pm1.264$ mg/kg) and lowest ($2.977\pm0.796$ mg/kg) in locations D and C, respectively. This disparity in the metal contents may have resulted from different wholesales sources where the fish were procured. Also, the metal levels in aquatic environments from where these marine fish species lived and were captured may have played a role in the variation observed in the metal contents (Okoli *et al*., 2022). Although, the concentrations of other metals varied insignificantly among the sampling locations, relatively higher levels of zinc ($3.954\pm1.144$ mg/kg) were recorded in Locations B while Location A had highest concentrations of copper

(0.126±0.061 mg/kg) and iron (0.110±0.005 mg/kg). Furthermore, the order of occurrence of the metals in the flesh of *S. scombrus* was lead > zinc > copper > iron, with lead having the highest mean concentration (3.463±0.932 mg/kg) while the iron concentration (0.106±0.005 mg/kg) was the lowest among the metals. This pattern of occurrence may have resulted from the essentiality of these metals; while lead is not known to have any physiological importance in fish species; zinc and copper are known as trace minerals whereas iron is an essential nutrient element (Ayanda *et al*., 2020).

Table 2 reveals that there were insignificant variations in the metal contents observed in *S. maderensis* from the sampling locations. However, relatively higher lead (3.749±1.162 mg/kg), and zinc (3.563±0.753 mg/kg) contents were recorded in fish samples obtained from Location B. The samples from Locations D and C had higher copper (0.235±0.353 mg/kg) and iron (0.113±0.073 mg/kg) concentrations, respectively. Just like the pattern observed in *S. scombrus* (Table 1), the order of occurrence of the metals in *S. maderensis* was lead > zinc > copper > iron. The nutritional importance of zinc, copper and iron and the capacity of fish species to utilise these metals (Ayanda *et al*., 2020) may have played important roles in the low levels of accumulation observed.

**Table 1:** Metal concentration (mg/kg) in *Scomber scombrus* obtained from frozen fish stores within Dutsin-Ma community

| Location | Lead | Zinc | Copper | Iron |
|---|---|---|---|---|
| Location A | 3.349±0.716$^{ab}$ | 2.986±0.650$^{a}$ | 0.126±0.061$^{a}$ | 0.110±0.005$^{a}$ |
| Location B | 3.166±0.055$^{ab}$ | 3.954±1.144$^{a}$ | 0.088±0.043$^{a}$ | 0.104±0.003$^{a}$ |
| Location C | 2.977±0.796$^{a}$ | 3.838±1.163$^{a}$ | 0.114±0.041$^{a}$ | 0.105±0.007$^{a}$ |
| Location D | 4.253±1.264$^{b}$ | 3.338±0.723$^{a}$ | 0.112±0.009$^{a}$ | 0.104±0.006$^{a}$ |
| Mean | **3.463±0.932** | **3.359±0.985** | **0.110±0.043** | **0.106±0.005** |

The concentration of the metals is expressed as mean±standard deviation. Means with different superscripts along each column signifies significant difference (P<0.05)

**Table 2:** Metal concentration (mg/kg) in *Sardinella maderensis* obtained from frozen fish stores within Dutsin-Ma community

| Location | Lead | Zinc | Copper | Iron |
|---|---|---|---|---|
| Location A | 3.364±0.905$^{a}$ | 3.101±0.896$^{a}$ | 0.070±0.057$^{a}$ | 0.101±0.059$^{a}$ |
| Location B | 3.749±1.162$^{a}$ | 3.563±0.753$^{a}$ | 0.221±0.321$^{a}$ | 0.094±0.035$^{a}$ |
| Location C | 3.360±1.270$^{a}$ | 3.190±0.809$^{a}$ | 0.121±0.057$^{a}$ | 0.113±0.073$^{a}$ |
| Location D | 2.977±0.819$^{a}$ | 2.864±0.716$^{a}$ | 0.235±0.353$^{a}$ | 0.093±0.069$^{a}$ |
| Mean | **3.362±1.041** | **3.179±0.799** | **0.162±0.240** | **0.100±0.059** |

The concentration of the metals is expressed as mean±standard deviation. Means with different superscripts along each column signifies significant difference (P<0.05)

As evident in Table 3, it is noteworthy that concentrations of the majority of the metals were relatively higher in *S. scombrus* than those observed in *S. maderensis*. Differences in the nutritional requirements and varying capacities of fish species to accumulate metals (Authur *et al*., 2021) could be responsible for the relatively higher metal levels recorded in *S. scombrus*. Although, the lead contents in both fish species were slightly higher than the allowable metal limits of the National Agency for Food and Drug Administration and Control (NAFDAC), World Health Organization (WHO), and Food and Agricultural Organization (FAO), the other metals were within the recommended levels of these local and international standards (Table 3). Hence, it can be inferred that the two fish species are safe for human consumption, while caution should be taken by consumers to avoid build-up of leas from the fish consumption.

**Table 3:** Comparison of metal contents in *Scomber scombrus* and *Sardinella maderensis* with local and international standards

| Sample/Standard | Lead (mg/kg) | Zinc (mg/kg) | Copper (mg/kg) | Iron (mg/kg) |
|---|---|---|---|---|
| *Scomber scombrus* | 3.463±0.932 | 3.359±0.985 | 0.110±0.043 | 0.106±0.005 |
| *Sardinella maderensis* | 3.362±1.041 | 3.179±0.799 | 0.162±0.240 | 0.100±0.059 |
| *NAFDAC | 2.000 | 50.0000 | 40.000 | 3.000 |
| *WHO/FAO | 2.000 | 100.000 | 73.000 | 3.000 |

*NAFDAC and WHO/FAO permissible limits (Oladele *et al*., 2023)

## CONCLUSION

The flesh of *Scomber scombrus* and *Sardinella maderensis*, obtained from frozen fish outlets located in Dutsin-Ma community, contained varying levels of the evaluated metals. Although, *S. scombrus* contained greater levels of majority of the evaluated metals, the metal concentrations in the flesh of both fish species were within the safe limits of local and international standards. Therefore, the flesh of the two fish species can be regarded as safe for human consumption. However, caution must be exercised by consumers of these fish species to avoid build-up of lead which may bioaccumulate over a long period of time.

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# POLLUTION STATUS AND CRISIS OF LAKE ALAU: FACTORS INFLUENCING THE POLLUTION AND SUGGESTED SOLUTIONS

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**ABSTRACT**

*Lake Alau, a vital freshwater reservoir near Maiduguri in Borno State, Nigeria, plays a crucial role in fisheries, irrigation, flood control, and domestic water supply. However, the lake faces severe pollution challenges resulting from agricultural runoff, urban waste disposal, deforestation, conflict-related displacement, and hydrological modifications. Studies reveal elevated levels of nutrients, suspended solids, heavy metals, and microbial pathogens, exceeding recommended water quality standards and threatening aquatic biodiversity, fisheries productivity, and public health. Pollution has caused a marked decline in fish populations, increased waterborne diseases, and jeopardized the livelihoods of surrounding communities. Contributing factors include weak policy enforcement, poor community awareness, and inadequate stakeholder engagement. Sustainable solutions such as integrated watershed management, stricter policy enforcement, eco-friendly farming practices, community-based waste management, and multi-stakeholder partnerships are urgently needed. This collective approach can help restore Lake Alau's ecological integrity and secure its long-term benefits for the region.*

**Keywords**: Lake Chad, Water pollution, Fisheries sustainability, Water quality management.

## INTRODUCTION

Over time, its socio-economic value expanded to include fisheries and local food production. Water bodies are critical ecological resources that support various human, economic, and environmental functions. Among these, inland lakes serve as vital sources of freshwater for drinking, agriculture, industry, and fisheries. However, with increasing anthropogenic pressure and environmental changes, many freshwater systems across the globe are experiencing unprecedented degradation. In Nigeria, particularly in the semi-arid northeast, Lake Alau stands out as a key water body sustaining the livelihoods of thousands through fishing, farming, and household consumption. Over the last two decades, the lake has increasingly shown signs of ecological distress. Its pollution status has become a subject of growing concern among environmental scientists, local communities, and policy makers.

However, the uncontrolled and unregulated activities surrounding its catchment such as agriculture, settlement expansion, and industrial runoff have resulted in a significant pollution load affecting both the quality of the water and the biodiversity within it.

### Importance of Lake Alau

Lake Alau plays a multifaceted role in the region. Economically, it supports subsistence and artisanal fisheries that serve as a major source of protein and income for surrounding communities. Hydrologically, the lake functions as a buffer against seasonal flooding, and its water is used for irrigation purposes. Ecologically, it provides a habitat for aquatic flora and fauna and contributes to the microclimate of the region. Furthermore, the lake has served as a critical resource for displaced populations during regional conflicts, particularly the Boko Haram insurgency, by supplying water and food resources (Gwana *et al.*, 2017).

**Geographical and Hydrological Context**

Lake Alau, located approximately 19 kilometers southeast of Maiduguri in Borno State, is an artificial reservoir constructed in the early 1980s for the purpose of irrigation, flood control, and domestic water supply (Peter and Alhassan, 2017). It draws inflow primarily from the River Yedzeram, a tributary of the River Komadugu-Yobe. Lake Alau lies within the Chad Basin, a region characterized by flat terrain, sparse vegetation, and seasonal rainfall. The lake's elevation stands at approximately 300 meters above sea level, with a total storage capacity of 112 million cubic meters at maximum flood level. The catchment area is influenced by seasonal inflow, and evaporation rates are high due to the semi-arid climate. This makes the lake highly sensitive to changes in water balance and quality.

**Pollution Status: Physico-Chemical Evidence**

Numerous water quality assessments have been carried out in Lake Alau, which collectively reveal deteriorating water quality in various parts of the lake. A study by Peter and Alhassan (2017) reported elevated levels of biological oxygen demand (BOD), total suspended solids (TSS), and nitrates, particularly during the dry season. Their findings showed that the BOD levels ranged between 2.6 and 4.3 mg/L indicative of organic pollution and nitrate concentrations exceeded the World Health Organization's (WHO) permissible limits for drinking water.

Similarly, Gwana *et al*. (2017) conducted a detailed physico-chemical analysis and found that conductivity levels fluctuated significantly (from 180 to 470 $\mu$S/cm), suggesting mineral enrichment from runoff and erosion. Dissolved oxygen (DO) levels also dropped below 5 mg/L in some parts of the lake, signaling reduced capacity to support aquatic life. Another significant concern is the potential for eutrophication, especially during periods of low water flow. Nutrient loading from fertilizer runoff and decaying organic matter creates the ideal condition for algal blooms, which deplete oxygen levels and result in fish kills and biodiversity decline. While direct evidence of large-scale algal blooms in Lake Alau is limited, indicators of nutrient enrichment suggest that the lake is on the verge of such a crisis if current trends continue.

**Factors Influencing Pollution in Lake Alau**

**1. Agricultural Runoff and Use of Agrochemicals**

Agriculture is one of the major economic activities in the Lake Alau catchment. Due to population growth and food insecurity challenges, farmers have resorted to intensified cultivation with increased reliance on chemical fertilizers and pesticides. During the rainy season, these chemicals are washed into surrounding waterways, eventually making their way into Lake Alau. Excess nitrogen and phosphorus from fertilizers significantly contribute to nutrient loading in the lake, potentially causing eutrophication and associated effects like algal blooms and fish mortality (Nwakaire *et al*., 2021).

**2. Deforestation and Soil Erosion**

The removal of vegetative cover in the Lake Alau watershed area for farming, firewood collection, and construction exposes the land to erosion. During rainfall, large volumes of topsoil are washed into the lake, increasing its sediment load. Sedimentation not only reduces water clarity and light penetration affecting photosynthesis but also alters the lake's depth and storage capacity. Fine sediments can clog fish gills and destroy spawning grounds, undermining fisheries productivity (Olalekan *et al*., 2019).

**3. Urban and Domestic Waste Disposal**

A critical contributor to Lake Alau's pollution is the discharge of untreated domestic and municipal waste. Settlements surrounding the lake, including Muna and Dusuman, often lack proper sewage infrastructure. Consequently, grey water and black water are discharged directly into the lake or its feeder streams. Solid waste comprising plastics, food remnants, and non-biodegradable materials is

frequently dumped near the lake banks, particularly during festive or market days.

**4. Conflict and Displacement**

The Boko Haram insurgency has significantly altered human-environment relationships in northeastern Nigeria. Thousands of people have been displaced from rural communities and now reside in camps or informal settlements near Lake Alau. These displacement dynamics place additional pressure on the lake for water and food resources. Moreover, the presence of makeshift structures and lack of sanitation facilities lead to indiscriminate defecation and waste dumping, which increase microbial and chemical pollution (Ali *et al*., 2020).

**5. Hydrological Modifications and Climate Change**

Hydrological changes, including the damming of upstream rivers and irrigation withdrawals, have reduced inflows to Lake Alau. Reduced water volume limits the lake's ability to dilute contaminants, leading to concentration of pollutants, especially during the dry season. Furthermore, climate variability has led to irregular rainfall patterns and prolonged dry spells, exacerbating eutrophication risks and raising water temperatures, which affects aquatic biodiversity (Umar *et al*., 2021).

**Types and Sources of Pollutants in Lake Alau**

These pollutants are broadly categorized into chemical, biological, and physical contaminants. Each type originates from different anthropogenic activities and contributes uniquely to the degradation of the lake's water quality.

**1. Organic and Inorganic Chemical Pollutants**

Chemical pollutants, including nitrogen compounds, phosphorus, heavy metals, and hydrocarbon residues, are introduced into Lake Alau through agricultural runoff, household waste, and industrial discharges. Nitrogen and phosphorus compounds, particularly from fertilizers, are among the most significant contributors to eutrophication. Their presence in large quantities supports algal overgrowth, leading to oxygen depletion and a cascade of ecological problems. Heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) are also present in trace amounts in the lake, primarily from pesticide use and leaching from nearby waste dumps. These metals are non-biodegradable and can bioaccumulate in aquatic organisms, posing serious risks to both fish and human health (Abubakar *et al*., 2022). Table 1 below summarizes some typical chemical contaminants reported in studies of Lake Alau and similar water bodies in the region.

**Table 1:** Selected Chemical Pollutants in Lake Alau and Their Potential Sources

| Pollutant | Major Source | Environmental Impact |
|---|---|---|
| Nitrates (NO3−) | Fertilizer runoff | Eutrophication, methemoglobinemia |
| Phosphates (PO4) | Agriculturalrunoff, detergents | Algal blooms, oxygen depletion |
| Lead (Pb) | Batteries, paint, pesticides | Neurotoxicity in humans, fish mortality |
| Mercury (Hg) | Industrial and electronic waste | Bioaccumulation, neurological damage |
| Cadmium (Cd) | Mining runoff, fertilizer residues | Kidney damage, aquatic toxicity |

**2. Microbial and Pathogenic Contaminants**

Microbial contamination is one of the most serious threats to public health in communities that rely on Lake Alau for drinking water or domestic use. The main sources of microbial pollution include open defecation, livestock access to water, poor waste management, and sewage effluent.Indicator organisms such as *Escherichia coli* (E. coli), *Salmonella spp.*, and *Shigella spp.* have been detected in water samples from lakes in northeastern Nigeria, including Lake Alau (Gwana *etal*., 2017). These pathogens are responsible for waterborne diseases like diarrhea, cholera, and typhoid fever. The rainy season typically

sees increased microbial loads due to surface runoff carrying fecal matter and organic waste. During the dry season, microbial concentrations often remain high because of reduced water volume and slower dilution.

### 3. Suspended Solids and Sedimentation

Suspended solids, primarily originating from erosion and runoff, contribute to the physical pollution of Lake Alau. These solids reduce light penetration and inhibit photosynthesis in aquatic plants. Sedimentation also disrupts the benthic ecosystem, affects spawning grounds for fish, and reduces the effective depth and volume of the lake.

High Total Suspended Solids (TSS) also increase water treatment costs and impact the efficiency of municipal filtration systems. Measurements of TSS in Lake Alau range between 80 and 250 mg/L in some locations, which exceeds the WHO guideline of 50 mg/L for drinking water (Ali *etal.*, 2020).

### 4. Seasonal Trends in Pollution

Pollution levels in Lake Alau fluctuate with the seasons, largely due to variations in rainfall, temperature, and human activity patterns. The rainy season, which spans from June to September, typically sees a spike in pollution load due to runoff from farms, markets, and settlements. During this period, nutrient loading, microbial contamination, and turbidity increase significantly.

**Table 2:** Seasonal Variation in Water Quality Parameters in Lake Alau (2022)

| Parameter | Rainy Season (Avg.) | Dry Season (Avg.) | WHO Limit (Drinking Water) |
|---|---|---|---|
| Ph | 6.2–7.5 | 7.4–8.2 | 6.5–8.5 |
| Dissolved Oxygen (mg/L) | 4.5 | 3.2 | >5 |
| Nitrate (mg/L) | 14.3 | 10.1 | 10 |
| E. coli (CFU/100mL) | 240 | 120 | 0 |
| Total Suspended Solids | 220 mg/L | 150 mg/L | 50 mg/L |

## Impact of Pollution on Aquatic Biodiversity and Fisheries

### 1. Decline in Fish Populations

Fish are among the most directly impacted organisms in Lake Alau. Pollution interferes with various aspects of fish biology, including reproduction, respiration, feeding, and growth. Exposure to low levels of dissolved oxygen (DO), heavy metals, and pesticide residues can cause mass fish kills or sub-lethal effects such as stunted growth and reproductive failure (Nweke *etal.*, 2022). Species such as *Clarias gariepinus*, *Tilapia zillii*, and *Heterotis niloticus*, once dominant in the lake, have recorded sharp declines in both catch and size. The bioaccumulation of metals such as mercury and cadmium in fish tissues also raises safety concerns for consumers, especially local residents who rely on the lake for their protein intake.

A 2021 survey by the Borno State Ministry of Environment reported that fish landing had dropped by nearly 60% compared to 2010 figures. This decline is linked to habitat destruction, eutrophication, and overfishing in polluted waters (Borno MOE, 2021).

### 2. Effects on Plankton and Aquatic Plants

Phytoplankton and zooplankton are essential to the aquatic food web, but their populations are sensitive to changes in nutrient levels and pH. Eutrophication can initially boost algal growth, but as algal blooms die off and decompose, they deplete dissolved oxygen, resulting in hypoxic or anoxic conditions (Omoregie *etal.*, 2021). This process leads to the die-off of zooplankton and fish larvae, affecting recruitment and productivity.

**3. Disruption of Ecological Balance**

Pollution alters the ecological balance of the lake. Sensitive species die off or migrate, while tolerant organisms like some cyanobacteria and opportunistic fish species dominate the ecosystem. This shift results in the loss of biodiversity, collapse of fisheries, and instability in ecosystem services like nutrient cycling, habitat provision, and natural purification.

**4. Public Health Implications**

The health of communities surrounding Lake Alau is closely tied to the quality of the lake's water. Unfortunately, pollution has made the lake a conduit for disease transmission and chronic exposure to harmful substances.

**5. Waterborne Diseases**

The presence of *E. coli*, *Shigella*, and other pathogens in the lake has been linked to outbreaks of waterborne diseases such as cholera, dysentery, and hepatitis A in Maiduguri and nearby IDP camps (WHO Nigeria, 2020). Open defecation practices, especially in informal settlements near the lake, exacerbate this issue.

**6. Heavy Metal Poisoning**

Communities that consume fish from Lake Alau are at risk of heavy metal poisoning due to bioaccumulation of contaminants such as lead and mercury in fish tissue. Chronic exposure to these metals is associated with neurological disorders, kidney damage, and developmental impairments in children (Adedeji and Oluwafemi, 2021).

**Water Quality Regulations and Policies**

Effective water resource management in Nigeria is guided by a blend of national and international frameworks. However, weak enforcement and limited stakeholder engagement have significantly undermined regulatory effectiveness in areas such as Lake Alau.

**1. National Regulations**

In Nigeria, the Federal Ministry of Environment (FME) and the National Environmental Standards and Regulations Enforcement Agency (NESREA) are responsible for setting environmental quality standards and ensuring compliance. The National Water Policy emphasizes integrated water resources management, while NESREA regulations set effluent discharge limits and water use practices. Despite these frameworks, many of the polluting activities around Lake Alau continue unchecked due to poor enforcement, lack of monitoring infrastructure, and limited political will (Obeta and Eze, 2020). Local governments, which are closest to the pollution sources, often lack the capacity or authority to implement water quality control measures.

**2. International Guidelines**

The World Health Organization (WHO) provides guidelines for drinking water quality, while the United Nations Environment Programme (UNEP) supports sustainable water management globally. Nigeria is also a signatory to the Sustainable Development Goals (SDGs)particularly Goal 6, which aims to ensure availability and sustainable management of water and sanitation for all by 2030. The inability to meet WHO standards for water quality and the challenges in achieving SDG 6 reflect the gaps in policy implementation at the national and local levels.

**3. Community Awareness and Stakeholder Involvement**

Public participation and community awareness are critical to sustainable environmental management. However, around Lake Alau, there is a widespread lack of awareness about pollution sources, health risks, and environmental responsibilities.

**4. Limited Environmental Education**

Many residents, including farmers and fishers, are unaware of how their actions contribute to pollution. Practices such as indiscriminate waste dumping, excessive fertilizer application, and open defecation are often carried out without understanding their long-term impact on water resources (Gwana *et al.*, 2021). Environmental education campaigns and community-based programs have been sporadic and underfunded. NGOs such as WaterAid Nigeria and Borno Environmental Action Team (BEAT) have made some efforts, but these are not sustained or widespread enough to cause behavioral change.

**Table 3:** Stakeholders in Lake Alau Management and Their Roles

| Stakeholder | Potential Role |
|---|---|
| Local Farmers and Fishers | Implement best practices, reduce chemical inputs |
| Traditional/Religious Leaders | Mobilize community action, promote sanitation |
| Government Agencies (FME, NESREA) | Enforce regulations, provide funding |
| NGOs and CBOs | Conduct education campaigns, monitor water quality |
| Academic Institutions | Research and data generation |

**5. Exclusion of Local Stakeholders**

Key stakeholders such as community leaders, traditional institutions, women's groups, and youth organizations are often excluded from decision-making processes. This exclusion fosters apathy and limits the effectiveness of interventions. Participatory water management models from countries like Kenya and India show that empowering local communities enhances compliance, boosts monitoring efforts, and increases sustainability (UNESCO, 2018).

**Suggested Solutions and Sustainable Management Strategies**

**1. Integrated Watershed Management**

Implementing a watershed management approach that includes soil conservation, controlled agricultural input use, and reforestation will reduce runoff and sedimentation. Buffer zones of vegetation should be established around the lake to filter pollutants before they enter the water body (FAO, 2020).Watershed protection should be coupled with the zoning of land use to restrict farming and housing developments close to the lake shore.

**2. Strengthening Policy Enforcement**

Environmental regulations must be strictly enforced. NESREA and the Borno State Ministry of Environment should collaborate to conduct regular monitoring, prosecute violators, and establish pollution permits for industries and large-scale farms. Local government councils must be empowered to act as the first line of defense.

The creation of a Lake Alau Management Authority (LAMA) could centralize governance, coordinate stakeholders, and implement conservation policies more effectively.

**3. Promotion of Eco-Friendly Technologies**

Farmers should be encouraged to adopt organic farming practices and use precision agriculture tools that minimize fertilizer and pesticide runoff. Smallholder irrigation should transition from flood irrigation to drip systems, which are more efficient and less polluting. For fishing communities, promoting cage aquaculture or closed-cycle fish farming systems can relieve pressure on natural stocks and reduce pollution from fish waste.

**4. Community-Based Waste Management**

Establishing community-based solid and liquid waste management systems is critical. Local leaders,

supported by NGOs, should organize cleanup campaigns, build latrines, and install waste collection points. Low-cost water filtration and chlorination technologies should be introduced to ensure access to safe drinking water.

## RECOMMENDATIONS FOR A MULTI-STAKEHOLDER APPROACH

### 1. Strengthening Local Governance and Capacity Building

Local governance structures must be empowered to enforce pollution control measures. The establishment of the Lake Alau Management Authority (LAMA), with representatives from local communities, government agencies, and NGOs, can provide an effective platform for monitoring pollution sources, allocating resources, and coordinating interventions. Capacity-building programs for local authorities, environmental officers, and community leaders will help to ensure the proper implementation of regulatory frameworks.

### 2. Community Engagement and Empowerment

As noted earlier, community involvement is essential for achieving long-term sustainability. Therefore, there should be continuous awareness-raising programs and training for local residents on the importance of water quality management. Involving communities in water quality monitoring can also foster a sense of ownership and accountability. Local fishers, farmers, and other residents should be encouraged to adopt practices such as organic farming, proper waste disposal, and sustainable water use.

### 3. Collaborative Research and Data Sharing

Partnerships with academic institutions such as the Federal University Dutsin-Ma and the University of Maiduguri can aid in the collection of environmental data, ecosystem monitoring, and research on pollution reduction strategies. Collaborative research projects can provide the scientific evidence needed to drive policy changes and inform adaptive management strategies. Data sharing between stakeholders will also facilitate timely responses to emerging pollution crises.

### 4. Public-Private Partnerships (PPPs) for Sustainable Investment

Private sector involvement is necessary for the financing of large-scale infrastructure projects. Government agencies should seek to establish Public-Private Partnerships (PPPs) for the development of waste management systems, eco-tourism facilities, and aquaculture systems. Engaging private investors with an interest in sustainable water management, such as local businesses, commercial farmers, and corporate social responsibility (CSR) programs, can significantly increase funding opportunities.

### 5. Policy and Regulatory Reform

It is essential to implement stronger environmental policies, particularly at the local government level. Local authorities should enforce waste management regulations, promote cleaner production practices, and regulate the use of harmful chemicals in agriculture. Strengthening the legal framework through legislative amendments and ensuring the involvement of environmental experts in policy formulation can lead to more robust environmental protection measures for Lake Alau.

## CONCLUSIONS

Lake Alau, like many water bodies globally, faces significant environmental stress due to pollution from multiple sources. The crisis is exacerbated by agricultural runoff, poor waste management, unsustainable fishing practices, and the encroachment of human settlements along the lake's shores. The current pollution levels threaten not only the ecosystem but also the livelihoods and health of local communities. The pollution crisis of Lake Alau is not insurmountable. With the right mix of policy reform, community engagement, technological intervention, and stakeholder collaboration, the lake can be restored to its former ecological health. The effort to save Lake Alau requires a shared commitment from all sectors of

societygovernment, civil society, academia, and the private sector.

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# ASSESSMENT OF HEAVY METALS BIOACCUMULATION IN *Clarias agboyensis* AND *Synodontis clarias* FROM EPE AND LEKKI LAGOONS, SOUTH WEST, NIGERIA

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**ABSTRACT**
*Heavy metals released into aquatic ecosystems accumulate in water and sediments, posing a risk to seafood and human health. These metals can bioaccumulate in fish and magnify in human organs after consumption, making it crucial to assess safety of seafood in the aquatic environment. Fish are vital protein source, and determining their safety is essential to protect human health. In this work, three vital organs (gills, gonad and liver) in two fish species (Clarias agboyiensis and Synodontis clarias) obtained from Epe and Lekki lagoons in Lagos state were evaluated for some heavy metals which include: Zinc, Cadmium, Copper, Iron, Nickel, Cobalt, Lead, Manganese, and Chromium. In all examined fishes, liver accumulated significantly ($P<0.05$), higher levels of Cadmium in Synodontis clarias when compared to Clarias agboyiensis from Epe and Lekki lagoons. The study found that heavy metal levels in fish organs were below permissible standards, indicating a moderate risk to human consumption. Essential elements like chromium, copper, and zinc were regulated by physiological mechanisms, but excessive levels can still pose a hazard. High levels of these metals can endanger both animal and human health, highlighting the need for continued monitoring of aquatic environment.*

**Keywords:** Heavy metals, Lagoons, Aquatic environment, Fish

## INTRODUCTION

Heavy metal pollution is ubiquitous in the natural environment (Oronsaye *et al.*, 2010), this results from diverse activities such as industrial affluence, foundry waste, wearing of metals parts and equipment, paints, auto-mobiles, mining, and rock weathering. Heavy metals are deposited on soil and can be leached into nearby water bodies, contaminating amphibian habitats. The major concern is their acute toxicity and ability to bio accumulate, causing harmful effects. Bioaccumulation of heavy metals can lead to immunosuppression and other deleterious effects in biological systems (Otitoloju and Don-Pedro, 2002). In recent years, heavy metal pollution has generated serious global concern, due to the adverse effects that these group of contaminants have on living organisms (Barson, *et al.*, 2014). These compounds are not readily degradable in the environment and thus accumulate in animal and human tissues to very high toxic levels leading to undesirable effects (Kaur and Mehra, 2012).Heavy metals in fish gonads may be transferred to the next fish generations resulting into diseases or illnesses (Terra *et al.*, 2008) and the significant parts of the fish, usually affected with highest load of such metals include the liver, kidney and gills. The contamination of water bodies with a variety of pollutants has become an issue of concern over the last few decades, not only because of the threat to public water supplies, but also the hazards to human consumption of fishery resources and other aquatic biotas (Butchiram *et al.*, 2019).

Lagoons are static sinks to toxic substances and effluents from anthropogenic activities (agriculture, urban and industrial sources) can accumulate to dangerous levels because they are depositional environments (Adeleye *et al.*, 2011). Among the many anthropogenic contaminants reaching coastal lagoons, heavy metals are of great environmental concern. Most heavy metal inputs are through fluvial processes, direct effluent discharge and in-situ activities producing metal containing effluents such as shipping and other harbor activities. Fish are particularly susceptible to water pollution and pollutants

may interrupt many physiological and biochemical pathways in case assimilated by fish tissue among many others (Durmaz *et al*., 2006). Fish serve as a crucial aquatic monitoring system because they are high in the aquatic food chain and reflect the overall health of the ecosystem (Abdallah and Morsy, 2014). Heavy metals released into aquatic ecosystems accumulate in water and sediments, then get absorbed by lower organisms. These metals are transferred through the food chain to higher trophic levels, including fish. When consumed, heavy metals can bio accumulate and magnify in human organs, posing a significant health risk. (Ozparlak *et al*., 2012).

Fish as a bio indicator species plays an increasingly important role in the monitoring of water pollution because it responds with great sensitivity to changes in the aquatic environment (Mondon *et al*., 2001). The exposure of fish to any stress induces a number of modifications in different organs, particularly gills, liver and spleen. Heavy metal toxicity can cause degenerative changes in the liver, altering enzyme levels and disrupting normal cellular metabolism. Liver damage from toxins can lead to the release of enzymes like lactate dehydrogenase (LDH), indicating hepatocellular damage. (Gaber *et al*., 2014). The aim of this work is to evaluate the levels of heavy metals in the gills, gonad, liver of the species (*Clarias agboyiensis* and *Synodontis clarias*) from two lagoons in order to ascertain how safe the consumption of this fish organs are. From the result obtained appropriate conclusion can be drawn on the safety of these organs.

## MATERIALS AND METHODS

### Description of Study Area

The study was carried out in Lekki and Epe Lagoons, which was further sub-divided into 8 stations namely: Ibeju Town, Omu, Abejuoye, Okera-kekere, Ejirin, Oko-Orisan, Oju-alaro and Chief fish jetty. Epe lagoon is situated between latitudes 003°50' -004°10'N and longitudes 06°35' - 06°40'E. the lagoon lies within the rainforest belt of southern Nigeria. The Lekki lagoon is one of the largest lagoons in west Africa and it supports a major fishery. The lagoon is located between Lagos and Ogun states of Nigeria and lies between longitude 003°55' and 4° 15' E and between latitude 6°25' and 6°37'N. (Figure 1).

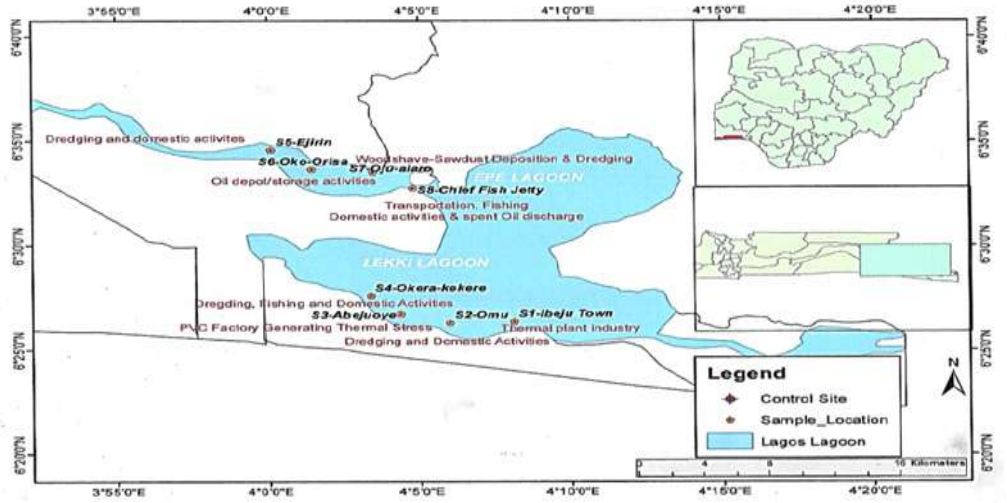
### Collection of Fish samples

The fish samples used for the study are *Synodontis clarias* (Plate1)and C*larias agboyiensis* (Plate 2) The choice of the organisms was made based on their availability, ecological niche and sensitive response to pollutants from hotspots. The fish samples were caught using a trap net set at the bottom of the lagoon. The mean length and weight of *Synodontis clarias* and C*larias agboyiensis* were 33.52 ± 0.22, 28.40 ± 0.25 cm and 210.06 ± 3.67 g, 185.2 ± 2.54 cm respectively.

### Collection of Fish Organs

Fish organs (gill, liver and gonad) were digested after dissection, according to AOAC (1990) methods. About 2g of partially thawed fish gill, liver and gonad were weighed into Teflon tubes and 4ml of concentrated NHO3 was slowly added to the tube. The tubes were then tightly closed and placed in a stainless-steel bowls. The bowls were placed on a hot plate and heated at 110°C for one hour and then to 150°c for three hours. Allow the samples to cool at room temperature, and then carefully open the bowls and transfer samples into 50ml polypropylene graduated tubes in a fume chamber, wearing nose guard. Rinse the tube with deionized water three times adding the wash to the tube. The gill, gonad and liver tissues were fixed in 3% formalin. The samples were analysed at the Anatomic and Molecular Pathology laboratory of the College of Medicine, University of Lagos Idi-Araba Lagos.

**Figure 1:** Map of Sampling Stations at Epe and Lekki Lagoons




***Sourse:*** *Field Survey, Department of Geography, University of Lagos*



**Plate 1 (A):** *Clarias agboyiensis*



**Plate 2 (B):** *Synodontis clarias*

**Statistical Analysis**

All metrics were reported as mean ± standard error (S.E), PAST Software version 3.18 (Hammer *et al.*, 2001) and statistical package SPSS 20.0 (SPSS Inc. Chicago, Illinois, USA) was used for statistical analyses. Data were analysed by One-Way Analysis of Variance, and significant differences ($p< 0.05$) resulting from the test were re analysed by the Duncan Multiple Range Test (DMRT).

**RESULTS**

Table 1 showed the bioaccumulation factor (BAF) of heavy metals from water to Gill of *Synodontis clarias* which indicates significant copper (Cu) level in the liver and least observed was Manganese (Mn) in the gonad at Epe Lagoon respectively. However, the bioaccumulation factor of heavy metal in gill decreased in the order of; Cr > Fe > Cd > Cu > Mn > Pb; In Gonads: Cd > Cr > Pb > Cu > Fe > Mn; In liver: Cu > Cd > Cr > Fe > Mn > Pb. At Lekki Lagoon, the most bioaccumulated metals were Cr in gills and liver of *Synodontis clarias* organs, while the least observed was Mn across all organs. The bioaccumulation factor of heavy metal in gill from water at the Lekki Lagoon decreased in the order of; Cr > Fe > Cd > Pb > Cu > Mn; In gonad: Cd > Cr > Pb > Cu > Fe > Mn; In Liver: Cr > Cu > Cd > Fe > Mn > Pb. Table 2 showed the bioaccumulation factor (BAF) of heavy metals such as copper (Cu) in the liver of *Synodontis clarias* was most significantly highest and the least observed was Manganese (Mn) in the gonad at Epe Lagoon respectively. However, the bioaccumulation factor of heavy metal in gill from water at the Epe Lagoon decreased in the order of; Cr > Fe > Cd > Cu > Pb > Mn; In Gonads: Cd > Cr > Pb > Cu > Fe > Mn; In liver: Cu > Cd > Cr > Fe > Pb > Mn. At Lekki Lagoon, the most

bioaccumulated metals were Cr in gills and liver of *Synodontis clarias* organs from the water, while the least observed was Mn and Fe in gonads. the bioaccumulation factor of heavy metal in gill from water at the Lekki Lagoon decreased in the order of; Cr > Fe > Cd > Pb > Cu > Mn; In gonad: Cd > Cr > Pb > Cu > Fe > Mn; In Liver: Cr > Cu > Cd > Pb > Fe > Mn.

**Table 1:** Bioaccumulation factors of heavy metals in *Clarias agboyiensis* organs from water of Epe and Lekki Lagoons

| | Cr | Mn | Cd | Cu | Pb | Fe |
|---|---|---|---|---|---|---|
| | | | **Epe Lagoon** | | | |
| Gill | $64.30\pm5.44^{d}$ | $1.21\pm0.02^{b}$ | $22.07\pm3.22^{b}$ | $16.19\pm4.55^{c}$ | $1.03\pm0.02^{b}$ | $56.85\pm8.02^{c}$ |
| Gonads | $17.66\pm7.98^{b}$ | $0.86\pm0.04^{a}$ | $29.24\pm8.66^{b}$ | $11.24\pm3.02^{c}$ | $5.44\pm1.06^{c}$ | $4.72\pm1.45^{b}$ |
| Liver | $59.24\pm8.54^{d}$ | $3.91\pm0.08^{c}$ | $22.29\pm9.77^{b}$ | $15.94\pm5.08^{c}$ | $0.50\pm0.08^{a}$ | $41.69\pm8.34^{c}$ |
| | | | **Lekki Lagoon** | | | |
| Gill | $48.61\pm6.22^{c}$ | $0.41\pm0.02^{a}$ | $32.43\pm1.01^{c}$ | $5.70\pm1.01^{b}$ | $5.77\pm1.06^{b}$ | $6.45\pm1.01^{b}$ |
| Gonads | $8.49\pm5.32^{a}$ | $0.25\pm0.01^{a}$ | $14.85\pm2.55^{a}$ | $0.75\pm0.03^{a}$ | $3.69\pm1.02^{b}$ | $0.29\pm0.03^{a}$ |
| Liver | $39.73\pm6.61^{c}$ | $0.63\pm0.01^{a}$ | $19.75\pm6.66^{a}$ | $0.64\pm0.02^{a}$ | $0.49\pm0.03^{a}$ | $5.24\pm1.12^{b}$ |
| FAO/WHO (2021) Limits | 0.60 | 0.50 | 0.50 | 0.50 | 2.00 | 0.50 |

*Means within the same column with different manuscript are significantly different ($p<0.05$)*

**Table 2:** Bioaccumulation factors of heavy metals in *Synodontis clarias* organs from water of Epe and Lekki Lagoons

| | Cr | Mn | Cd | Cu | Pb | Fe |
|---|---|---|---|---|---|---|
| | | | **Epe Lagoon** | | | |
| Gill | $69.39\pm7.03^{d}$ | $1.24\pm0.42^{b}$ | $26.90\pm6.01^{b}$ | $15.67\pm3.02^{b}$ | $1.44\pm0.01^{a}$ | $56.85\pm9.87^{c}$ |
| Gonads | $21.18\pm2.12^{b}$ | $0.88\pm0.04^{a}$ | $31.16\pm5.03^{c}$ | $12.53\pm1.07^{b}$ | $5.17\pm2.03^{c}$ | $4.73\pm0.77^{b}$ |
| Liver | $71.97\pm9.05^{d}$ | $3.98\pm0.77^{c}$ | $97.25\pm9.52^{d}$ | $25.63\pm5.01^{c}$ | $1.28\pm3.98^{d}$ | $41.69\pm8.87^{c}$ |
| | | | **Lekki Lagoon** | | | |
| Gill | $53.49\pm4.32^{c}$ | $0.41\pm0.01^{a}$ | $22.76\pm0.03^{b}$ | $27.09\pm0.32^{c}$ | $1.37\pm0.05^{a}$ | $9.99\pm1.03^{b}$ |
| Gonads | $9.46\pm1.03^{a}$ | $0.26\pm0.04^{a}$ | $15.57\pm3.88^{a}$ | $0.89\pm0.41^{a}$ | $3.56\pm0.31^{b}$ | $0.20\pm0.04^{a}$ |
| Liver | $50.67\pm9.41^{c}$ | $0.65\pm0.11^{a}$ | $21.72\pm5.77^{b}$ | $26.16\pm5.77^{c}$ | $7.15\pm1.01^{b}$ | $5.20\pm0.89^{b}$ |
| FAO/WHO (2021) Limits | 0.60 | 0.50 | 0.50 | 0.50 | 2.00 | 0.50 |

*Means within the same column with different manuscript are significantly different ($p<0.05$)*

## DISCUSSION

Evaluation and monitoring programs for heavy metal bioaccumulation serve as a biomarker for fish from contaminated environment which provides information about the environmental status of an ecosystem. Thus, these biomarkers are designed for different aspects of risk assessment of an aquatic ecosystem. Nevertheless, several studies have shown that fish tissue alterations are reliable and efficient tools to detect and monitor environments that are influenced by anthropogenic activities (Adams *et al.*, 2000), which also helps to foresee potential environmental risks (Paulo *et al.*, 2012). Fish organs, such as the gonads, liver and gills, are metabolically active tissues that accumulate metals at higher levels, as previously reported (Kennedy, 2011). In this research, it was observed that the measured concentrations of heavy metals levels in the two lagoons were higher than the permissible limit of (FAO, 2012), and it portends a potential danger to the consumption of fish from these lagoons. Fish accumulated metals in their organs through bioaccumulation from sediment and water column of Lekki and Epe Lagoon possibly due to anthropogenic activities in both Lagoons (Armah *et al.*, 2010). There were differences in the metal level across the species and organs indicating a threat when consuming fish from the coastal water.

However, occurrence of excessive levels of chromium, cadmium, copper and iron from this study is regarded as a potential hazard which can endanger both animal and human health and this is in total agreement with the study of Iftah *et al*. (2015) who reported bioaccumulation and toxicity of metals in Shingi fish *Heteropneustes fossils* and its possible impacts on human health.

Although the levels of metal in the organ of the fish species in both lagoons were above the permissible standards, metals showed significant differences ($p<0.05$) in the organs of both species, except Mn which showed no significant difference ($p>0.05$) in the organs of the studied fishes in Lekki Lagoon. This result aligned with the findings of Ejimadu *et al*. (2015) in organs of some fish species from Lagos Lagoon. Hence, the metals used in this research posed moderate risk to consumers of these fish species from the coastal ecosystem. chromium, copper and zinc are essential element and are regulated by physiological mechanisms in most organism. However, occurrence of excessive levels of them is regarded as potential hazard which can endanger both animal and human health (Wright and Welbourn,2002). Among the studied organs in both species, heavy metals were found to be more concentrated in the gills. These results agreed with the findings of Okoye (1991), who observed the same trend in Lagos Lagoons. Gills are important for respiration and osmoregulation, acid-base balance and nitrogenous waste excretion (Orosanye *et al.*, 2010), it is possible that the damage of the fills could be a direct result of the heavy metals, pesticides, sewage and fertilizers which are conveyed by the water. The high levels of heavy metals observed in this study, may be due to influx of effluents into the lagoons. Effluents enter the Lagos Lagoon from industrial, domestic, and agricultural sources, including untreated sewage, factory waste containing chemicals and heavy metals, and runoff from agricultural and urban areas. This pollution comes from numerous rivers and canals, as well as direct discharge from settlements, and has led to significant water quality degradation.

## CONCLUSION

The result of the present study has shown that Epe and Lekki lagoons are moderately contaminated with heavy metals. This investigation also showed that the heavy metal contents in the gill, liver and gonads of *Clarias agboyiensis* and *Synodontis clarias* varied and some of them were below the permissible limits. In order to avert further negative impacts by heavy metals on the Lagoons, it is advocated that regular monitoring of heavy metals in fish within the Lagoons be carried out. Such monitoring would ensure that safety limits for heavy metals in fish are not exceeded in order to safeguard the health of people who depend on the water body for their source of fish supplies. A sedimentology of the Lagoons, is also suggested as sediments serve as repositories for heavy metals and are thus a potential source of contamination.

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# EFFECT OF RED TASSEL (*Emilia sonchifolia*) ON THE HAEMATOLOGY OF *Clarias gariepinus* FINGERLINGS

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**ABSTRACT**
*This study was conducted to investigate the effects of red tassel (Emilia sonchifolia) flower extract on the haematological parameters of Clarias gariepinus fingerlings. Ten fingerlings each in 18 aquaria were exposed to graded concentrations (0, 1000, 1250, 1500, 1750, and 2000 mg/L) of E. sonchifolia extract over a 96-hours trial. Haematological indices assessed included Packed Cell Volume (PCV), Haemoglobin (Hb), Red Blood Cell count (RBC), White Blood Cell count (WBC), Mean Corpuscular Volume (MCV), Mean Corpuscular Haemoglobin (MCH), and Mean Corpuscular Haemoglobin Concentration (MCHC). Findings revealed that moderate concentrations (1000–1500 mg/L) of E. sonchifolia enhanced WBC Hb, and PCV levels, suggesting improved immune function and physiological stability. However, higher concentrations (1750–2000 mg/L) slightly reduced PCV and RBC values, indicating possible mild haematotoxicity. The water quality parameters; dissolved oxygen reduced while the temperature increased significantly with increase in time and concentrations of the treatment. These results suggest that E. sonchifolia may serve as a natural immunostimulant in aquaculture.*

**Keywords**: Medicinal plant, African Catfish, Haematological

## INTRODUCTION

The use of medicinal plants in aquaculture is gaining increasing attention due to their eco-friendliness, affordability, and wide-ranging pharmacological effects (Akinmoladun *et al.*, 2020). *Emilia sonchifolia*, commonly referred to as red tassel flower, is a medicinal plant found in tropical Asia and Africa, traditionally used in ethnomedicine to treat fever, inflammation, wounds, and microbial infections (Rahman *et al.*, 2018). This plant is known to contain various bioactive compounds, such as flavonoids, alkaloids, tannins, saponins, and terpenoids, which have potential health-enhancing properties (Kumar *et al.*, 2021).

There is an urgent need to manage fish health sustainably without relying heavily on synthetic drugs and antibiotics that could lead to resistance and environmental pollution. C*larias gariepinus* (African catfish) is a widely cultured species in Africa due to its resilience and economic value. However, under stressful farming conditions, fish are prone to disease outbreaks and metabolic disorders, which are often reflected in their haematological status (Tombari *et al.*, 2020). Monitoring blood parameters provides crucial insight into the internal physiological state of fish, including their immune competence and response to treatments (Gabriel *et al.*, 2019).

Several medicinal plants have been studied for their beneficial effects in aquaculture. For example, extracts from neem, garlic, moringa, ginger, and bitter leaf have shown positive influences on fish haematology, growth, and disease resistance (Ekanem *et al.*, 2017; Tombari *et al.*, 2020). These botanicals often contain bioactive constituents that stimulate immune responses or act as antioxidants, thereby improving fish vitality and survival rates. However, very few studies have investigated the effects of *E. sonchifolia* on fish physiology. This study explores the impact of aqueous *E. sonchifolia* flower extract on the haematological profile of C. *gariepinus* fingerlings, with the aim of evaluating its efficacy and safety as

a natural additive in aquaculture systems.

## MATERIALS AND METHODS

This study was carried out in the wet laboratory of the Department of Fisheries and Aquaculture, Faculty of Agriculture and Forestry, University of Cross River State, Obubra Campus, Cross River State, Nigeria. *Clarias gariepinus* fingerlings of mean weight 22.5±0.3 g and length 9.25±0.4 cm was obtained from Raphael's Fish Enterprise, Ikom LGA of Cross River State. The fish were sorted into ten specimens per tank filled with 20 liters of stream water in 30 liters plastic aquaria. Fresh flowers of *E. sonchifolia* were collected, thoroughly washed, and air-dried in shade for one week. The dried plant material was milled into powder, and stored at 4°C until use. The powder was measured in different concentrations, and poured directly into each experimental group. The experiment was carried out for 96 hours.

### Water Quality Parameters

The water temperature was checked at intervals, during the experiments, using mercury in glass thermometer. The temperature meter EZ-9910 was inserted inside of the aquarium for about three minutes and removed thereafter to read and record the values indicated on the mercury.

A dissolved oxygen meter, model DO-9100, was used to measure this electronically and to the nearest 0.1 mg/L. After being turned on, calibrated, and having the probe submerged in the water for one minute, the dissolved oxygen meter's stable readings were taken and recorded.
The pH was also measured using the electronic method, model CRP-100. This is carried out by simply turning on the meter, and the probe is inserted into the water after calibration to the nearest 0.0 mg/L and the vales are read off and recorded accordingly.

One hundred and eighty C*larias gariepinus* fingerlings were distributed into six groups with three replicates each to complete the range finding test, which provided the guide for the concentration to be used in definitive test. The definitive test was given concentrations of T1 (1000 mg/L), T2 (1250 mg/L), T3 (1500 mg/L), T4 (1750 mg/L), and T5 (2000 mg/L).

### Blood Sampling and Haematological Evaluation

At the end of the 96 hours exposure, three fish were randomly selected from each replicate. 2 ml of blood was collected by caudal puncture into EDTA-coated tubes and taken to the laboratory for analysis. The automated haematology analyzer was used for the analysis. The haematological parameters analyzed include: PCV, Hb WBC, RBC, MCV, MCH, and MCHC using standard methods.

### Data Analysis

Data were subjected to one-way ANOVA using SPSS version 25. Differences between means were compared using Duncan's Multiple Range Test at a 5% level of significance ($p < 0.05$).

## RESULTS

The result on water quality parameters on table 1 shows a decrease in dissolved oxygen and pH, and a corresponding increase in the temperature with increase in time and quantity of *Emilia sonchifolia* powder, across the experimental groups.

**Table 1:** Summary of water quality parameters of *Emilia sonchifolia* leaves powder on C. *gariepinus* fingerlings

| | Parameters | 0mg/L | 1,000mg/L | 1,250mg/L | 1,500mg/L | 1,750mg/L | 2,000mg/L |
|---|---|---|---|---|---|---|---|
| **Before** | Temp. (°C) | 25.53±0.3$^{a}$ | 25.52±0.3$^{a}$ | 25.40±0.3$^{a}$ | 25.44±0.3$^{a}$ | 25.53±0.3$^{a}$ | 25.55±0.3$^{a}$ |
| | $DO_{2(mg/L)}$ | 6.24±0.1$^{a}$ | 6.27±0.1$^{a}$ | 6.28±0.1$^{a}$ | 6.27±0.1$^{a}$ | 6.30±0.1$^{a}$ | 6.28±0.1$^{a}$ |
| | pH | 6.29±0.1$^{a}$ | 6.42±0.1$^{a}$ | 6.39±0.1$^{a}$ | 6.37±0.1$^{a}$ | 6.32±0.1$^{a}$ | 6.34±0.1$^{a}$ |
| **24 Hrs** | Temp. (°C) | 26.36±0.2$^{a}$ | 26.47±0.2$^{a}$ | 27.52±0.2$^{b}$ | 27.72±0.2$^{b}$ | 28.51±0.2$^{c}$ | 28.73±0.2 |
| | $DO_{2(mg/L)}$ | 6.68±0.1$^{b}$ | 4.83±0.1$^{a}$ | 4.77±0.1$^{a}$ | 4.76±0.1$^{a}$ | 4.63±0.1$^{a}$ | 4.60±0.1$^{a}$ |
| | pH | 6.76±0.1$^{b}$ | 6.74±0.1$^{b}$ | 6.75±0.1$^{b}$ | 6.74±0.1$^{b}$ | 6.63±0.1$^{b}$ | 6.42±0.1$^{a}$ |
| **48 Hrs** | Temp. (°C) | 27.31±0.2$^{a}$ | 27.34±0.2$^{a}$ | 27.36±0.2$^{a}$ | 28.23±0.2$^{b}$ | 28.86±0.2$^{b}$ | 28.87±0.2$^{b}$ |
| | $DO_{2(mg/L)}$ | 6.43±0.2$^{c}$ | 4.76±0.2$^{b}$ | 4.43±0.2$^{a}$ | 4.42±0.2$^{a}$ | 4.32±0.2$^{a}$ | 4.21±0.2$^{a}$ |
| | pH | 6.73±0.1$^{b}$ | 6.68±0.1$^{b}$ | 6.62±0.1$^{b}$ | 6.61±0.1$^{b}$ | 6.47±0.1$^{a}$ | 6.43±0.1$^{a}$ |
| **72 Hrs** | Temp. (°C) | 27.59±0.3$^{a}$ | 27.94±0.3$^{a}$ | 28.26±0.3$^{b}$ | 28.73±0.3$^{b}$ | 28.94±0.3$^{b}$ | 29.04±0.3$^{c}$ |
| | $DO_{2(mg/L)}$ | 5.88±0.2$^{c}$ | 4.09±0.2$^{b}$ | 4.01±0.2$^{b}$ | 3.97±0.2$^{a}$ | 3.96±0.2$^{a}$ | 3.96±0.2$^{a}$ |
| | pH | 6.73±0.1$^{b}$ | 6.63±0.1$^{b}$ | 6.32±0.1$^{a}$ | 6.21±0.1$^{a}$ | 6.02±0.1$^{a}$ | 6.02±0.1$^{a}$ |
| **96 Hrs** | Temp. (°C) | 27.84±0.2$^{a}$ | 28.30±0.2$^{b}$ | 28.32±0.2$^{b}$ | 29.22±0.2$^{c}$ | 29.76±0.2$^{c}$ | 30.03±0.2$^{d}$ |
| **After** | $DO_{2(mg/L)}$ | 5.62±0.1$^{c}$ | 4.02±0.1$^{b}$ | 4.00±0.1$^{b}$ | 3.52±0.1$^{a}$ | 3.42±0.1$^{a}$ | 3.32±0.1$^{a}$ |
| | pH | 6.76±0.1$^{c}$ | 6.53±0.1$^{c}$ | 6.52±0.1$^{c}$ | 6.22±0.1$^{b}$ | 6.01±0.1$^{b}$ | 5.99±0.1$^{a}$ |

Results for haematological alterations is shown on table 2. There was significant decrease in PCV, and RBC, but with significant increase in Hb, WBC. The MCV, MCH and MCHC however, were stable across the groups, after 96 hours exposure of C. *gariepinus* to the plant powder.

**Table 2:** Summary of the effect of *E. sonchifolia* leaves powder on haematological parameters of C. *gariepinus* fingerlings

| Conc/Parameters | PCV (%) | Hb (g/dl) | WBC (x10 $^{-9}$L) | RBC(x10 $^{-12}$L) | MCV (Fl) | MCH (Pg) | MCHC (%) |
|---|---|---|---|---|---|---|---|
| $T_0$ (0mg/l) | 34.33±0.3 $^{a}$ | 11.53±0.1 $^{a}$ | 4.60±0.1 $^{a}$ | 5.30±0.2 $^{a}$ | 74.33±0.3 $^{a}$ | 25.67±0.1 $^{a}$ | 34.33±0.2 $^{a}$ |
| $T_1$ (1,000mg/l ) | 36.00±0.1 $^{b}$ | 12.20±0.1 $^{b}$ | 4.63±0.1 $^{a}$ | 5.40±0.1 $^{a}$ | 74.67±0.3 $^{a}$ | 25.00±0.1 $^{a}$ | 33.07±0.2 $^{a}$ |
| $T_2$ (1,250mg/l) | 37.33±0.1 $^{b}$ | 12.37±0.1 $^{b}$ | 4.72±0.2 $^{a}$ | 5.53±0.1 $^{a}$ | 74.57±0.3 $^{a}$ | 26.00±0.1 $^{a}$ | 35.13±0.3 $^{b}$ |
| $T_3$ (1,500mg/l) | 38.67±0.2 $^{b}$ | 12.73±0.1 $^{b}$ | 4.73±0.2 $^{a}$ | 5.00±0.1 $^{a}$ | 74.00±0.3 $^{a}$ | 26.00±0.1 $^{a}$ | 35.03±0. 3$^{b}$ |
| $T_4$ (1,750mg/l) | 33.33±0.1 $^{a}$ | 11.67±0.1 $^{a}$ | 5.33±0.1 $^{b}$ | 4.73±0.1 $^{b}$ | 74.33±0.1 $^{a}$ | 26.33±0.1 $^{a}$ | 34.00±0.3 $^{a}$ |
| $T_5$ (2,000mg/l) | 33.67±0.1 $^{a}$ | 11.82±0.1 $^{a}$ | 5.83±0.1 $^{b}$ | 4.13±0.2 $^{b}$ | 74.67±0.1 $^{a}$ | 26.00±0.1 $^{a}$ | 33.67±0.3 $^{a}$ |

## DISCUSSION

The administration of *E. sonchifolia* extract produced differential effects on the haematological indices of C. *gariepinus*. Although not significant, the WBC counts were elevated in T1 - T3 compared to the control, indicating an activated immune system. These increases may be attributed to bioactive compounds such as flavonoids and tannins that stimulate leukocyte production (Kumar *et al.*, 2021). The decline in dissolved oxygen with increasing concentration observed in the present study can be attributed to microbial decomposition of organic constituents in the extract, which might have elevated biochemical oxygen demand and affected gill respiration (Okomoda *et al.*, 2019).

Haemoglobin and PCV values showed significant improvement in the mid-dose groups (T1 - T3), suggesting enhanced erythropoiesis and better oxygen transport capacity. This could be linked to the iron-rich phytoconstituents in the extract which support haem synthesis (Rahman *et al.*, 2018). RBC counts mirrored these trends, peaking at T2 and T3 before declining at T4 and T5.

At higher concentrations (1750–2000 mg/L), PCV, Hb, and RBC began to decline slightly, though not below physiological limits. This suggests that excessive concentrations might induce cellular stress or toxicity, which can impair haematopoiesis or result in hemolysis. Similar observations were reported by (Ekanem *et al.*, 2017), who noted that high doses of herbal extracts could overwhelm the physiological capacity of fish, leading to reduced blood quality.

The calculated indices (MCV, MCH, and MCHC) remained within normal ranges across treatments, although slight variations occurred. MCHC values increased in T2 and T3, indicating efficient haemoglobin synthesis, while MCV remained stable, implying no significant change in erythrocyte size. Overall, these results confirm the hypothesis that *E. sonchifolia* has immunostimulatory and haematopoietic potential when used at appropriate concentrations.

## CONCLUSION

This study demonstrated that aqueous extract of *Emilia sonchifolia* plant exerts beneficial effects on the haematological parameters of C*larias gariepinus* fingerlings at moderate concentrations. Enhanced WBC and Hb levels in the 1000–1500 mg/L groups signify improved immune and oxygen-carrying capacity, while higher doses may pose mild haematotoxic risks. These findings highlight the potential of *E. sonchifolia* as a natural immunostimulant in aquaculture practices. Further studies should be carried on the chronic effects of *Emilia sonchifolia* on fish histology, metabolism, and reproductive health

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# THE EFFECTS OF ANIONIC SURFACTANT-CONTAINING DETERGENT (VIVA PLUS) ON *Clarias gariepinus* (BURCHELL, 1822) FINGERLINGS

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**ABSTRACT**
*The experiment was conducted in the Department of Fisheries and Aquaculture, Adamawa State University (ADSU), Mubi. The study aimed to assess the acute toxicity of a detergent (Viva Plus) on Clarias gariepinus fingerlings exposed to various concentrations (4 mg/L, 8 mg/L, and 12 mg/L) of the detergent. The experiment consists of three treatments & control, with three replicates. Eighty (80) C. gariepinus fingerlings of 1.7g mean weight were purchased the departmental farm, twenty of them were used for range test to determine the lethal concentration $Lc_{50}$. Sixty (60) fingerlings were assigned to 4 treatments ($T_0$. $T_1$. $T_2$, and $T_3$), the experiment lasted for 96 hours. The results obtained were analyzed by the use of Prism GraphPad, and one-way ANOVA at 5% significant level for water quality parameters. Behavioral changes, mortality rates, and physicochemical parameters of the cultured water were observed. The highest mortality of 9 fingerlings was recorded in 12mg/L of the detergent, while the least mortality of 5 was observed in the 4mg/L treatment. Dissolved oxygen ranged from 3.79-5.89mg/L; hydrogen ion concentration (pH) ranged from 6.0-9.06; temperature ranged from 24.6-28.9°C; electrical conductivity ranged from 85-110µS/cm. The study showed that Viva Plus detergent is toxic to fingerlings of C. gariepinus, therefore, its usage should be discouraged as a cleaning substance in all production facilities. It also called for further research on the effects on eggs and embryos, on adults, and on other fish species.*

**Keywords**: Detergent, Fingerlings, Concentration, Treatment, Mortality

## INTRODUCTION

Water pollution is one of the most pressing environmental issues facing the world in the twenty-first century, resulting from the discharge of numerous contaminants into water systems through domestic and other anthropogenic activities that alter water's natural characteristics (Enemuadia, 2017, and Mustafa *et al.*, 2017). Detergents are common household products used for cleaning domestic materials. The "after wash" of these detergents is usually discharged into the aquatic environment, such as reservoirs, lakes, rivers, streams, etc, or finds its way into the water through natural seepage and gradually leads to pollution. Toxicity is a function of concentration and the duration of exposure of an organism to a toxicant. The validity of a detergent as a toxicant depends on the response of the affected organism to its mode of action on chemical and physical structures (Moss *et. al*, 2020). Fish is one of the most sensitive aquatic organisms affected by detergent pollution. Abel (1974) documented that synthetic detergents are acutely toxic to fish with concentrations between 0.4 and 40mg/L. Okwuosa and Osuala, (2020) reported that considerable amounts of detergents have been found to exist in Nigerian freshwater systems, where they generally affect several aquatic organisms, in many communities. Depending on the amount, nature, and type of the toxin, toxicity can be acute or chronic (Ayofe *et al.*, 2020).

It is acute when the consequences of exposure to a relatively significant quantity of toxin provided in a single dosage appear quickly (Essien-Ibok *et al.*, 2019). Chronic toxicity occurs when an organism is exposed to low amounts of toxin on a regular or irregular basis over a long period, for years. It is characterized by long-term consequences that can be lethargic or non-lethal (Essien-Ibok *et al.*, 2019). The contamination of the aquatic environment with detergents due to bioaccumulation has become a matter of concern, not only because of the threats that such pollutants pose to aquatic organisms but also because of the public health implications. In Nigeria, Viva detergent is one of the most extensively used synthetic surfactants in cleaning goods (Isyaku and Solomon, 2016). The contaminants kill fish or bioaccumulate in them in several natural ways to cause pathological changes and physiological dysfunctions (Enemuadia, 2017). Exposure to lower concentrations may not be lethal to the affected species, but still, they may affect internal functions and structures, which could affect the effectiveness of vital functions and processes. However, in recent years the use of Stimulus-responsive hydrogels could be a key potential to minimizing environmental pollution challenges particularly heavy metals contaminants (Negut and Visan, 2025).

## MATERIALS AND METHODS

The experiment was conducted in the Department of Fisheries and Aquaculture, Adamawa State University (ADSU), Mubi. It is located in the North-Eastern part of Adamawa State, Nigeria. It lies between latitude $10^0$32'N to $10^0$11'N and longitude $13^0$12'E to $13^0$35'E. The detergent Viva Plus used was purchased from the Mubi market. Eighty (80) Clarias gariepinus fingerlings of 1.7±0.2g mean weight were purchased from the Department of Fisheries and Aquaculture fish farm. A range test was carried out within 24 hours before the commencement of the experiment proper. Sixty (60) fingerlings of C. gariepinus were randomly assigned to four treatment groups: a control and three treatments labelled $T_0$, $T_1$, $T_2$, and $T_3$, replicated three times. Acute toxicity test of the detergent at 0mg/L, 4mg/L,8mg/L, and 12mg/L concentrations was applied to the experimental groups ($T_0$, $T_1$, $T_2$, and $T_3$), respectively. Each treatment consists of 15 fingerlings, giving a total of sixty fingerlings used. The experiment was conducted according to APHA (2003). Data collected was subjected to Prism Graph pad Version 5.0 Logarithm and Arithmetic graph method after the methods of Finney (1971) to determine the limit of the toxicant efficacy. One-way Analysis of Variance (ANOVA) at 5% probability level was used to test for significant differences between various water quality parameters.

## RESULTS

**Table. 1:** Mortality rates, percentage mortality, and probit kill values of C*larias gariepinus* Fingerlings exposed to acute concentrations of Viva plus detergent

| Conc (mg/L) | Log of conc | Total number of fish exposed | Mortality death | % Mortality | Probit kill value |
|---|---|---|---|---|---|
| 0 | 0 | 15 | 0 | 0.00 | 0.00 |
| 4 | 0.60 | 15 | 5 | 33.33 | 4.57 |
| 8 | 1.90 | 15 | 8 | 53.33 | 5.05 |
| 12 | 1.07 | 15 | 9 | 60.00 | 5.25 |

The results of the acute toxicity bioassay showing the mean mortality of C*larias gariepinus* are presented in the Table.2, above. It showed that mortality occurred in all the treatments except the control. The highest mortality of 9 was recorded in the highest concentration (12mg/L) of Viva Plus solution, while the least mortality of 5 was observed in the 4mg/L treatment.

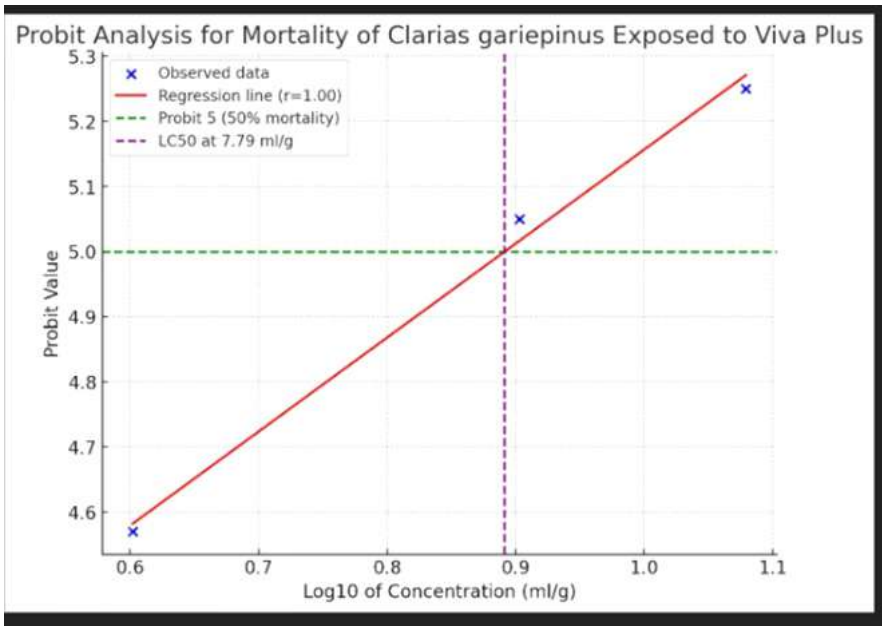



**Figure 1:** Probit Analysis Graph showing mortality of C*larias gariepinus* to Viva Plus

**Table 3:** Physico-chemical Parameters of Test Water

| Parameter | Range | Mean ± SE |
|---|---|---|
| Dissolved Oxygen (DO) (mg/L) | 3.79-5.89 | 1.27 ± 0.05 |
| Hydrogen Ion Concentration (pH) | 6.0-9.06 | 8.48 ± 0.02 |
| Temperature (°C) | 24.6-28.9 | 26.76 ± 0.08 |
| Electrical Conductivity ( µS/cm) | 85-110 | 91.36 ± 27.37 |

## DISCUSSION

The results of C*larias gariepinus* fingerlings exposed to detergent (Viva plus) showed that C. *gariepinus* fingerlings of 10g mean weight and 12.20cm mean length were generally sensitive to the detergent aqueous solution. At a concentration of 12mg/L, there was 60% mortality, while mean mortalities of 33, 53, and 60% were recorded in the treatments containing 04, 08, and 12mg/L of the toxicant. No mortality was recorded in the control (0mg/L). Physical changes observed in C*larias gariepinus* fingerlings exposed to the acute toxicity of detergent include stress, restlessness, loss of balance, gasping for breath, erratic swimming before death; this is in line with the findings of Tawari-Fufeyin *et al*. (2008), who made similar observations when C. *gariepinus* fingerlings were exposed to different toxicants. It is evident from this experiment that synthetic detergents are toxic to C. *gariepinus fingerlings*, which is in line with the report by Abel (1974) that synthetic detergents are acutely toxic to fish at concentrations between 0.4 and 40mg/L. Detergents are common household products used for the cleaning of domestic materials; there's hardly a house that doesn't use them as a household cleaning substance. The "after wash" of these detergents is discharged into aquatic environments deliberately or by natural seepage, thereby affecting fish. This was earlier observed by Okwuosa and Osuala (2020), who reported that considerable amounts of detergents have been found in Nigerian freshwater systems, where they generally affect several aquatic organisms, in many communities. The use of detergents with Soapnuts and other plant based natural surfactants is suggested (Waren et al., 2025),

## CONCLUSION

The results of this work clearly indicate that most household detergents, particularly Viva Plus, have toxic effects on fish; therefore, their use can be minimized.

The use of detergents containing natural or plant-based surfactants should be encouraged for domestic or industrial uses.

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# NUTRIENT AND PHYSICOCHEMICAL ASSESSMENT OF FISH POND WASTEWATER FOR SUSTAINABLE AGRICULTURAL REUSE IN CALABAR SOUTH, CROSS RIVER STATE

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**ABSTRACT**
*The discharge of untreated fish pond wastewater poses ecological and public health risks due to its high nutrient content and organic load. This study aimed to assess the nutrient and physicochemical quality of fish pond wastewater from three selected farms in Calabar South Local Government Area, Cross River State, Nigeria, evaluating its potential for agricultural reuse. Composite wastewater samples were collected and analyzed for nitrogen species (ammonia: 0.45–0.52 mg/L; nitrite: 0.12–0.15 mg/L; nitrate: 1.20–1.35 mg/L) and orthophosphate (0.30–0.35 mg/L) using standard spectrophotometric methods. Physicochemical parameters including pH (7.25–7.30), dissolved oxygen (6.8–7.1 mg/L), temperature (28.5–28.8 °C), turbidity (12.5–14.0 NTU), and electrical conductivity (450–470 μS/cm) were also measured. Statistical analyses revealed significant differences in nitrite ($p = 0.034$) and orthophosphate ($p = 0.028$) concentrations among farms, with Aqua Vista Farm exhibiting the highest levels. No significant variation was found in physicochemical parameters across sites. Nutrient concentrations negatively correlated with dissolved oxygen, highlighting potential risks of oxygen depletion and eutrophication. Overall, the nutrient-rich wastewater presents an opportunity for sustainable agricultural reuse, contingent on proper management to mitigate environmental impacts.*

**Keywords:** Fishpond wastewater, nutrient analysis, physicochemical properties, agricultural reuse

## INTRODUCTION

A fish pond is a man-made water body specifically designed for the purpose of fish farming. In these controlled environments, fish are cultivated and raised to meet various needs such as personal consumption, commercial sales, and recreational activities. The design and management of fish ponds allow for regulation of critical factors including water quality, feeding, and breeding to ensure optimal fish growth and productivity. Fish farming serves as a reliable protein source and significantly contributes to food security and income generation. However, it also produces wastewater that can present considerable environmental and public health challenges if not properly managed (Campanati *et al.*, 2021; Arshad *et al.*, 2024). Fish pond wastewater, a by-product of aquaculture activities, often contains organic matter, uneaten feed, and fish excreta, which introduce various nutrients like nitrogen and phosphorus. While these nutrients are essential for nutrient cycling within the pond ecosystem, their uncontrolled release into the environment can lead to water pollution, eutrophication, and disruption of aquatic ecosystems. This pollution negatively impacts biodiversity and the health of neighbouring river bodies and communities (Okon *et al.*, 2025; Opeh *et al.*, 2025; Boyd *et al.*, 2025).

The composition of fish pond wastewater varies depending on pond activities and can include organic components, nutrients, chemical residues from medications, bacteria, viruses, and parasites (Inyang-Etoh *et al.*, 2024). Untreated, these contaminants degrade water quality, pose threats to aquatic life, contaminate drinking water, and impact human health. These risks underscore the importance of recycling and treating fish pond wastewater. Effective treatment and recycling help conserve water, a

critical resource in areas with limited clean water supply, and reduce aquaculture's environmental footprint. Recycling fish pond wastewater transforms waste into a resource, enabling its reuse in agriculture for irrigation and soil amendment, thereby reducing freshwater dependence and promoting sustainability. Various agricultural by-products such as sugarcane bagasse, orange peels, and onion peels have been investigated for their effectiveness in treating wastewater, providing cost-effective and eco-friendly pollutant removal options (Abaie *et al*., 2021). This study aims to assess the nutrient and physicochemical quality of fish pond wastewater from selected fish farms in Cross River State. Identifying wastewater composition and potential applications, the research seeks to support sustainable aquaculture practices, protect aquatic ecosystems, and promote public health. Ultimately, the study will contribute to developing effective wastewater management strategies aligned with environmental sustainability and resource efficiency objectives.

## MATERIALS AND METHODS

### Study area

The study was conducted in selected fish farms located within Calabar South Local Government Area (LGA) of Cross River State, Nigeria. This south-eastern Nigerian region has a tropical climate characterized by high humidity and rainfall, which favours aquaculture. The geographical coordinates of Calabar South LGA range approximately between 4°58′N to 5°10′N latitude and 8°17′E to 8°22′E longitude.

### Sample collection

The study focused on three active fish farms: the University of Calabar Fish Farm, Aqua Vista Farm and Resort at Anantigha, and Water Tight Fish Farm along Iman Street. These sites were selected for their engagement in aquaculture and differing environmental and management practices. Composite samples were obtained at each site by collecting wastewater from three ponds within each farm to capture spatial variability. One-litre sterilized containers were used to collect samples according to standard procedures outlined by the American Public Health Association (APHA, 2012). Samples were stored in coolers with ice packs and immediately transported to the laboratory for analysis to maintain sample integrity.

### Analysis of wastewater for nutrient and physicochemical parameters

The nutrient analysis focused on quantifying nitrogen species (ammonia, nitrite, and nitrate) and phosphorus in the form of orthophosphate using spectrophotometric methods. Key physicochemical parameters, including pH, dissolved oxygen (DO), temperature, turbidity, and electrical conductivity (EC), were also assessed. pH measurements were conducted with a calibrated pH meter, while DO levels were determined using the Winkler titration method. Temperature and electrical conductivity were recorded with a multiparameter water quality meter, and turbidity was measured employing a nephelometric turbidity unit (NTU) device. All analyses followed standard protocols to ensure accuracy and reproducibility as outlined by APHA (2012) and Boyd *et al*., 2025).

### Statistical analysis

Data analysis was carried out using One-way ANOVA and post-hoc Tukey's tests to identify significant differences among farms ($p < 0.05$). Correlation analysis was used to explore relationships between variables (Asuquo *et al*., 2025).

## RESULTS AND DISCUSSION

### Nutrient concentrations in fish pond wastewater

In this study, the mean ammonia concentrations ranged from 0.45 ± 0.08 mg/L at the University of Calabar Fish Farm to 0.52 ± 0.10 mg/L at Aqua Vista Farm. Nitrite levels were relatively low, between 0.12 ± 0.03 mg/L and 0.15 ± 0.04 mg/L across farms. Nitrate was the dominant nitrogen species, with

means ranging from 1.20 ± 0.25 mg/L to 1.35 ± 0.30 mg/L. Orthophosphate concentrations varied from 0.30 ± 0.07 mg/L to 0.35 ± 0.08 mg/L. Aqua Vista Farm consistently exhibited slightly higher mean concentrations for most nutrients compared to other farms (Figure 1).

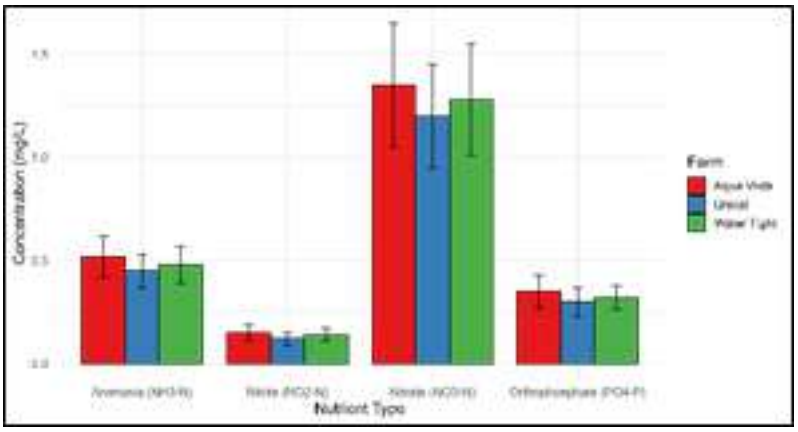



**Figure 1.** Mean concentrations of nutrients in wastewater samples from selected fish farms in Calabar South LGA

Statistical analysis showed significant differences among the farms for nitrite ($F = 3.89$, $p = 0.034$) and orthophosphate ($F = 4.12$, $p = 0.028$), with post-hoc Tukey's tests confirming that Aqua Vista Farm had significantly higher levels than the University of Calabar Fish Farm (mean difference for nitrite = 0.03 mg/L, $p = 0.031$; orthophosphate = 0.05 mg/L, $p = 0.025$) (Tables 1). The elevated nitrite and orthophosphate levels at Aqua Vista Farm might be attributed to intensive feeding practices, higher stocking density, or less efficient pond management, leading to nutrient accumulation from uneaten feed and fish excreta (Ogbin *et al.*, 2024; Boyd *et al.*, 2025). These findings align with previous studies highlighting feed input as a primary source of nutrients in aquaculture wastewater (Boyd *et al.*, 2025).

**Table 1.** Nutrient concentrations in fish pond wastewater from selected fish farms in Calabar South LGA

| Nutrient (mg/L) | University of Calabar Fish Farm | Aqua Vista Farm and Resort | Water Tight Fish Farm | F-value | p-value |
|---|---|---|---|---|---|
| Ammonia ($NH_3$-N) | 0.45 ± 0.08 | 0.52 ± 0.10 | 0.48 ± 0.09 | 2.35 | 0.112 |
| Nitrite ($NO_2$-N) | 0.12 ± 0.03 [a] | 0.15 ± 0.04 [b] | 0.14 ± 0.03 [ab] | 3.89 | 0.034 |
| Nitrate ($NO_3$-N) | 1.20 ± 0.25 | 1.35 ± 0.30 | 1.28 ± 0.27 | 1.45 | 0.256 |
| Orthophosphate ($PO_4$-P) | 0.30 ± 0.07 [a] | 0.35 ± 0.08 [b] | 0.32 ± 0.06 [ab] | 4.12 | 0.0 28 |

Note values are presented as mean ± SD; Superscripts indicate significant differences between means; different letters denote statistically significant differences based on Tukey's post-hoc test ($p < 0.05$)

**Physicochemical properties of wastewater**

The measured physicochemical parameters—pH, dissolved oxygen (DO), temperature, turbidity, and electrical conductivity (EC)—were consistent with typical tropical aquaculture pond conditions (Table 2). The pH values were slightly alkaline, ranging narrowly from 7.25 ± 0.15 to 7.30 ± 0.12 across farms. Dissolved oxygen concentrations ranged between 6.8 ± 0.9 mg/L and 7.1 ± 1.0 mg/L, indicating generally well-oxygenated waters conducive to fish health. Temperature was stable, approximately 28.5 ± 1.2 °C to 28.8 ± 1.1 °C, reflecting the tropical climate of the region. Turbidity values ranged from 12.5 ± 3.4 NTU to 14.0 ± 4.1 NTU, likely resulting from suspended solids such as feed particles and sediment disturbance. Electrical conductivity averaged between 450 ± 50 and 470 ± 55 $\mu$S/cm, suggesting similar ionic content across ponds.

**Table 2:** Physicochemical properties of fish pond wastewater across selected fish farms in Calabar South LGA

| Parameter | University of Calabar Fish Farm | Aqua Vista Farm and Resort | Water Tight Fish Farm | F-value | p-value |
|---|---|---|---|---|---|
| pH | 7.25 ± 0.15 | 7.30 ± 0.12 | 7.28 ± 0.14 | 0.78 | 0.467 |
| Dissolved Oxygen (mg/L) | 6.8 ± 0.9 | 7.1 ± 1.0 | 6.9 ± 0.8 | 1.02 | 0.382 |
| Temperature (°C) | 28.5 ± 1.2 | 28.8 ± 1.1 | 28.6 ± 1.3 | 0.56 | 0.576 |
| Turbidity (NTU) | 12.5 ± 3.4 | 14.0 ± 4.1 | 13.2 ± 3.7 | 2.98 | 0.067 |
| Electrical Conductivity ($\mu$S/cm) | 450 ± 50 | 470 ± 55 | 460 ± 52 | 1.34 | 0.279 |

Note values are presented as mean ± SD; No significant difference ($p > 0.05$)

No statistically significant differences were observed among the farms for any of these physicochemical parameters ($p > 0.05$) (Table 2), suggesting consistent environmental conditions and management practices. The stable pH range supports microbial processes involved in nutrient cycling (Boyd *et al.*, 2025), while adequate DO levels facilitate aerobic microbial degradation of organic matter and nitrification (Arshad *et al.*, 2024). Moderate turbidity and EC suggest minimal stress from suspended solids and salts, respectively.

**Relationships and ecological implications**

Noteworthy correlations were found between nutrient concentrations and physicochemical properties. Ammonia and nitrite were positively correlated with orthophosphate ($r = 0.55$ and 0.60 respectively; $p < 0.05$), indicating linked nutrient cycling processes in the ponds. Both ammonia and orthophosphate showed significant negative correlations with dissolved oxygen ($r = -0.48$ and -0.55, respectively; $p < 0.05$), suggesting that increased nutrient loads may contribute to oxygen depletion through enhanced microbial respiration and eutrophication (Boyd *et al.*, 2025). Oxygen depletion can lead to anaerobic conditions detrimental to fish and aquatic biodiversity, generating toxic metabolites and impairing nitrification, which exacerbates nitrogen toxicity risks (Arshad *et al.*, 2024). These dynamics underscore the importance of maintaining balanced nutrient and oxygen levels to preserve pond ecosystem stability and optimize conditions for agricultural reuse of wastewater.

**Agricultural reuse considerations**

The nutrient-rich nature of the fish pond wastewater, particularly nitrogen and phosphorus compounds, presents opportunities for agricultural reuse as fertilizers, improving soil fertility and crop yields while reducing reliance on synthetic fertilizers (Sanchez *et al.*, 2019; Abaie *et al.*, 2021). However, the presence of elevated nutrient concentrations combined with oxygen depletion highlights risks of eutrophication and potential adverse environmental impacts if wastewater is applied untreated (Arshad *et al.*, 2024). Appropriate treatment and management interventions, such as aeration, controlled feeding, and sedimentation, are essential to maximize benefits and minimize risk (Boyd *et al.*, 2025).

## CONCLUSION

The study revealed significant variations in nitrite and orthophosphate levels among farms, with Aqua Vista Farm exhibiting the highest values. Stable physicochemical conditions across farms support healthy aquaculture systems, yet negative correlations between nutrient concentrations and dissolved oxygen indicate environmental risks related to oxygen depletion and eutrophication. Effective monitoring and management practices are critical to mitigating these risks and ensuring wastewater safety for reuse.

Overall, the nutrient and physicochemical profiles support the integration of fish pond wastewater into sustainable agricultural practices, aligned with environmental conservation goals.

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# OXIDATIVE STRESS IN *Coptodon guineensis* EXPOSED TO BENZALKONIUM CHLORIDE IN THE LABORATORY

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**ABSTRACT**
*This study assessed changes in some antioxidants enzymes which include Catalase (CAT); Glutathione S-transferases (GST); Superoxide dismutase (SOD); Glutathione Peroxidase (GPx) and Malondialdehyde (MDA) in the plasma of Coptodon giuneensis exposed to benzalkonium chloride. A total of 180 C. guineensis comprised of 90 each of juvenile (mean length 7.88±0.89cm; mean weight 70.54±4.02g) and adult (mean length 13.66±0.54cm; mean weight 150.88±9.11g) were exposed to this chemical at concentrations of 0.00(control), 0.05, 0.10, 0.15, 0.20 and 0.25 mg/L, for a period of 15 days to evaluate the oxidative stress induced by this pesticide. Blood samples were collected from these fish and were analysed spectrophotometrically with Randox diagnostic test kits. Results from antioxidants analysis showed that the values of CAT, GST, SOD and MDA significantly ($p<0.05$) increased when compared to the control values. While the values of GPx reduced significantly ($p<0.05$) in all the concentrations of exposure. These variations were more pronounced in the fish exposed to 0.20 and 0.25 mg/l concentrations of the pesticide.*

**Keywords:** Antioxidants; Tilapia; Toxicity, Aquatic environment, Pollution

## INTRODUCTION

Alterations in the balance between prooxidants and antioxidants in the cell of an organism, which results in biochemical and physiological effects, are known as oxidative stress (Romeo *et al*., 2022). This is a harmful condition in which increase in free radical production and decrease in antioxidant levels can lead to potential damage (Ahmad *et al*., 2024). Indicators of oxidative stress include changes in antioxidant enzyme activity, damaged DNA bases, protein oxidation products, and lipid peroxidation products. Oxidative stress is known to play a large role in the pathology of several human diseases, including atherosclerosis, pulmonary fibrosis, neurodegenerative diseases and cancer, as well as aging pathology (Amado *et al.*, 2023). Aerobic organisms have developed a comprehensive antioxidant defense system in a living organism, comprising both molecular and enzymatic defenses, against the dangers of oxygen radicals, thereby preventing excess oxidation and damage (Li *et al.*, 2020). Oxidative stress can equally be described as veritable disparity between the production of reactive oxygen species (ROS) and the cells' ability to reduce ROS, detoxify reactive intermediates, and/or repair damage that may occur in cellular molecules. These differences may occur as a result of increased ROS production, a decrease in defense mechanisms, or both. ROS are endogenously produced from a wide number of sources within the cell. However, and very importantly, many environmental parameters are known to cause oxidative stress (Faheem *et al.*, 2022).

In fishes, the antioxidant defense mechanisms depend on the low molecular weight and enzyme system antioxidants. Exposure to chemical can cause the dose and time-dependent oxidative stresses in fish due to the high production of reactive oxygen species, high level of peroxidases and low level of glutathione (Sun *et al.*, 2023). The fishes have complex antioxidant mechanisms include superoxide dismutase (SOD), catalase (CAT), glutathione S-transferase (GST), and glutathione peroxidase (GPx) that controlled the reactive oxygen species (ROS) and oxidative damage (Dar *et al*., 2021). These defensive

mechanisms help to neutralize the impact of ROS resulting from the metabolism of various chemicals (Nishida, 2021). These antioxidant defense enzymes (SOD, CAT, and GPx) in fishes could be used as biomarkers of exposure to aquatic pollutants (Ansari *et al.*, 2022). Also, endogenous enzymatic and non-enzymatic antioxidants are essential for the conversion of ROS to harmless metabolites as well as to protect and restore cellular metabolism and functions (Batool *et al.*, 2022). Oxidative stress is a comparative measure of the relationship between the free-radical causing agents and their network of antioxidants (Dabas *et al.*, 2023). Benzalkonium Chloride (is a broad-spectrum antimicrobial agent and cationic surfactant used as a disinfectant and preservative in cleaning products, personal care items, and pharmaceuticals. As a quaternary ammonium compound, it disrupts microbial cell membranes, killing bacteria, fungi, and enveloped viruses. While effective at low concentrations, BKC can cause skin irritation and is linked to potential antibiotic resistance with overuse(Kumar *et al.*, 2023). This study therefore assessed oxidative stress in C*optodon guineensis* exposed to benzalkonium chloride in the laboratory.

## MATERIALS AND METHODS

### Experimental Location and Fish

The study was carried out in African Regional Aquaculture Center, an outstation of Nigerian Institute for Oceanography and Marine Research, Buguma, Rivers State, Nigeria. A total of 180 C.*guineensis* comprised of 90 each of juvenile (mean length 7.88±0.89cm; mean weight 70.54±4.02g) and adult (mean length 13.66±0.54cm; mean weight 150.88±9.11g) sizes were sourced from ponds during the low tide. The fishes were transported in six open 50l open plastic containers to the laboratory and acclimated for a period of seven days.

### Preparation of Test Solutions and Exposure of Fish

In the present study, commercial formulation of Benzalkonium Chloride (BKC) was used. The chemical was purchased from a commercial outlet in Port Harcourt, Nigeria. C.*guineensis* were exposed to the chemical at the concentrations of 0.00 control, 0.05, 0.10, 0.15, 0.20 and 0.25 mg/L in triplicates. Five fish were randomly distributed into each test tank. The experiment lasted for a period of 15 days. The water in the tanks was renewed daily with the stock solution. The fish were fed twice daily at 3% body weight with a commercial feed.

### Analytical procedure

At the end of each experimental period, 2ml of fresh blood sample was collected by making a caudal puncture with the help of fine needle and poured in heparinized sample bottles. Blood samples were centrifuged immediately for 15 minutes at 5000 rpm. Plasma specimens were separated, pipetted into eppendorf tubes and stored in a refrigerator at -20°C until assayed (Ellman, 2009). The results were read using a universal microplate reader on a Jenwayvisible spectrophotometer (Model 6405). The activity of antioxidants in centrifuged plasma was determined spectrophotometrically using the method of Beechey *et al*. (2001). Water quality parameters were also determined using the methods APHA (2001).

### Statistical Analysis

All the data were expressed as mean and standard deviation of mean. The statistical package, SPSS Version 22 was used for the data analysis. The means were separated using two ways ANOVA and the two means were considered significant at 5 %( $P<0.05$).

## RESULTS

The water quality parameters (Table 1) were within the same range except in DO, where a lesser values were obtained at higher concentration of the BKC. The effects of BKC on the antioxidants in the plasma of C.*guineensis* juveniles are presented in Table 2. It was observed that the values of CAT, GST, SOD, and

MDA SOD increased with increasing concentrations of the chemical. While GPX reduced significantly when compared to the control values. The same trend was observed in the antioxidants of adult fish exposed to the pesticide (Table 3), where the values of CAT, GST, SOD, and MDA SOD increased with increasing concentrations of the pesticide. While, GPX reduced significantly when compared to the control values

**Table1:** Physico-Chemical Parameters of Water in Experimental Tanks of C.*guineensis* Exposed To Bezalkonium Chloride

| Concentrations (mg/l) | DO (mg/l) | Temperature (°C) | pH | Salinity (ppt) | $NH_3$ (mg/l) |
|---|---|---|---|---|---|
| 0.00 | 6.05±0.33 | 29.77±276 | 6.67±1.66 | 15.32±2.02 | 0.02±0.01 |
| 0.05 | 5.75±0.44 | 29.89±3.12 | 6.64±1.02 | 15.29±1.44 | 0.02±0.01 |
| 0.10 | 5.50±0.70 | 29.55±1.02 | 6.66±1.69 | 15.32±1.66 | 0.02±0.01 |
| 0.15 | 5.20±0.82 | 29.96±3.11 | 6.64±0.61 | 15.42±1.88 | 0.03±0.01 |
| 0.20 | 4.81±0.55 | 29.80±5.66 | 6.66±0.33 | 15.33±2.01 | 0.03±0.01 |
| 0.25 | 4.10±0.92 | 29.55±4.67 | 6.63±0.77 | 15.43±1.77 | 0.03±0.01 |

Means within the same column with different super scripts are significantly different (P<0.05)

**Table 2:** Antioxidants Levels in C.*guineensis* Juveniles Exposed To Bezalkonium Chloride

| Concentration (mg/l) | CAT (U/g) | GST (U/g) | SOD (U/g) | GPx (U/g) | MDA (nmol/g) |
|---|---|---|---|---|---|
| 0.00 | 60.04±4.32 a | 2.08±1.09 a | 4.86±0.55 b | 28.42±0.86 b | 66.09±9.44 a |
| 0.05 | 64.90±9.33 a | 3.09±1.08 a | 6.33±0.08 a | 25. 98±0.90 b | 78.03±7.99 a |
| 0.10 | 72.07±7.55 b | 4.07±1.55 a | 7.02±0.32 a | 20.66±0.77 b | 81.77±3.03 b |
| 0.15 | 74.77±5.98 b | 8.11±1.09 b | 9.55±1.09 a | 18.09±0.55 a | 85.03±9.33 b |
| 0.20 | 81.03±4.55 c | 10.01±0.88 c | 14.32±0.55 b | 15.30±0.44 a | 108.89±12.33 c |
| 0.25 | 86.02±5.77 c | 11.0 1±0.43 c | 18.05±0.54 b | 14.02±0.65 a | 119.02±11.71 c |

**Means within the same column with different super scripts are significantly different (P<0.05)**
**Key: CAT- Catalase; GST-** Glutathione S-transferases; **SOD- Superoxide dismutase; GPX- Glutathione Peroxidase; MDA-** Malondialdehyde

**Table 3:** Antioxidants Levels in C.*guineensis* Adults Exposed To Bezalkonium Chloride

| Concentration (mg/l) | CAT (U/g) | GST (U/g) | SOD (U/g) | GPx (U/g) | MDA (nmol/g) |
|---|---|---|---|---|---|
| 0.00 | 82.77±4.90 a | 3.77±1.32 a | 6.11±0.90 b | 35.00±0.86 c | 79.01±9. 99a |
| 0.05 | 85.89±9.02 a | 4.82±1.12 a | 7.44±0.78 a | 30.04±0.92 c | 88.07±7.43 a |
| 0.10 | 92.88±7.65 b | 6.54±1.55 a | 15.87±0.66 b | 28.42±0.41 b | 92.03±9.00 b |
| 0.15 | 96.88±6.54 b | 10.04±1.23 b | 18.59±1.88 b | 23.89±0.72 b | 95.77±9.88 b |
| 0.20 | 110.04±6.11 c | 15.67±0.42 c | 20.88±0.41 c | 20.88±0.84 b | 110.54±12.87 c |
| 0.25 | 139.76±9.44 c | 19.43±0.77 c | 22.05±0.77 c | 18.88±0.42 a | 125.88±11.98 c |

**Means within the same column with different super scripts are significantly different (P<0.05)**
**Key: CAT- Catalase; GST-** Glutathione S-transferases; **SOD- Superoxide dismutase; GPX- Glutathione Peroxidase; MDA-** Malondialdehyde

## DISCUSSION

The antioxidant enzymes have been shown to work in a cooperative or synergistic manner to protect against oxidative stress and tissue-specific damage. These enzyme systems have been proposed as a biomarker of reactive oxygen species (ROS) mediating contaminant exposure and as a potential tool in environmental risk assessment (Liu, 2022). The ROS are detoxified by a set of antioxidant enzymes that

protect macromolecules such as proteins, lipids and nucleic acids against damage (Livingstone *et al.*, 2020). Several studies revealed that exposure to contaminants, including BKC, in aquatic ecosystems can enhance the intracellular formation of ROS which could cause oxidative damage to biological systems (Akinrotimi *et al.*, 2025). Earliest biological indicators of toxicant-induced oxidative stress are observed as shifts in enzymatic activity or changes in other biochemical systems. Antioxidant systems include superoxide dismutase (SOD), catalase (CAT), glutathione-s-transferase, glutathione peroxidase (GPx) and glutathione (GSH) are the protective agents identified as early indications of cellular susceptibility to oxidative injury caused by free radicals (Jordaan *et al.*, 2023).The antioxidant defense systems are divided into two categories: enzymatic (e.g., SOD, CAT, GPx and GST) and nonenzymatic (e.g., GSH). Catalase a primary antioxidant defense component protects fish from oxidative stress by converting the hydrogen peroxide to oxygen and water (Simonata *et al.*, 2023). In the present study CAT activity increased in BKC exposed fish at 15 days of exposure. Previously Akinrotimi *et al.* (2025) reported that CAT activity increased in the plasma of C.*gariepinus* due to an effective antioxidant defense system acting against oxidative stress caused by toxicants exposures and also compensating for the decrease in other antioxidant enzymes, such as GPX. The low levels of CAT could be attributed to high production of superoxide anion radical. In the present study, GST level in the plasma of C. *guineensis* increased under BKC exposures at 15 days of exposure period. A similar observation has been reported by Li et al. (2021) in rainbow trout exposed to verapamil chemical. They concluded that the induction of GST is probably due to the primary defence system involving GST in protecting the fish from oxidative stress and they suggested that the chemical induces increased synthesis GST.

SOD is a class of enzymes that catalyse the binding of ROS with water to generate $H_2O_2$ and it is the first enzymatic defence against the superoxide anion. While CAT is responsible for the breakdown of $H_2O_2$ to water and oxygen, protecting the cell from the damaging action of $H_2O_2$ and the hydroxyl radical. In the present study, SOD and CAT level increased significantly in the plasma of the exposed fish with increased concentration of BKC and exposure duration. Similar result was reported by Dabas *et al (*2023*)* in the tissue of freshwater fish C*hanna punctuates* exposed to cadmium. In the present study, different doses of BKC concentration decreased the GPx activity in the plasma of experimental fish when compared to control group. It may be due to reduced activity of GSH which is used as a substrate for GPx. Similar results were reported by Sunaina and Ansari, (2021) who reputed the same trend in Zebra fish (*Danio rerio*). Lipid peroxidation has been considered as the first step of cellular membrane damage by toxicants during exposure (Ghaffar *et al.*, 2022). In the present study, MDA level significantly increased in the plasma of BKC-exposed fish. This result is in agreement with the submission of Li. *et al.* (2020) in which they demonstrated that exposure to heavy metals increased MDA level in plasma of O. *niloticus*. They indicated that the increase in lipid peroxidation implied that excess ROS had been produced in the plasma upon exposure to heavy metals.

## CONCLUSION AND RECOMMENDATIONS

The current study findings showed that BKC generated oxidative stress, as seen by elevation in SOD, CAT, GST and MDA levels and reduction in GPX levels. When determining the risk of pollutants in aquatic ecosystems, the regulatory authorities may find it useful to incorporate the use of oxidative stress biomarkers with a fish model. More studies on the toxicokinetics and dynamics of BKC are needed to have a better understanding of the mechanisms of action that result in the development of oxidative stress.

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# PLASTICS POLLUTION ON AQUATIC ENVIRONMENT: A REVIEW

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**ABSTRACT**
*Plastic pollution is one of the most serious environmental issues that the world is currently facing. The continuous usage of plastic items combined with inadequate waste management and recycling procedures has created a global crisis that has an impact on human health, wildlife, and ecosystems. In African countries like Nigeria, is grappling with the detrimental effects of plastic waste on its ecosystems and communities. Land and marine-based plastic wastes have negative effects on human, aquatics systems and wildlife. Societal challenges contributing to plastic pollution in Nigeria include poor waste management practices, insufficient capacity and investment in waste collection infrastructure and prevalence of single use plastic bags. This study recommends improved waste management practices, regulatory measures, increased research efforts, public awareness and education as feasible strategies for mitigating plastic pollution in Nigeria.*

**Keywords:** Nigeria, plastic waste, waste management, pollution, aquatic systems

## INTRODUCTION

The quality of emerging environmental pollutants (EEPs) in the environment influences its ability to sustain life at all levels (Richardson and Kimura, 2017). One of such EEP is "plastic," a broad term that refers to polymeric materials that may include additional substances to enhance performance and/or lower expenses (Vert et al., 2012). These polymeric materials are combined with other substances (additives) to boost efficiency, cut costs, or create the intended color (Hahladakis, et. al, 2018). Plastic pollution presents a significant global environmental challenge, affecting aquatic life, biodiversity, and human health in all water bodies across the globe (Blettler and Wantzen, 2019). In the 1950s, the estimated annual production of plastics worldwide was around 1.5 million tons, while by 2007, it had surged to nearly 250 million tons (PlasticEurope, 2008). With the ongoing rise in annual plastic production, it was recorded to be about 322 million tons in 2016, and this figure continues to grow by 10% each year (PlasticEurope, 2016; Crew et al., 2020). In 2020, the global plastic production was estimated to reach approximately 367 million metric tons (Tiseo 2022). Each year, an estimated 5 to 13 million tons of plastic are believed to enter the oceans (World Economic Forum, 2016).

Plastic pollution remains in water bodies for many years as it doesn't fully biodegrade; instead, it breaks down into tiny particles known as microplastics (Richard, 2004). These particles can often be mistaken for small fish, krill, and plankton, while plastic bags can be confused with jellyfish, particularly by sea turtles. Since plastic cannot be digested and does not easily pass through the digestive system, its consumption leads to various problems for marine animals, such as starvation, malnutrition, intestinal blockages, and absorption of toxins, all of which can ultimately result in death (NRCD, 2020).

Despite the significant physiological and toxicological impacts of plastic pollution (Gkoutselis et al., 2021), there is limited data regarding the potential effects of plastic pollution across different environmental contexts in Nigeria. As the most populous country in Africa, Nigeria is a major consumer of plastic and a significant contributor to global plastic pollution (Dumbili et al., 2020), ranking second among the countries generating the most plastic waste in terms of projected waste production and plastic waste generated by 2024, with an estimated total of 3.5 million tons, which marks a considerable rise

compared to earlier studies (Figure 1) (Nature, 2024). Additionally, approximately 88% of plastic waste is not recycled (Babayemi et al., 2018).

In Nigeria, the recycling of plastic waste is inadequate, with most of it ending up in landfills and oceans where it can take hundreds of years to decompose. Plastic bags negatively impact the environment by infiltrating the soil and gradually releasing harmful chemicals; these toxic substances seep into freshwater systems and oceans. Eventually, plastics break down in the soil, leading to the unfortunate reality that aquatic creatures consume them, often resulting in choking and death (GIS, 2018). This paper investigates the consequences of plastic pollution on aquatic ecosystems, analyzing its sources, effects on marine and freshwater environments, and possible strategies for mitigation.

**Sources of Plastic Pollution in Aquatic Environments**

**Land-Based Sources**

The majority of plastic pollution comes from land-based sources, including urban runoff, industrial discharges, and poor waste management practices (Jambeck et al., 2015). Urban runoff carries plastic waste from roads, sidewalks, and stormwater systems into bodies of water. Industrial discharges can contain plastic pellets used in production processes, which may flow into rivers and oceans. Inadequate waste management practices, such as littering and limited recycling options, worsen the issue. In various developing nations, like Nigeria, waste management systems frequently fall short, resulting in large quantities of plastic waste being dumped into rivers that then carry the debris to the oceans (Lebreton et al., 2017).

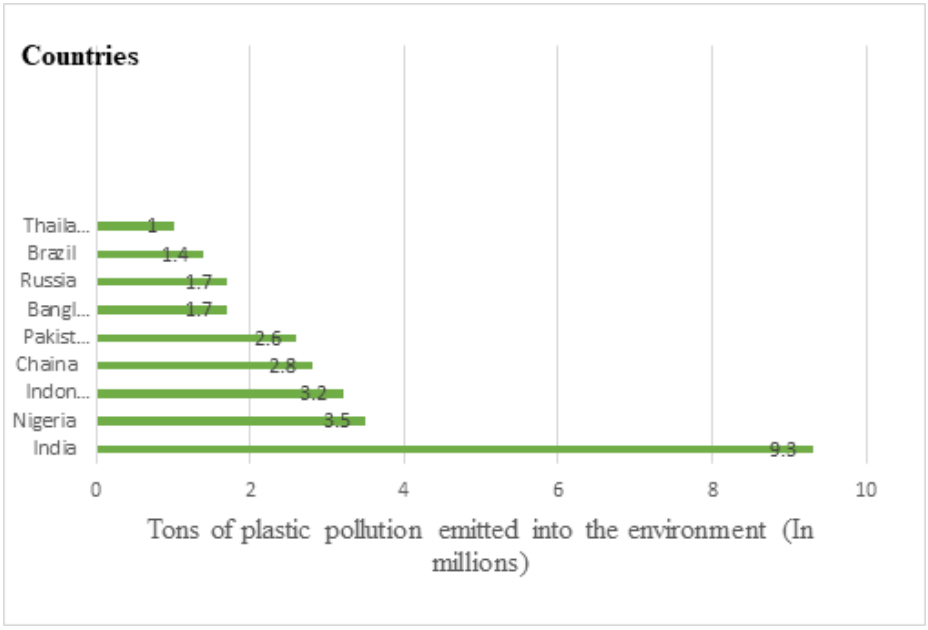



Figure 1: Top rank countries producing the largest amount of mismanaged plastic
source: *Nature - A Local-to-Global Emissions Inventory of Macroplastic Pollution, 2024*.

**Marine-Based Sources**

Marine sources of plastic pollution stem from fishing gear, maritime activities, and aquaculture practices (GESAMP, 2016). Equipment used in fishing, including nets, lines, and traps, may be abandoned or discarded in the ocean, leading to "ghost fishing," where lost gear continues to ensnare marine life (Macfadyen et al., 2009). Maritime operations contribute to plastic pollution through the illegal dumping of waste and the unintentional loss of cargo. Aquaculture practices, which focus on the breeding of marine species, can introduce plastic materials like feed bags and other equipment into the environment. For example, it is estimated that around 640,000 tonnes of fishing gear is either lost or thrown away in the

seas annually (Macfadyen et al., 2009).

**Atmospheric Deposition**

Recent research indicates that microplastics can be transported via the atmosphere and subsequently deposited into water bodies (Dris et al., 2016). Atmospheric microplastics stem from sources like synthetic fibers from textiles, particles from tire degradation, and dust generated in urban environments. These particles can be carried by wind across vast distances and ultimately deposit into oceans, lakes, and rivers through atmospheric deposition (Allen et al., 2019). This pathway is not well understood, yet it represents a considerable source of pollution, especially in remote locations where there is little direct human influence, yet microplastics are still detected.

**Types of Plastics in Aquatic Environments**

**Macroplastics**

Macroplastics refer to large plastic debris, typically greater than 5mm in size, including items like bottles, bags, and packaging materials (Barnes et al., 2009). These plastics are highly visible and can inflict physical harm on marine animals through ingestion or entanglement. For instance, marine mammals, birds, and turtles can get caught in plastic waste, resulting in injuries, drowning, or limited movement (Laist, 1997). Furthermore, animals may consume macroplastics, misidentifying them as food, which can lead to internal injuries, blockages, and death. Approximately 8 million metric tons of macroplastics are estimated to enter the oceans each year (Jambeck et al., 2015). Large organisms can also ingest macroplastics, causing gut blockages that can ultimately result in starvation. Notable cases include whales, dolphins, and porpoises found deceased on beaches with stomachs filled with plastics, likely having died from starvation (Jacobsen et al., 2010).

**Microplastics**

Microplastics are tiny plastic particles less than 5mm in size. They arise from the degradation of larger plastics or from microbeads found in personal care products (Cole et al., 2011). Microplastics are widespread and can be consumed by a variety of aquatic organisms, ranging from plankton to fish, leading to bioaccumulation and biomagnification. Research has detected microplastics in marine organisms across all trophic levels, highlighting their extensive distribution (Thompson et al., 2004). A study by Doherty et al., 2024, examined fish, sediments, and water from inland rivers throughout Nigeria's six geopolitical zones and found that River Benue had the highest concentration of microplastics in fish, while Rivers Ogun and Benue exhibited the highest concentrations in water samples. In sediments, Rivers Yauri and Benue showed the greatest amounts.

**Nanoplastics**

Nanoplastics are defined as particles smaller than 1,000 nanometers. They are less thoroughly researched but are believed to present considerable risks due to their diminutive size and capacity to penetrate biological tissues and cells (Gigault et al., 2018). Nanoplastics can form from the continued breakdown of microplastics and can exist in both marine and freshwater ecosystems. Because of their small dimensions, they can traverse cellular membranes, possibly causing toxic effects at the cellular and molecular levels (Koelmans et al., 2015).

**Effects of Plastic Pollution on Aquatic Ecosystems**

**Impact on Freshwater Ecosystems**

**Bioavailability of Microplastics**

Microplastics are easily found in freshwater systems and can be consumed by organisms across all levels of the food web (Wagner et al., 2014). Research has detected microplastics in various species, including fish,

amphibians, and even sources of drinking water (Kosuth et al., 2018). Freshwater species, such as zooplankton, insects, and fish, have been shown to consume microplastics, which can result in physical damage and possible chemical exposure. The occurrence of microplastics in freshwater habitats raises concerns regarding the transmission of plastics and their chemicals through the food web, which in turn could impact human health (Horton et al., 2017).

**Impact on Biodiversity**

The presence of plastics in freshwater habitats can lead to a decrease in biodiversity. Species unable to cope with plastic pollution may decrease in number, while those that can adapt might thrive, causing disruptions within the ecosystem (Eerkes-Medrano et al., 2015). Invasive species can use floating plastics as platforms to spread to new areas, further aggravating the disruption of local ecosystems. Furthermore, the physical presence of plastics can modify habitats and diminish the availability of resources for indigenous species. For instance, plastics can cover the surfaces of lakes and rivers, obstructing sunlight and hindering photosynthetic processes in aquatic vegetation (Windsor et al., 2019).

**Ecosystem Services**

Freshwater ecosystems offer crucial services like water purification, flood management, and habitats for diverse species. Plastic pollution can hinder these services, resulting in broader environmental and economic repercussions (Hoellein et al., 2014). Plastics can obstruct waterways, disrupting water flow and heightening the risk of flooding. Additionally, the presence of plastics can degrade water quality, making it less suitable for drinking and recreational activities. The financial burden associated with the cleanup of plastic pollution and addressing its effects on freshwater ecosystems can also be substantial (Boucher & Friot, 2017).

**Impact on Marine Ecosystems**

**Physical Harm to Marine Life**

Plastic debris poses risks of entanglement and ingestion, resulting in injury or mortality among marine creatures (Kühn et al., 2015). For instance, sea turtles often confuse plastic bags for jellyfish, while seabirds mistake plastic fragments for food (Wilcox et al., 2018). Entangled animals may experience wounds, infections, and reduced mobility, which can hinder their ability to feed, migrate, and reproduce. Consuming plastics can result in malnutrition, internal injuries, and ultimately death. More than 700 species of marine animals are estimated to have been affected by plastic debris (Gall & Thompson, 2015).

**Chemical Contamination**

Plastics have the capability to absorb and concentrate harmful chemicals from their surroundings, such as persistent organic pollutants (POPs) (Rochman et al., 2013). When marine organisms ingest these plastics, the chemicals can accumulate in the food web, creating health risks for both wildlife and humans (Teuten et al., 2009). Chemicals like polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) can be transferred from plastics to marine creatures, resulting in toxic impacts. This chemical contamination can interfere with the reproductive and immune systems of marine animals and might also present dangers to humans consuming contaminated seafood (Hermabessiere et al., 2017).

**Habitat Disruption**

Plastic pollution can modify habitats, such as coral reefs and mangroves, by physically covering and suffocating them. This disrupts the ecological equilibrium and influences the species reliant on these habitats for survival (Lamb et al., 2018). For instance, coral reefs can suffer damage from plastic debris that causes physical wear and blocks sunlight, essential for the photosynthesis of symbiotic algae. Mangroves, which function as vital nurseries for numerous marine species, can also be affected by plastic

waste that clogs their root systems, limiting oxygen exchange and nutrient accessibility (Ivar do Sul & Costa, 2007).

**Effects of Plastic Pollution on Human**
**Ingestion of Microplastics**
Humans come into contact with microplastics primarily through eating seafood and drinking water. The long-term health implications of consuming microplastics are currently under investigation, with concerns focusing on possible toxicity and endocrine disruption (Wright & Kelly, 2017). Microplastics have the ability to carry hazardous chemicals that may seep into the human system when ingested. Research has found microplastics in human stool samples, confirming that they are both consumed and eliminated, but the complete range of their health effects remains unclear (Schwabl et al., 2019).

**Chemical Exposure**
Plastics can release harmful substances such as bisphenol A (BPA) and phthalates, which are recognized for their detrimental effects on human health (Talsness et al., 2009). These substances can disrupt the endocrine system, resulting in reproductive and developmental complications. For instance, BPA has been associated with several health issues, including cancer, diabetes, and heart diseases (Vandenberg et al., 2012). Phthalates, which are often used as plasticizers, have been linked to reproductive toxicity and negative impacts on fetal development (Meeker et al., 2009).

**Strategies for Mitigating Plastic Pollution**
**Policy and Regulation**
The government can establish policies and regulations to minimize plastic production and usage. For instance, implementing charges and levies on disposable (single-use) plastic bags can promote the reuse of bags and raise awareness about land-based and marine plastic pollution issues among retailers, shop operators, supermarkets, and local market vendors (Dembili and Henderson, 2020). Concerning the use of plastic sachets and bags, enacting legislation to ban single-use plastic bags, as outlined in the Draft National Environmental Regulations (Plastic Waste Control) 2023, would significantly mitigate plastic waste (Nesrea, 2024).

**Technological Innovations and Research**
The government should support academic research and fund studies addressing plastic pollution in Nigeria to pinpoint specific challenges and effective solutions (Yalwaji et al., 2022). One notable instance of research advancement in this field is the creation of new recyclable (biodegradable) plastics. Enhancements in waste management infrastructure are also vital for lessening plastic pollution (Hopewell et al., 2009). Biodegradable plastics, derived from renewable resources such as corn starch and sugarcane, can shorten the lifespan of plastic waste in nature. Enhanced recycling technologies, like chemical recycling, can revert plastic waste to its original monomers, facilitating the production of new plastics from recycled materials (Ragaert et al., 2017).

**Public Awareness and Education**
Increasing public consciousness about the effects of plastic pollution and encouraging behavioral changes are critical to diminishing plastic waste. Educational initiatives and community engagement can lead to notable modifications in consumption behaviors and waste management practices (Hartley et al., 2018). Programs designed to inform the public about reducing, reusing, and recycling plastics can help cultivate a sustainability-oriented culture. Activities such as community clean-up events and initiatives aimed at plastic-free living can also involve citizens and foster collective efforts against plastic pollution (Xanthos & Walker, 2017).

**Clean-up Efforts**

Coordinated clean-up initiatives, including beach clean-ups and river cleaning efforts, can assist in eliminating plastic debris from the environment. Investigating technologies like ocean clean-up systems and microorganisms that consume plastic can also be valuable (Bergmann et al., 2015). The Ocean Clean-up project, for instance, seeks to extract plastic from the Great Pacific Garbage Patch using large-scale cleaning systems. Research into bacteria and fungi that degrade plastic presents possible natural solutions for breaking down plastic waste in the environment (Kanehiro et al., 2019).

## CONCLUSION

Plastics are inexpensive, lightweight, and versatile, leading to their widespread usage without adequate disposal methods. They contain various harmful substances, including bisphenol A, phthalates, alkylphenol additives, and flame retardants, which are detrimental to the environment, especially to aquatic life through direct ingestion or indirectly through exposure to water, air, sediments, and food. Nonetheless, if appropriate actions are not taken regarding plastic use and production in the coming years, aquatic ecosystems are likely to suffer significant harm, potentially leading to the extinction of numerous fish species and adverse effects on the entire ecosystem.

## RECOMMENDATION

Plastic pollution represents a grave threat to aquatic habitats, impacting both marine and freshwater ecosystems, biodiversity, and human health. Tackling this challenge requires a comprehensive strategy that includes policy changes, technological advancements, raising public awareness, and coordinated clean-up activities. By collaborating, we can reduce the effects of plastic pollution and safeguard our aquatic environments for generations to come.

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# WATER QUALITY PARAMETERS AND THEIR INFLUENCE ON *Clarias gariepinus* HEALTH AT THE UNIVERSITY OF CALABAR FISH FARM, NIGERIA

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**ABSTRACT**

*Aquaculture production in Nigeria faces recurring challenges from suboptimal water quality, which compromises fish health, growth and farm productivity. This study assessed the effects of pH, dissolved oxygen (DO), temperature, ammonia and conductivity on Clarias gariepinus fingerlings at the University of Calabar Fish Farm (UCFF). Ten treatments with initial pH ranging from 4.5 to 11.0 (10 tanks per treatment series; 10 fingerlings each) were monitored daily across two months. Key findings show optimal survival and growth in the pH range 6.5–9.0, while extremes (low <6.5 and high >9.0) produced markedly elevated mortality (50–100%). Ammonia concentrations (0.04–0.47 mg/L) frequently exceeded the conservative safety threshold (<0.02 mg/L) in extreme treatments; DO fluctuated (11.3–15.8 mg/L) in response to biomass collapse. Chi-square analysis confirmed significant differences in survival across pH groups ($\chi^2 = 58.96$, $df = 2$, $p < 0.001$). Findings indicate that pH acts as a major modulator of water chemistry, interacting with ammonia and DO to influence fish health. The study recommends routine parameter monitoring, pH stabilization (liming or buffering), aeration, and integrated biosecurity to reduce losses.*

**Keywords:** *Clarias gariepinus*, pH, dissolved oxygen, ammonia, aquaculture sustainability

## INTRODUCTION

Aquaculture is the fastest-growing food production sector and a key protein source in low- and middle-income countries (FAO 2024). In Nigeria, output has expanded but remains constrained by environmental and management challenges, with water quality being the most critical (Boyd 2020; Olaosebikan *et al.*, 2021). Water quality regulates essential physiological processes in fish respiration, osmoregulation, metabolism, and immunity, directly influencing growth, survival, and farm productivity (Svobodová *et al.*, 2023).

Important parameters in pond and tank culture include temperature, pH, dissolved oxygen (DO), ammonia, conductivity, and turbidity. These interact: temperature shapes metabolic rates and oxygen solubility; pH determines the ratio between ionized ammonium ($NH_4^+$) and toxic unionized ammonia ($NH_3$); DO supports aerobic metabolism; and conductivity reflects ionic balance relevant to osmoregulation (Boyd 2020; Svobodová *et al.*, 2023). In tropical aquaculture, small shifts in pH or temperature can yield major biological effects (Adeyemo and Kuye 2022). At high pH, the toxic $NH_3$ fraction increases, damaging gills and raising mortality risks (Boyd 2020). Low pH can cause acidosis, gill irritation, and impaired microbial activity, further aggravating ammonia toxicity (Svobodová *et al.*, 2023). DO values above 5 mg $L^{-1}$ are generally recommended for tropical freshwater species, as lower levels reduce feeding, growth, and survival (Boyd 2020). Yet DO may rise paradoxically after mass mortalities when oxygen demand collapses, complicating interpretation. Similarly, while 25–32°C supports efficient metabolism in *Clarias gariepinus*, higher temperatures both decrease oxygen solubility and increase oxygen demand, exacerbating hypoxia (Adeyemo and Kuye 2022).

Studies across Nigeria link poor water quality to disease and low productivity (Adebayo and Oluwafemi 2022; Eze and Ogbaran 2021; Ogunji *et al*., 2023). Interventions such as liming, aeration, and clay filtration improve outcomes but are inconsistently applied (Udo and Antai, 2022; Ogunji *et al*., 2023). The University of Calabar Fish Farm offers a controlled platform to assess pH gradients and their effects on *Clarias gariepinus*. This study aims to quantify parameter responses, evaluate growth and mortality, and analyse their interactions to guide aquaculture management in Nigeria.

## MATERIALS AND METHODS

The study was carried out at UCFF, Calabar, Nigeria, using *Clarias gariepinus* fingerlings. Experimental tanks were set up with 10 treatments representing different pH ranges (4.5–11.0), each stocked with 10 fingerlings. Parameters (pH, temperature, DO, ammonia, and conductivity) were monitored daily for two months using calibrated meters. Growth (length and weight) and mortality were recorded. Post-treatment adjustments included application of hydrochloric acid and calcium carbonate. Data were analyzed using descriptive statistics, Pearson correlation, chi-square, and SPSS v26.

## RESULTS AND DISCUSSION

### Water quality summary by treatment (averages)

Table 1 shows mean temperature, DO and ammonia by treatment (averages across available weeks). Temperature remained stable across treatments; DO and ammonia varied with pH extremes.

**Table 1:** Average water quality parameters by treatment (available weeks).

| Treatment | Initial pH | Avg Temp (°C) | Avg DO (mg L¹) | Avg Ammonia (mg L) |
|---|---|---|---|---|
| 1A | 4.5 | 25.00 | 12.93 | 0.13 |
| 1B | 5.4 | 25.02 | 13.40 | 0.50 |
| 2A | 5.5 | 25.35 | 15.75 | 0.04 |
| 2B | 6.4 | 25.35 | 13.55 | 0.08 |
| 3A | 6.5 | 25.05 | 12.02 | 0.16 |
| 3B | 9.0 | 25.02 | 12.33 | 0.16 |
| 4A | 9.1 | 25.50 | 12.50 | 0.47 |
| 4B | 10.0 | 25.50 | 12.40 | 0.47 |
| 5A | 10.1 | 25.40 | 11.60 | 0.12 |
| 5B | 11.0 | 25.40 | 11.30 | 0.18 |

*Notes:* Temperature across treatments: 25.00–25.50°C. DO ranged 11.3–15.8 mg $L^{-1}$; ammonia ranged 0.04–0.50 mg $L^{-1}$ (higher in some extreme treatments).

### Fish health outcomes (mortality and growth)

**Table 2:** Fish health outcomes by treatment (initial mean length/weight; final mortality; available post-treatment growth where survivors present).

| Treatment | Initial pH | Final Mortality (%) | Initial Length (cm) | Initial Weight (g) | Post -length (cm) [last available] | Post -weight (g) [last available] |
|---|---|---|---|---|---|---|
| 1A | 4.5 | 50 | 4.03 | 0.44 | 6.84 (2nd) | 2.36 (2nd) |
| 1B | 5.4 | 50 | 4.34 | 0.54 | 6.24 (2nd) | 1.91 (2nd) |
| 2A | 5.5 | 100 | 4.40 | 0.60 | N/A | N/A |
| 2B | 6.4 | 100 | 4.36 | 0.56 | N/A | N/A |
| 3A | 6.5 | 0 | 4.29 | 0.58 | 11.58 (3rd) | 14.38 (3rd) |
| 3B | 9.0 | 10 | 4.29 | 0.55 | 12.03 (3rd) | 15.12 (3rd) |
| 4A | 9.1 | 100 | 4.34 | 0.54 | N/A | N/A |
| 4B | 10.0 | 100 | 4.50 | 0.67 | N/A | N/A |
| 5A | 10.1 | 100 | 4.17 | 0.56 | N/A | N/A |
| 5B | 11.0 | 100 | 4.46 | 0.64 | N/A | N/A |

*Notes:* For treatments with 100% mortality, no post-treatment growth data exist. T3 (6.5–9.0) displayed best survivorship and growth.

To clarify overall effects, treatments were grouped as low pH (<6.5), optimal (6.5–9.0) and high pH (>9.0). Contingency counts and chi-square test:

**Table 3:** Contingency table: survival by pH category (n = 100 initial fingerlings).

| pH Category | n (fish) | Survived | Died |
|---|---|---|---|
| Low (<6.5 ) | 40 | 10 | 30 |
| Optimal (6.5 –9.0) | 20 | 19 | 1 |
| High (>9.0) | 40 | 0 | 40 |

Chi-square: $\chi^2 = 58.96$, df = 2, $p < 0.001$ (statistically significant difference in survival across pH categories).

Pearson correlations showed that pH deviation vs mortality: $r = 0.32$, $p = 0.38$ (weak, non-significant linear trend but U-shaped pattern). Ammonia vs mortality: $r = 0.45$, $p = 0.20$ (moderate trend). DO vs mortality: $r = -0.28$, $p = 0.44$ (negative but non-significant; DO often rose after mass mortality events). Temperature remained stable (~25°C) and thus was not the principal driver of mortality. The dominant pattern was a U-shaped relationship between pH and mortality: survival was highest in the intermediate pH window (6.5–9.0) and fell markedly at both low and high extremes. The chi-square test strongly supports that survival differs by pH category ($p < 0.001$). The Pearson correlations were weak or moderate and not significant for linear relationships because the pH mortality relationship is non-linear; extremes in both directions caused dramatic outcomes.

High-pH tanks (T4 and T5) showed elevated ammonia concentrations (e.g. 0.47 mg $L^{-1}$ in T4), which would increase the proportion of unionized $NH_3$ at higher pH and thereby exacerbate toxicity (Boyd 2020). Low-pH tanks experienced acid stress and possible gill damage; while some low-pH tanks had partial survival (T1), others collapsed faster. DO values were often within "acceptable" ranges (>5 mg $L^{-1}$) but DO alone could not offset toxic stress from high ammonia or severe pH deviations: notably, DO sometimes spiked after mass mortalities (biomass demand fell), giving a misleading impression of "safe" oxygen levels if not temporally contextualized. Surviving fingerlings in the optimal pH group (T3) showed robust growth lengths reaching ~11.6–12.0 cm and weights 14–15 g in later readings underscoring the importance of maintaining pH within the 6.5–9.0 window for production. High mortality in extreme treatments precluded productivity, and partial losses in some low-pH tanks produced suboptimal performance. These findings echo Nigerian studies reporting productivity losses due to water-quality deviations, including the influence of ammonia toxicity and DO instability (Adebayo and Oluwafemi 2022; Eze and Ogbaran 2021). The importance of pH buffering and routine monitoring is consistent with recommendations in the literature and FAO guidance (Boyd 2020; FAO 2024).

## CONCLUSION

This study demonstrates clearly that pH extremes are a dominant and non-linear driver of mortality and suppressed growth in C*larias gariepinus* at UCFF, acting through interactions with ammonia and DO. Maintaining pH in the 6.5–9.0 range supports survival and growth; both alkaline and acidic extremes rapidly increase mortality risk, often mediated or amplified by elevated non-ionized ammonia. Routine monitoring, timely corrective action (liming or acidification as appropriate), aeration, and biofiltration are essential management measures to reduce losses and improve farm productivity.

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# BIOACCUMULATION AND BIOMAGNIFICATION OF HEAVY METALS; A REVIEW ON ITS SOURCE AND EFFECT IN AQUATIC ECOSYSTEM

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**ABSTRACT**
*Heavy metals are among the strongest pollutants affecting the environment, are discharged into the aquatic ecosystems through the effluents of several industries, resulting in serious aquatic pollution. Fish primarily absorb heavy metals through their gills and digestive tract when consuming contaminated food. Absorption also occurs via the skin and they are transported via blood circulation, various organs and tissues, and tend to concentrate in well-perfused tissues, such as the liver, spleen, and kidneys, where they accumulate to different extents. The biomagnification describes the increasing concentration of toxins as they move up the food chain, with organisms at higher trophic levels accumulating greater amounts through predatory consumption. The review assess the extent of bioaccumulation of heavy metals such as Mercury (Hg), Cadmium (Cd), Lead (Pb), Arsenic (As), and Chromium (Cr) in different tissues of aquatic organisms and also to evaluate the potential of biomagnification of heavy metals along the aquatic food chain with organisms at higher trophic levels accumulating greater amounts through predatory consumption. Consuming contaminated fish is associated with serious health consequences such as diabetes, Alzheimer's disease, diarrhea, stomatitis, and different forms of cancer. Regulatory bodies such as NESREA, ME&EP and USEPA should be Proactive in implementing guidelines and monitoring of municipal waters and aquatic environment as it is integral in preventing and managing heavy metal pollution. Monitoring compliance with environmental regulations on the discharge of industrial effluents into water bodies is important to reduce the introduction of hazardous heavy metals.*

**Keywords**: Heavy metals, Bioaccumulation, Biomagnification, Aquatic Ecosystem

## INTRODCUTION

The accumulation of heavy metals in water bodies is one of the most critical issues regarding environmental and public health around the globe (Rajeshkumar and Li, 2018). The modern era of industrial development, urban growth, and agricultural expansion has acted like a catalyst in the introduction of heavy metals into water bodies (Singh *et al.*, 2022). Such metals consist of Mercury (Hg), Cadmium (Cd), Lead (Pb), Arsenic (As), Copper (Cu) and Chromium (Cr), which are known to be detrimental to both aquatic organisms and humans (Barile and Los, 2024). In contrast to organic pollutants, heavy metals are non-organic and non-biodegradable pollutants, meaning they are non-decomposable substances that persist to exist in the environment and get trapped in the tissues of living beings over time due to a process known as bioaccumulation (Gray, 2002).

This article comprehensively reviews the different aspects of heavy metals as hazardous materials with a special focus on their aquatic environmental persistence, toxicity for living organisms, bio-accumulative and biomagnification potential. The bioaccumulation and biomagnification of these elements and its implications for human health are discussed with a special coverage on fish

**Essential and Non-Essential Heavy metals**

Regarding their roles in biological systems, heavy metals are classified as essential and nonessential. Essential heavy metals are important for living organisms and may be required in the body in quite low concentrations. They are essential for growth and stress resistance as well as for biosynthesis and function of different biomolecules such as carbohydrates, chlorophyll, nucleic acids, growth chemicals, and secondary metabolites (Appenroth, 2010). Either deficiency or excess of an essential heavy metal leads to diseases or abnormal conditions. Nonessential heavy metals have no known biological role in living organisms. Examples of essential heavy metals are Manganese (Mn), Iron (Fe), Copper(Cu), and Zinc (Zn), while the heavy metals like Cadium (Cd), Lead (Pb), Mercury (Hg), and Arsenic (As) are toxic and are regarded as biologically nonessential (Jovic *et al.*, 2012).

**Sources of Heavy Metal Contamination in Aquatic Environment**

Heavy metals in surface water systems can come from natural or anthropogenic activities. The natural processes are formed by geographical process such as volcanic eruptions, weathering of rocks and leaching into rivers, lakes and oceans due to the action of water (Akthar *et al.*, 2021). The anthropogenic sources are formed through human activities such as agricultural effluents, industrialization activities and activities of domestic sewage into the water bodies.

**Volcanic eruptions**

Volcanic ash is the most widely-distributed product of explosive volcanic eruptions and areas hundreds of kilometers distant from an erupting volcano can receive ash falls. Even minor quantities of ash can disrupt the water system. Volcanic ash falls on the water system causing water contamination with turbidity, acidification, and low pH. Surface coatings on fresh volcanic ash are highly acidic due to the influence in the plume of aerosols composed of the strong mineral acids $H_2SO4$, HCl and HF. Therefore, when freshly-erupted ash comes into contact with water, it has the potential to lower the pH beyond acceptable limits for the protection of aquatic life (Steward *et al.*, 2006).

**Industrial effluents**

The major source of contamination of surface and groundwater water is the discharge of manufacturing effluents without treatment inside the water bodies. Wastewater, which comprises several microorganisms, heavy metals, nutrients, radionuclides, pharmaceutical, and personal care products, all find their way to surface water resources causing irreversible damage to the aquatic ecosystem and to humans as the aesthetic value of such water is compromised (Edokpayi *et al.*, 2017). Pollutants like acid, a toxic metal, dyes, and other untreated waste discharged from industries cause water pollution. Urban runoff in industrialized areas found that stormwater significantly contributes to transport of lead and copper, with levels peaking during heavy rainfall events (Smith and Doe, 2020)

**Agriculture activities**

Agricultural systems have expanded and intensified in response to the ever-increasing demand for food. The overuse and misuse of agrochemicals such as herbicides designed to increase productivity have resulted in higher pollution loads in the environment, including rivers, lakes, aquifers, and coastal waters (Anju *et al.*, 2018). Aquatic ecosystems are also affected by agricultural pollution; for example, eutrophication caused by the accumulation of nutrients in lakes and coastal waters has impacts on biodiversity and fisheries. Agricultural systems have expanded and intensified in response to the ever-increasing demand for food (Mateo-Sagasta *et al.*, 2017). Farms discharge large quantities of agrochemicals, organic matter, drug residues, sediments, and saline drainage into water bodies. The resultant water pollution poses demonstrated risks to aquatic ecosystems, human health, and productive activities (Verma *et al.*, 2020). Agricultural Waste released into aquatic habitats has led to several deleterious effects on aquatic organisms, including fish, concentrates pollutants right from polluted

water, and lengthily through the food chain.
Insecticides, herbicides, and fungicides are applied intensively in agriculture in many countries. When improperly selected and managed, they can pollute water resources with carcinogens and other toxic substances that can affect humans (Schreinemachers and Tipraqsa, 2012).

**Mining**
Environmental pollution by heavy metals is very prominent in areas of mining and old mine sites, and pollution reduces with increasing distance away from mining sites. Mining operation have been extensively studied and identified as a major contributor to environmental contamination with metals like lead, mercury and arsenic (Brown and Harris, 2019). Water pollution is a major concern for mining activity (Sumi and Thomsen, 2001). Large amounts of water produced from mine drainage, mine cooling, aqueous extraction, and other mining processes increases the potential for these chemicals to contaminate ground and surface water. Surface water is principally degraded by various factors like an accidental spill of toxic chemicals, erosion of waste material, or discharging of contaminant water from mines.

**Electroplating**
Electroplating industries effluent contaminates air, water, and soil. Electroplating is a major polluting industry because it discharges toxic materials and heavy metals through water, air emissions, and solid waste in an environment that various processing industries have reported containing high amounts of heavy metals such as nickel, iron, lead, zinc, chromium, cadmium and copper (Anju *et al*., 2018).

**Pathways of Heavy Metal Uptake**
Fish primarily absorb heavy metals through their gills (respiratory route) and digestive tract (dietary route) when consuming contaminated food. Less commonly, absorption occurs via the skin (waterborne route) (Rajkowska and Protasowicki –2013). They are transported via blood circulation, bind with blood proteins, are distributed to various organs and tissues, and tend to concentrate in well-perfused tissues, such as the liver, spleen, and kidneys, where they accumulate to different extents (Authman *et al.*, –2015). Balancing the uptake and elimination of heavy metals is crucial for maintaining the health of fish; therefore, upon higher heavy metal concentrations, fish will be vulnerable to stress, utilizing more energy to cope (Sfakianakis *et al.* –2015). However, they can exceed their capacity and overwhelm their bodies, causing detoxification to fail, resulting in toxicity. Furthermore, the affinity of certain metals for specific target organs plays a vital role in bioaccumulation (Authman *et al., –2015)*.

In C*larias anguillaris*, Cd, Pb, Co, and Cr are highly accumulated in most organs (Akan *et al.*, 2012). The Bio accumulation of Cd, Cr, Co, Ni, and Pb in the operculum, gills, heart, kidney, and muscle of *Hydrocynus forskahlii*, *Hyperopisus bebe* and C*larias gariepinus* collected from the Downstream Ogun Coastal Water, Nigeria(Murtala *et al.*, 2012), who reported that significant bioaccumulation was related to the species (*Hydrocynus forskahlii* , *Hyperopisus bebe* and C*larias gariepinus*), and the distribution pattern was dependent on the heavy metal concentrations in water as follows (Ni > Cr > Co > Cd > Pb) in all fish species. The concentrations of heavy metals in the tissues of fish species (*Solea solea* and *Solea aurata*) and shrimp (*Penaeus semisulcatus*) from the Yumurtalik zone of the Iskenderun Gulf, Turkey, were found to be in the order Fe > Zn > Pb > Cu > Cd, and their bioaccumulation patterns were significantly higher in the liver than in the muscle and gills in *Solea solea* and *Solea aurata*, while those in *Penaeus semisulcatus* were in the order Zn > Fe > Pb > Cu > Cd, and their bioaccumulation patterns were in the order of liver > gills > muscle, except for Pb and Fe, which were in the order of gills > liver > muscle (Aytekin *et al.*, 2019).

**Biomagnification**
It describes the increasing concentration of toxins as they move up the food chain, with organisms at higher trophic levels accumulating greater amounts through predatory consumption (Mehana *et al.*, 2020). Both pathways contribute to the bioaccumulation of metals within aquatic organisms, resulting in adverse effects even when environmental concentrations are relatively low.

**Heavy Metals Toxic Effect on Human Health**
Heavy metals are actively involved in the rise of numerous diseases, including diabetes, Alzheimer's disease, and different forms of cancer (Ara-Marini *et al.*, 2020). Besides unique metals show specific indications of their toxicity, the following have been described as general signs associated with copper, lead, zinc, mercury, cadmium, and arsenic, poisoning: gastrointestinal (GI) dysfunctions, diarrhea, stomatitis, shivering, hemoglobinuria inducing a rust-red depression, and pneumonia when volatile vapors and fumes are inhaled (Friend and John, 2018).

**National/International Guidelines and Regulatory Bodies**
Numerous national and international bodies have created policies aimed at controlling heavy metal pollution in Aquatic ecosystem.

**National Environmental Standard and Regulations Enforcement Agency (NESREA)**
The Nigeria Agency is responsible for the development and protection of the environment, biodiversity conservation and sustainable development of Nigeria natural resources in general and environmental technology including coordination and liaison with relevant stakeholders within and outside Nigeria on matters of enforcement of environmental standards, regulations, rules, laws, policies and guidelines.

**Metallurgical Inspectorate and Environmental Protection (MI&EP)**
The Metallurgical Inspectorate and Environmental Protection department is a specialized arm of the ministry of steel and development in Nigeria. The department is responsible for overseeing and regulating the steel and other metals sector in Nigeria. It also ensures that all metallurgical activities comply with national and international standards for quality, safety, and environmental sustainability.

**United State Environmental Protection Agency (USEPA)**
The agency plays a crucial role in establishing and regulating the permissible level of heavy metals in aquatic ecosystem to protect both aquatic life and human health

## CONCLUSION
The pollution of aquatic ecosystems through different sources of contamination results in the accumulation of heavy metals and poses a significant threat to the aquatic environment and human life. Heavy metals like Mercury (Hg), Cadmium (Cd), Lead (Pb), Arsenic (As), and Chromium (Cr) which, through bioaccumulation and biomagnification, contaminate aquatic life and subsequently, the human food chain. Consuming contaminated fish with accumulation of heavy metals is associated with serious health consequences such as diabetes, Alzheimer's disease, diarrhea, stomatitis, and different forms of cancer

## RECOMMENDATION
Regulatory bodies such as NESREA, ME&EP and USEPA should be Proactive in implementing guidelines and monitoring of municipal waters and aquatic environment as it is integral in preventing and managing heavy metal pollution.

Monitoring compliance with environmental regulations on the discharge of industrial effluents into water

bodies is important to reduce the introduction of hazardous heavy metals.
Community campaigns regarding safe consumption practices can greatly lessens health risks by raising awareness and promoting informed choices related to the intake of fish and water.

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# ADSORPTION OF TETRACYCLINE FROM POND WASTEWATER USING ZEOLITE PRODUCED FROM ORANGE ZEST

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**ABSTRACT**
*Fish farmers use antibiotics such as tetracycline to fight infections, preventive measures and to promote growth. After usage, the water is discharged into nearby drains, streams and rivers where the tetracycline gets to the ecosystem where they can have negative effect on the receiving water body. Thus, it is of essence that fish pond wastewater is treated using locally produced materials such as organic zeolites to remove antibiotics such as tetracycline in pond wastewater before being discharged into the environment. Zeolite was produced from orange zest using standard procedures and the wastewater obtained from tetracycline (adsorbate) treated fish ponds were passed through varying dosages of the orange zest (adsorbent) being 1 g, 2g, 4 g, and 5 g. Orange zest dosage of 5 g, 4 g, 2 g and 1 g had the percentage removal of 87.30±0.92, 61.77±4.37, 26.32±4.88 and 21.55±5.12 respectively. Zeolite produced from orange zest through alkali fusion when applied at 5 g can adsorb 111.10±8.36 (mg/g) of tetracycline from wastewater obtained from Clarias gariepinus pond which is equivalent to 87.30±0.92% removal.*

**Keywords:** *Orange zest, zeolite, wastewater, Clarias gariepinus*

## INTRODUCTION

Veterinary antibiotics (such as tylosine, tetracycline, sulfonamides and bacitracin) are used globally to treat disease, protect the health of animals and incorporated into animal feed to improve their growth rate (Sarmah *et al.*, 2006). However, the inappropriate use of antibiotics threatens ecological balance and poses a significant risk to human health (Dandhi *et al.*, 2025). Another challenge of antibiotic usage is the risk of resistant bacteria developing and spreading beyond fish farms especially during times of intensive drug application (Benbrook, 2002). To mitigate the effects of antibiotics in wastewater on the environment, a range of methods including oxidation, photolysis, UV-degradation, nanofiltration, reverse osmosis, and adsorption has been used for their remediation from aqueous systems (Patel *et al.*, 2019). Sustainability requires that materials and technologies for treating polluted water are affordable, operated without much difficulty and produced locally (Senanu *et al.*, 2023). Adsorption technologies are a lowcost alternative, easily used in developing countries where there is a dearth of advanced technologies, skilled personnel, and available capital, and adsorption appears to be the most broadly feasible pharmaceutical removal method (Patel *et al.*, 2019). Zeolites, known for their high porosity, are widely used in wastewater treatment but are typically produced from expensive materials but they can also be produced using agricultural wastes (Abdulrazak *et al.*, 2025). So, this study evaluated the efficiency of zeolite produced from orange zest to adsorb tetracycline from fish pond wastewater.

## MATERIALS AND METHODS

*Clarias gariepinus* (600 ± 50 g, n=25) were reared in 1000 L plastic tanks and the water volume was kept at 700 litres. After procurement, the fish were acclimatized for 14-days in plastic tanks and were fed with a commercial, non-medicated 4mm fish feed twice daily. The medicated feeding phase began after acclimatization by adapting a dosage of 75 to 80 mg/kg of tetracycline as reported by Choudhary *et al.*,

(2024). The fish were fed a diet with tetracycline at a dosage of 75 mg per kilogram of fish body weight. Thus, each pond containing 15 kg of fish was fed a total daily dose of 1,125 mg of tetracycline. This dose was achieved by thoroughly mixing approximately 4.5 capsules of commercial tetracycline tablets (each contains 250 mg) into the daily feed ration for each pond. Vegetable oil was added at 5% to ensure proper adhesion of tetracycline to the feed pellets. After mixing, the feed was dried for 30 minutes in the dark and stored at 4 °C for immediate use. The feeding frequency was reduced from twice daily to a single daily feeding during the medication feed period to ensure the complete medicated feed ration was consumed by the fish. The fish were fed this medicated diet for seven days before taking the first effluent samples to the lab. During these 7 days the pond water remained unchanged with no water replacement. This was followed by a 14-day withdrawal period to allow for fish metabolism and excretion before replicating. After replication the second effluent samples were collected from each pond properly labelled and subsequently used for the experimental procedure.

Orange zest (OZ) was sourced from local markets and fruit vendors in Zaria Kaduna State, Nigeria. It was utilized in the synthesis of zeolitic material using the alkali fusion method as described by Abdulrazak *et al*. (2025). All prepared tetracycline solutions were analysed using a UV-Vis spectrophotometer (UV–visible Cary300, Agilent Technologies, Santa Clara, CA, USA). The instrument was first calibrated and scanned across the 200–400 nm UV range to identify the wavelength of maximum absorption (λmax). Residual tetracycline concentrations were determined at λmax of 268 nm. Linearity was assessed using calibration standards ranging from 0.8 to 100 $\mu$g/mL, while the precision of the measurements was evaluated as relative standard deviation (RSD %) for each concentration. Additionally, the limit of detection (LOD) and limit of quantification (LOQ) were calculated.

The removal of tetracycline from aquaculture effluents was investigated through adsorption employing varying dosages (1 g, 2 g, 4 g, and 5 g) of MgFZOZ at optimized conditions and the experiment was performed in triplicates. Upon sample collection, the pond effluent samples were filtered using Whatman No. 1 filter paper to eliminate suspended particulate matter, thereby isolating dissolved compounds for subsequent analysis. Initial concentrations of tetracycline in each pond effluent were determined prior to treatment. Subsequently, precise amounts of MgFZOZ were introduced into 250 mL conical flasks, to which 25 mL of the aquaculture effluent was added. The flasks were then incubated under the established optimal parameters using an incubator shaker set to 150 rpm to ensure consistent agitation throughout the adsorption process. After completion, aliquots were withdrawn from each flask, filtered, and analysed spectrophotometrically with a UV–Vis spectrophotometer (Cary 300, Agilent Technologies, Santa Clara CA, USA) to quantify the remaining tetracycline concentration. The Qe: amount of adsorbate adsorbed per unit mass of adsorbent at equilibrium (mg/g) was assessed as well as the percentage oxytetracycline removal. Data obtained was managed using excel and analysed using SPSS. Mean values were separated using Tukey's HSD ($p < 0.05$).

**RESULTS**

The amount of adsorbate removed by the adsorbent as well as the percentage removal is indicated in Table 1.

**Table 1.** Adsorption of oxytetracycline (adsorbate) from fish pond wastewater by varying dosages of MgFZOZ (adsorbent)

| Parameter | 1g MgFZOZ | 2 g MgFZOZ | 4 g MgFZOZ | 5 g MgFZOZ |
|---|---|---|---|---|
| Qe: amount of adsorbate adsorbed per unit mass of adsorbent at equilibrium (mg/g) | 27.76±8.89$^{c}$ | 33.85±9.16$^{c}$ | 78.68±9.06$^{b}$ | 111.10±8.36$^{a}$ |
| Minimum (mg/g) | 21.16 | 27.32 | 69.42 | 105.72 |
| Maximum (mg/g) | 40.88 | 47.43 | 91.07 | 123.53 |
| % Oxytetracycline removal by orange zest | 21.55±5.12$^{c}$ | 26.32±4.88$^{c}$ | 61.77±4.37$^{b}$ | 87.30±0.92$^{a}$ |
| Minimum (%) | 16.87 | 22.50 | 55.35 | 86.35 |
| Maximum (%) | 28.86 | 33.48 | 64.77 | 88.57 |

Means ± SD followed by the same superscripts are not significantly different ($p < 0.05$) using Tukey's HSD

MgFZOZ at 5 g had the highest removal of tetracycline of 111.10±8.36 (mg/g) which were significantly higher than that of MgFZOZ at 4 g, 2 g and 1 g respectively. While the percentage removal was 87.30±0.92%.

## DISCUSSION

In general, adsorption of tetracycline is a relatively inexpensive and simple method and adsorption techniques are increasingly used to remove organic particles from contaminated streams (Amangelsin *et al*., 2023). The 87.30±0.92% of tetracycline removal by 5 g MgFZOZ in this study is comparable with Heidari *et al*. (2018) who used a composite photocatalytic material (Bi2Sn2O7-C3N4/Y) for the degradation of tetracycline and reported maximum rate of tetracycline degradation was 80.4%, and the concentration of $Bi_2Sn_2O_7$-$C_3N_4$/Y zeolite was 1 g/L. Zeolites are known as microporous aluminosilicates comprising of $SiO_4$ and $AlO_4$-type tetrahedrons (Khaleque *et al*., 2020; Mazzeo *et al*., 2023) and these may be responsible for the adsorptive abilities of the MgFZOZ to the oxytetracycline molecules.

## CONCLUSION

Zeolite produced from orange zest through alkali fusion when applied at 5 g can adsorb 111.10±8.36 (mg/g) of tetracycline from wastewater obtained from *Clarias gariepinus* pond which is equivalent to 87.30±0.92% removal.

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# OXIDATIVE STRESS RESPONSE OF *Heterobranchus bidorsalis* EXPOSED TO RICIN ACTIVE INGREDIENT IN *Ricinus communis* (CASTOR OIL SEED)

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**ABSTRACT**
*Medicinal plants have always played vital roles in human healthy living. Amongst them is the species Ricinus communis (castor oil) plant with high traditional and modern medicinal values., However, there is a dearth of information on the Piscicidal potentials of this active ingredient Ricin, therefore, this study examines 96h $LC_{50}$ toxicity, sub-lethal concentration and effect on some parameters on the exposed fish (Heterobranchus bidorsalis). Ricin (toxin) was extracted from the seed of Ricinus communis (castor oil plant) using cold water maceration and Heterobranchus bidorsalis juveniles were subjected to a range finding test before a 96-hours $LC_{50}$ acute toxicity test, four doses (100, 125, 160 and 200 mg/l) of ricin extract and the negative (0mg/l) control. Heterobranchus bidorsalis was afterwards exposed to sub-lethal concentrations corresponding to 10% (11.7mg/l), 20% (23.4mg/l), 30% (34.1mg/l) of the 96-h $LC_{50}$ (117 mg/l), 0mg/l negative control and 4mg/l of Cyclophosphamide positive control for 21 days to assess the cytogenotoxic effects using piscine micronucleus (MN) test. Changes were also observed in the oxidative stress parameters examined and there was apoptosis in the DNA structure monitored. The research therefore confirmed the effect of ricin active ingredient in Ricinus communis (Castor oil seed).*

**Keywords**: Ricin, acute toxicity, DNA fragmentation and sub-lethal

## INTRODUCTION

Several plant materials have shown to be toxic to aquatic organism, such phytospecies are *Ricinus communis*, *Thevetiamirifonia*, *Euphodiapaganorum*, *Balanitesaegyptiaca*, *Adeniumobesum* and *Azadirachtaindica* (Fafioye, 2005 and Akinwande*et al.*, 2007). Ricin is a highly potent protein toxin derived from the seeds of the castor oil plant, *Ricinus communis*. Its primary mode of action is to inhibit protein synthesis in eukaryotic cells. This process, known as depurination, makes ricin a potent cytotoxic agent. Adediwura and Ajibesin (2012), reported castor oil beans *Ricinus communis* as one of the toxic plants and plant parts in a south western state in Nigeria. Balet*et al.*, (2015) report lethal concentration of fresh and dried extracts of castor (*Ricinus communis)* beans for Molluscicidal and Piscicidal activities in an aquaculture system. Improper disposal of castor processing waste, accidental spillage, or natural leaching into the water body, Ricin is a potent toxin. While its effects on mammals are well-documented, its specific toxicity and sub-lethal effects on aquatic organisms, particularly fish, are less understood, Heritable mutations which can affect future generation, impacting population viability, abnormalities, birth defects and genetic diversity could occur. Fish are at various trophic levels. Understanding how ricin affects them can provide insights into potential bioaccumulation in the food web, and its resultant Effects on human, this work seeks to investigate the oxidative effects and genotoxic effects of ricin on juveniles of *Heterobranchus bidorsalis*,

## MATERIALS AND METHODS

### Experimental fish

Juveniles of *H. bidorsalis* (Geoffroy saint-Hilaire, 1809) was purchased from a reputable farm in Ibadan environs, they were weighed, with average weight of 21.12 ± 1.5g. They were left to acclimatize and fed with 2mm commercial feed under laboratory conditions in a static system for weeks before the

commencement of the experiment. Temperature was measured by mercury-in-glass thermometer, pH in situ by meters, dissolved oxygen, and Nitrite and ammonia were determined for water on each sampling day by standard methods (APHA, (2023).

**Experimental procedure**
A completely randomized design was used in triplicate to test the toxicity level of ricin on the species. The 96h-$LC_{50}$ value was determined for *H. bidorsalis*, toxicity data obtained from the study was estimated using probits

**Collection of Plant samples**
*R. communis* seed (Family Euphorbiaceae) was collected from Ibadan metropolis and was taken to the Department of Botany, faculty of science, University of Ibadan, for proper identification and taxonomy.

**Extraction procedures of pure Ricin (active ingredient) from castor beans**
The ricin was extracted from the seed of *R. communis* by the method of Sousa*et al*. (2019). Extraction of ricin was done, first harvesting the seed from the shrub and then air dried for those that are not totally dried. The seed was then separated from the shell and thoroughly washing and re-air dried.
In preparing the protein material, the castor beans were first grounded into small particle size and were later soaked in n-hexane to remove the oil. After the oil has been removed, the pressed cake or pomace
The extraction was carried out in the pharmacological chemistry organic lab, of the University of Ibadan.

**Test Procedure**
A range finding test with space factor of 0.5 was carried out in order to determine the range of concentrations for the definitive test

**Definitive Test (Acute toxicity test)**
Acute toxicity test was used to determine the short-term toxicity (4 days) of the active ingredient on the fish species, measuring lethality. It was conducted to determine the 24h-LC50 value of ricin with definitive test in a static system in a laboratory according to (standard methods of OECD guideline No 425 (OECD, 2024). Toxicity experiment was performed by the method of OECD guideline 423 (2021). A set of 10 sample each were randomly exposed to each of the four concentrations of the active ingredient (Ricin) 100, 125, 160 and 200mg/l respectively, obtained after the range finding test and 0mg/l as control of the bioassay.

**Determination of Sub-lethal Concentrations (In vivo Exposure Experiment)**
20 juvenile each were distributed randomly among exposure duration groups. Five 30 litres rectangle white plastic tanks were used for the exposure of various concentrations of the test Ricin; first plastic tank for negative control or control, second for solvent control (Cyclophosphamide 4mg/l), third, fourth and fifth Plastic tanks for 10%, 20% and 30% (11.7, 23.4, 35.1mg/l respectively) of Ricin extract, following the OECD guideline No 425(OECD 2024).

The exposure was continued up to 504hrs (21 days), The test fish were fed twice daily with 5% feed per body weight and the water for the treatment and control groups were replaced every 48 hrs to reduce volatilization of less stable substances in the ricin and maintain concentration of the ricin as well as reduce accumulation of metabolic wastes and remains of food particles. Blood sampling were done on the (21day) at the rate of five fishes (n=5) from each test concentrations. The specimens maintained in borehole water and those exposed to Cyclophosphamide 4mg/l were considered as the negative and solvent controls (positive), respectively. On each sampling day of (1, 7, 14 and 21 days) Blood sample collected was done by incising the lateral vein using 1ml heparinized syringe. (Tiano*et al*., 2000) and was

taken for oxidative and DNA fragmentation analysis.

**Fish DNA Fragmentation process**
The isolated DNA is run on 0.8% agarose gel and the photograph is taken under UV light. As shown in Figure, chromosomal DNA is detected on the upper portion of the gel in control fish sample.

**Statistical analysis**
One- way analysis of variance (ANOVA) and afterwards subjected to Duncan multiple range test (DMRT), the significances in the treatments were also compared for the result of the oxidative stress test samples at $p < 0.05$ using IBM SPSS statistics 20.

**RESULTS**
**Table 1:** Mean physico-chemical parameters of water during the 96 hours exposure of *H. bidorsalis* to varying concentrations of Ricin

| Concentration (mg/l) | pH | Temperature ($^0$C) | Dissolved Oxygen (mg/l) | Nitrite (mg /l) | Ammonia (mg/l) |
|---|---|---|---|---|---|
| 0.00 control | 7.12 ± 0.02 | 25.20 ± 0.14 | 8.30 ± 0.04 | 0.14 ± 0.02 | 0.03 ± 0.09 |
| 100 | 6.80 ± 0.15 | 25.68 ± 0.12* | 8.10± 0.04* | 0.17 ± 0.04 | 0.54 ± 0.23* |
| 125 | 6.60± 0.44* | 26.10 ± 0.10* | 7.52 ± 0.38* | 0.37 ± 0.05* | 0.65 ± 0.20* |
| 160 | 6.30 ± 0.10* | 26.50 ± 0.15* | 7.33 ± 0.34* | 0.52 ± 0.03* | 0.69 ± 0.08* |
| 200 | 6.10± 0.03* | 26.70± 0.03* | 6.80 ± 0.16* | 0.59 ± 0.04* | 0.79 ± 0.02* |

* Values significantly different from control group ($p<0.05$) CYP = Cyclophosphamide

**Table 2:** Mean physico-chemical parameters of water during the 21 days exposure of *H. bidorsalis* to various concentrations of Ricin

| Concentration (mg/l) | pH | Temperature ($^0$C) | Dissolved Oxygen (mg/l) | Nitrite (mg/l) | Ammonia (mg/l) |
|---|---|---|---|---|---|
| 0.00 | 7.10 ± 0.00 | 27.99 ± 0.03 | 8.09 ± 0.03 | 0.14 ± 0.02 | 0.05 ± 0.00 |
| 11.7 | 7.00± 0.02 | 27.45 ± 0.01* | 6.80 ± 0.01* | 0.17 ± 0.01 | 0.47 ± 0.17* |
| 23.4 | 6.71± 0.28* | 26.30 ± 0.02* | 6.34 ± 0.02* | 0.30 ± 0.01* | 0.51 ± 0.33* |
| 35.1 | 6.69 ± 0.05* | 26.22 ± 0.01* | 5.86 ± 0.02* | 0.33 ± 0.02* | 0.68 ± 0.33* |
| Positive control (CYP - 4.00) | 7.00 ± 0.01* | 28.54 ± 0.01* | 7.22 ± 0.13* | 0.18 ± 0.01 | 0.06 ± 0.00 |

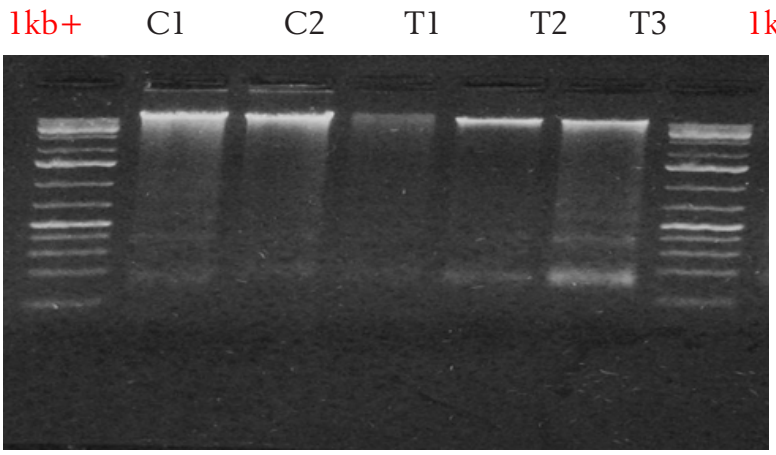
* Values significantly different from control group ($p<0.05$)
CYP = Cyclophosphamide

**Table 3.** Oxidative stress parameters of *H. bidorsalis* juveniles subjected to different concentrations ricin at day 21 of exposure.

| Parameters | Negative control (0.00mg/l) | Positive control CYP (4g/l) | 11.7mg/l | 23.4mg/l | 35.1mg/l |
|---|---|---|---|---|---|
| TP (µg/dl) | 14.88±1.09 $^{a}$ | 14.02±2.26 $^{a}$ | 14.75±0.57 $^{a}$ | 3.66±0.37 $^{a}$ | 15.71±0.67 $^{a}$ |
| GPx(units/mg protein) | 12.07±0.96 $^{b}$ | 9.98±0.89 $^{a}$ | 10.98±1.50 $^{ab}$ | 9.69±0.64 $^{a}$ | 11.54±0.51 $^{ab}$ |
| GSH (µg/ml) | 569.82±116.10 $^{b}$ | 635.96±215.13 $^{b}$ | 557.43±74.95 $^{b}$ | 255.74±146.5 $^{a}$ | 268.73±109.55 $^{a}$ |
| GST (unit/mg protein) | 47.55±11.17 $^{bc}$ | 53.34±11.16 $^{c}$ | 36.89±5.40 $^{bc}$ | 31.47±10.00 $^{ab}$ | 17.84±5.35 $^{a}$ |
| $H_2O_2$ (µmol/mg protein) | 2.65±2.82 $^{a}$ | 5.08±1.30 $^{a}$ | 2.74±0.55 $^{a}$ | 3.72±0.43 $^{a}$ | 2.42±0.52 $^{a}$ |
| MDA (µmol/mg protein) | 5.33±0.55 $^{d}$ | 3.42±0.66 $^{c}$ | 2.20±0.82 $^{b}$ | 1.51±0.51 $^{ab}$ | 0.97±0.06 $^{a}$ |
| MPO (µmol/mg protein) | 2.01±0.21 $^{b}$ | 0.62±0.20 $^{a}$ | 2.14±1.05 $^{b}$ | 1.56±0.45 $^{ab}$ | 1.22±0.57 $^{ab}$ |
| SOD (units/mg protein) | 3.16±1.85 $^{b}$ | 3.93±1.85 $^{b}$ | 0.21±0.75 $^{a}$ | 1.42±0.15 $^{a}$ | 1.38±0.60 $^{a}$ |
| CAT (units/mg protein) | 2.94±1.17 $^{a}$ | 3.59± 1.17 $^{a}$ | 4.21±0.75 $^{b}$ | 6.20±0.90 $^{c}$ | 8.17±0.02 $^{d}$ |

Different superscript value significantly different from negative control ($p<0.05$) along the rows TP= Total Protein, GPx= Glutathione peroxidase, GSH= Glutatathione, GST=Glutathione transferase, $H_2O_2$ = Hydrogen Peroxide, MDA = Malondehyde, MPO= Mycloperoxidase, SOD= Superoxide dismutase, CAT= Catalase, CYP= Cyclophosphamide

**Fish DNA fragments**




**C1= Negative control; C2= Positive control; T1 = 1.7mg/l; T2= 23.4mg/l; T3 =35.1mg/l**
**Figure 1:** Fish DNA fragmentation after 504hrs sub-lethal concentration expose to ricin.

## DISCUSSION

### Oxidative stress parameters of *H. bidorsalis* juveniles

The antioxidant enzymatic system protects organisms from the toxic effects of the activated oxygen species and helps to maintain cellular homeostasis by removing reactive oxygen species (ROS The level of biomarkers of oxidative stress was evaluated in *H. bidorsalis* exposed to varying sub lethal concentration of ricin, the bioassay showed significant variation in the level of all the tested parameters. Fish upon exposure to pollutants elicit the production of reactive oxygen species ROS (Halliwell and Gutteridge 1999) As the ROS level increase, the biological system develops a first line defence mechanism by modulating the activities of antioxidants such as catalase (CAT) superoxide dismutase (SOD) and glutathione related enzymes (Bagnyukova*et al.*, 2006).Thus, the results clearly infer ricin -induced oxidative stress. $H_2O_2$ is a major component of the ROS produced intracellularly during physiological and pathological processes, in addition to being the cause of oxidative damage (Krohn, *et al.*, 2009).

Catalyzes the breakdown of hydrogen peroxide to water and molecular oxygen to protect cells against the toxic effects of hydrogen peroxide, There was significant in the catalase activity during experimental periods which is probably a response to ricin induced toxic stress and serves to neutralize the impact of

increased ROS generation (John, *et al.*,2001) Similar observation was made by Li *et al.*,(2010). Accordingly, the activity of malondialdehyde (MDA) is increased and that of catalase is decreased as oxidative defence in fish, Catalase activity thus serves as a potential oxidative stress biomarker in fish toxicity studies(Kaviraj and Gupta 2014).
One very unique and interesting finding was observed in the present study that the SOD increased where far less compare to result obtained from the positive (Cyclophosphamide) and negative (0mg/l) controls. Therefore, it may be concluded based on the results that SOD takes the lead in order to detoxify the oxyradicals followed by corresponding increase in CAT activity.

**Fish DNA Fragmentation**
Fragmentation of DNA in the form of a ladder due to endonucleolytic attack is reportedly considered as an apoptosis and DNA damage related event shown in fig.1. DNA fragmentation was considered as one of the later steps in apoptotic program (Hickey, et al., 2001) DNA ladder formation is observed in *Heterobranchus Bidorsalis* exposed to ricin. Evidence of fragmentation of the genetic material was observed.

The results predict that DNA fragmentation patterns are detected in DNA extracted from cells treated with ricin, but no DNA fragmentation are detected in controls. Molecular markers of the biological effects of contaminants on organisms (Biomarkers) can be used as diagnostic and prognostic early warning tests to detect and assess the effects of pollution, particularly low concentrations of complex mixtures of contaminants, on environmental quality (Tennant, *et al.*, 2001).Fragmentation of DNA in the form of a ladder due to endonucleolytic attack is reportedly considered as an apoptosis and DNA damage related event. DNA fragmentation was considered as one of the later steps in apoptotic program (Hickey, et al., 2001)

## CONCLUSION
The study investigate the effect of ricin the active ingredients in castor oil seed (*Ricinus communis*) on *Heterobranchus Bidorsalis*. Since fish serve as an excellent model for the assessment of genotoxicity in aquatic environment under both laboratory and field conditions. Genotoxic evaluation of aquatic environment is a key mechanism for translating the principle of sustainable development into action, though fish die first, next is human. Conclusively the project work is an eye opener to genotoxic effect of ricin and a need to tackle it, otherwise it residual effect could be a course of worry in the near future,

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# BLUE BIOTECHNOLOGY AND GENETICS - BBG

# MORPHOMETRIC STUDIES OF FISH FAMILIES (CICHLIDAE AND LATIDAE) OF CHALLAWA GORGE DAM, KANO STATE, NIGERIA

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**ABSTRACT**
*This research was carried out to study the morphological characteristics of fish families Latidae and Cichlidae from Challawa Gorge Dam in Kano State, Nigeria using morphometric measurements. A total of 203 specimens, 168 Cichlidae and 35 Latidae family were collected (November-December 2023) from the fisher folks at landing site Challawa Gorge Dam, examined and analyzed for morphometric characterization. The results revealed that all the morphometric characters of Cichlidae and Latidae in Challawa Gorge Reservoir varied, whereas the total length in all the families shows a linear relationship with the rest of the morphometric features as they increase with increase in total length. A significant linear relationship was established and represented by the equation: $Y = a + bX$ ranged ($r^2 = 0.7 - 0.902$) for Cichlidae, and ($r^2 = 0.24 - 0.986$) for Latidae. In conclusion, these findings are very useful in stock assessment, population dynamics, sustainable management and conservative measures of Fish belonging to families Latidae and Cichlidae in Challawa Gorge Dam.*

**Keywords**: Cichlidae, Challawa Gorge Dam, Latidae, Morphometric character

## INTRODUCTION

Cichlidae, commonly known as tilapia, is a fish family originally native to Africa and the Middle East, where it is widely distributed. Due to various factors, several species have been introduced to different countries across Africa and other regions worldwide (Blessing, 2019). Cichlids exhibit remarkable morphological diversity, largely due to rapid and extensive trophic radiation occurring repeatedly across various lakes, reservoirs, and rivers (Gu *et al.*, 2014; Huda and Zuheir, 2015). In 2022, the global wild catch of tilapia species, together with carp, reached 7.2 million tonnes, making them the second most significant group of wild-caught fish and the fourth most commonly farmed fish worldwide. Consequently, tilapia represent the sixth most important fish family globally (FAO, 2023).

The Latidae family consists of large, fish-eating species that hold significant value in commercial, artisanal, and recreational fisheries (Koblmüller *et al.*, 2021). This family includes eleven species found in marine, brackish, and freshwater habitats across the Indo-Pacific and African freshwater systems. In Africa, seven species of the genus Lates inhabit major freshwater bodies (Froese and Pauly, 2009; Iwatsuki *et al.*, 2018; Fricke *et al.*, 2021; Koblmüller et al., 2021). Latidae are freshwater species endemic to several African river and lake basins, including the Nile, Chad, Senegal, Niger, and Congo basins (Froese and Pauly, 2009; Basiita *et al.*, 2018).

Studying morphometric traits in fish is crucial for distinguishing between populations and for taxonomic classification. Morphometric measurements remain one of the simplest and most direct methods for identifying fish stocks and provide essential data for taxonomic and evolutionary research. Both morphometric and meristic analyses serve as powerful tools to assess the distinctiveness within species (Felix *et al.*, 2021). In fisheries science, morphometric analysis is essential for understanding relationships between body parts and for identifying stock origins, distinguishing stocks, or recognizing commercially important fish species (Carpenter *et al.*, 1996; Nyingi *et al.*, 2021). Morphological studies aid phylogenetic research and provide data for genetic improvement programs. Variations in morphology

among populations help define population structure and can reflect short-term environmental changes, guiding effective fisheries management (Tamario *et al.*, 2019). In Nigeria, reports on morphological diversity of fishes within populations of the same species includes studies by Olufeagba *et al.* (2015), Ezeafulukwe *et al.* (2015), Adaka *et al.* (2016), Ikpeme *et al.* (2017), Chiaha *et al.* (2024), Kazeem and Nurudeen (2025).

Odioko and Becer (2022) reported that Nigerian inland water bodies generated about $164 billion, which is under 50% of their estimated fishery potential. One significant inland water resource in northern Nigeria is the Challawa Gorge Dam, a major reservoir on the Challawa River, a tributary of the Kano River, itself a key tributary to the Hadejia River (Nazeef *et al.*, 2018). Besides serving irrigation, fishing, and municipal water supply, the dam was designed with a hydropower capacity of approximately 3 megawatts (Nazeef *et al.*, 2018). Important freshwater fish families found there include Latidae and Cichlidae (Nazeef *et al.*, 2018). Therefore, using Challawa Gorge dam as a case study, this research aimed at using morphometric as a tool in identifying selected fish species which will provide better understanding of the species diversity and potentiality of the dam.

## MATERIALS AND METHODS

### Study Site

The sampling was conducted at the Challawa George dam, Karaye Local Government area of Kano State, Nigeria (Fig. 1). The Challawa George dam is geographically located between Latitude 11°45°0″N – 11°45°0″N and Longitude 7°55°0″E – 8°3°30″E, which has a catchment area of approximately 3857 km$^2$. (Nazeef *et al.*, 2018).

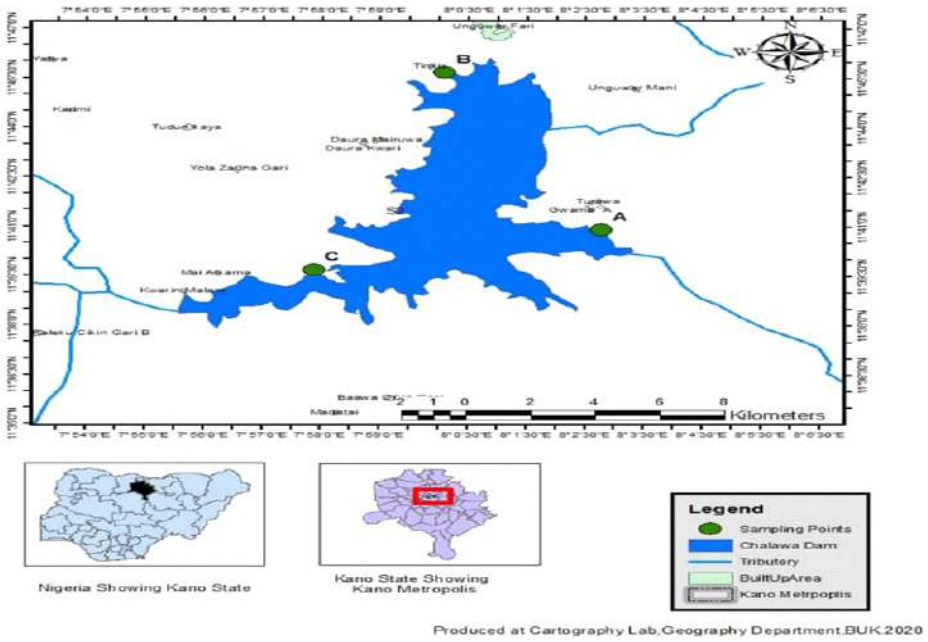



**Figure 1:** Map of Challawa Gorge Dam showing the Sampling Stations

### Fish Sample Collection

A total number of two hundred and three (203) freshly caught samples belonging to Cichlidae (12.46% abundance) and Latidae (2.47% abundance) families were randomly selected and bought from commercial fishermen at the landing sites (Turawa, Tinkis and Ma) of Challawa George dam between November and December 2023. The fishermen used a wide range of fishing gears such as cast nets, gillnets, and non-return (gura trap) to catch fish, and an outboard engine canoe to convey the fish to the

landing site. Fish samples were immediately immersed in ice and transported to the laboratory of Department of Biological Science, Faculty of Science, Bayero University, Kano State, where the fish samples were identified by using keys and works provided by Adesulu and Sydenham (2007). The formular n=z2p(1-p)/d by Charan and Biswas (2013) which was adopted by Nazeef *et al*. (2018) was used to determine the sample size where; n= Sample size, z= from distribution table (1.96), p= prevalence of previous studies and d= significant level (5%).

**Measurement of Morphometric Characters**

Data on morphometric characters such as Standard length, Total length, Anal fin base length, Pelvic fin base length, Eye diameter, Dorsal fin base length, Head length, Caudal peduncle length, Pectoral length, Body depth, Dorsal fin base length, Pre-dorsal length, Pre-pelvic length, Pre-orbital length, Peduncle depth (table 1) were measured according Olaosebikan and Raji (1998) to using measuring board to the nearest cm. The description of the morphometric characters measured are as follows:

Standard length (SL-cm): Distance from the tip of the snout to the end of hypural plate. Total length (TL-cm): The distance from tip of the snout to the tip of longest caudal fin ray. Anal fin base length (AFL-cm): Length of the longest anal fin ray. Pelvic fin base length (PFL-cm): Length of the longest pelvic fin ray. Eye diameter (ED-cm): Distance from the posterior to the anterior eye rims in the longitudinal axis. Dorsal fin base length (DFL-cm): Length of the longest dorsal fin ray. Head length (HL-cm): The distance from tip of the snout to the posterior point of opercular membrane. Caudal pendule length (CFL-cm): Length of the longest caudal fin ray. Pectoral length (PFL): Length of the longest pectoral fin ray. Body depth (BD-cm): The distance from the ventral surface of the fish at deepest part to the anterior end of first dorsal fin.

**Statistical Analysis**

Basic descriptive statistics including minimum value, maximum value, mean, and standard deviation were computed for the morphometric measurements. To standardize the differences in the overall body size among Cichlidae and Latidae samples, all the morphometric measurements data were divided by Total length (TL) following the method of Hubbs and Lagler (1947) and presented as ratio.

## RESULTS

**Morphometric Characters of the Family Cichlidae from Challawa George Dam**

A total of (168) fish belonging to Cichlidae and 35 of Latidae family was obtained from Challawa George dam and used for morphometric studies. The Total length ranged from 11 cm to 22.60 cm with the mean value of 14.58± 2.17cm. Standard length ranged from 9.00 cm to 18.60 cm with a mean value of 11.64± 1.80cm. Body depth ranged from 1.70 cm to 7.80 cm with a mean value of 4.67± 0.71 cm. Results for other morphometric characters are presented in Table 1.

**Table 1:** Morphometric Characters of the Family Cichlidae from Challawa George Dam

| Characters | Mean ± SD | Minimum | Maximum |
|---|---|---|---|
| Anal fin base Length (cm) | 2.11±0.49 | 1.20 | 3.90 |
| Body depth (cm) | 4.67±0.71 | 1.70 | 7.80 |
| Caudal Peduncle Depth (cm) | 1.34±0.28 | 0.70 | 2.50 |
| Dorsal fin base Length (cm) | 6.79±1.11 | 4.50 | 10.16 |
| Eye Diameter (cm) | 0.92±0.13 | 0.70 | 1.40 |
| Head Length (cm) | 3.93±0.66 | 2.90 | 6.10 |
| Pectoral Length (cm) | 4.30±0.87 | 0.50 | 6.70 |
| Peduncle depth(cm) | 1.88±0.55 | 0.80 | 7.10 |
| Pelvic fin base Length (cm) | 0.93±0.21 | 0.40 | 1.70 |

| | | | |
|---|---|---|---|
| **Post-orbital Length** | 1.38±0.38 | 0.40 | 2.80 |
| **Pre-dorsal Length (cm)** | 4.24±0.71 | 2.80 | 6.60 |
| **Pre-orbital Length (cm)** | 1.64±0.39 | 0.80 | 2.60 |
| **Pre-pelvic Length (cm)** | 4.55±0.72 | 3.40 | 7.10 |
| **Standard Length (cm)** | 11.64±1.80 | 9.00 | 18.60 |
| **Total Length (cm)** | 14.58±2.17 | 11.00 | 22.60 |

**Morphometric Characters of the Family Latidae from Challawa George Dam**

A total of thirty-five (35) fish belonging to Latidae family was obtained from Challawa George dam and used for morphometric studies. The Total length ranged from 7.10 cm to 30.00cm with the mean value of 17.27± 4.02cm. Standard length ranged from 6.00cm to 25.00cm with a mean value of 14.72± 3.38cm. Body depth ranged from 1.60 cm to 7.40 cm with a mean value of 4.10± 1.05 cm. Results for other morphometric characters are presented in Table 2.

**Table 2:** Morphometric Characters of the Family Latidae from Challawa George Dam

| Characters | Mean ± SD | Minimum | Maximum |
|---|---|---|---|
| **Anal fin base Length (cm)** | 1.88±0.53 | 0.80 | 3.40 |
| **Body depth (cm)** | 4.10±1.05 | 1.60 | 7.40 |
| **Caudal Peduncle Depth (cm)** | 2.79±0.72 | 1.00 | 4.90 |
| **Dorsal fin base Length (cm)** | 3.02±0.76 | **1.05** | **5.20** |
| **Eye Diameter (cm)** | 1.03±0.17 | 0.6 | 1.70 |
| **Head Length (cm)** | 5.12±1.28 | 2.10 | 8.70 |
| **Pectoral Length (cm)** | 2.44±0.63 | 0.90 | 4.30 |
| **Peduncle depth(cm)** | 2.10±0.54 | 0.9 | 3.80 |
| **Pelvic fin base Length (cm)** | 1.19±0.31 | 0.40 | 2.10 |
| **Post-orbital Length** | 2.42±0.7 0 | 0.6 | 3.50 |
| **Pre-dorsal Length (cm)** | 6.46±1.54 | 2.80 | 11.30 |
| **Pre-orbital Length (cm)** | 1.66±0.87 | 0.90 | 5.10 |
| **Pre-pelvic Length (cm)** | 5.11±1.17 | 2.00 | 8.50 |
| **Standard Length (cm)** | 14.72± 3.38 | 6.00 | 25.00 |
| **Total Length (cm)** | 17.27± .02 | 7.10 | 30.00 |

**Morphometric Characters of the Family Cichlidae from Challawa George Dam Expressed as Percentage of Total Length (TL-cm)**

Morphometric Characters of the Family Cichlidae from Challawa George Dam Expressed as Percentage of Total Length (Table 3) showed that standard length had the highest percentage (79.84 %), followed by Dorsal fin base length (46.38 %) while eye diameter had the least percentage (6.31%).

**Table 3.** Morphometric characters of Family Cichlidae from Challawa George Dam Expressed as Percentage of Total Length (TL-cm)

| Characters | Percentage of Total Length (%) |
|---|---|
| Anal fin base Length (cm) | 14.47 |
| Body depth (cm) | 32.03 |
| Caudal Peduncle Depth (cm) | 9.19 |
| Dorsal fin base Length (cm) | 46.38 |
| Eye Diameter (cm) | 6.31 |
| Head Length (cm) | 26.95 |
| Pectoral Length (cm) | 29.49 |
| Peduncle d epth(cm) | 12.89 |
| Pelvic fin base Length (cm) | 6.38 |
| Post -orbital Length | 11.25 |
| Pre -dorsal Length (cm) | 29.78 |
| Pre -orbital Length (cm) | 9.47 |
| Pre -pelvic Length (cm) | 31.21 |
| Standard Length (cm) | 79.84 |

**Morphometric Characters of the Family Latidae from Challawa George Dam Expressed as Percentage of Total Length (TL-cm)**

Morphometric Characters of the Family Latidae from Challawa George Dam Expressed as Percentage of Total Length (Table 4) showed that standard length had the highest percentage (85.23 %), followed by Pre-dorsal length (37.41 %) while eye diameter had the least percentage (5.96%)

**Table 4:** Morphometric Characters of the Family Latidae from Challawa George Dam Expressed as Percentage of Total Length (TL-cm)

| Characters | Percentage of Total Length (%) |
|---|---|
| Anal fin base Length (cm) | 10.89 |
| Body depth (cm) | 23.74 |
| Caudal Peduncle Depth (cm) | 16.16 |
| Dorsal fin base Length (cm) | 17.46 |
| Eye Diameter (cm) | 5.96 |
| Head Length (cm) | 29.65 |
| Pectoral Length (cm) | 14.13 |
| Peduncle depth(cm) | 12.16 |
| Pelvic fin base Length (cm) | 6.29 |
| Post -orbital Length | 14.01 |
| Pre -dorsal Length (cm) | 37.41 |
| Pre -orbital Length (cm) | 9.61 |
| Pre -pelvic Length (cm) | 29.59 |
| Standard Length (cm) | 85.23 |

**Length- Morphometric Relationship of Family Cichlidae and Latidae from Challawa George Dam**

Length- Morphometric relationship of Family Cichlidae and Latidae from Challawa George Dam (Table 5) was estimated for (203) specimen. The normal plot of total length (TL – cm) against Morphometric Characters Family Cichlidae and Latidae from Challawa George Dam is shown in Fig. 2 and Fig. 3. A significant linear relationship was established and represented by the equation: $Y = a + bX$, $R^2$ ranged (0.7 - 0.902) for Cichlidae, and (0.24- 0.986) for Latidae

**Table 5.** Length- Morphometric relationship of Family Cichlidae and Latidae from Challawa George Dam Fish Family

| Characters | Cichlidae (n=168) | | | Latidae (n= 35) | | |
|---|---|---|---|---|---|---|
| | a | b | $R^2$ | a | b | $R^2$ |
| **Anal fin base Length (cm)** | 0.201 | -0.812 | 0.78 | 0.126 | -0.129 | 0.911 |
| **Body depth (cm)** | 0.307 | 0.074 | 0.474 | 0.256 | -0.322 | 0.953 |
| **Caudal Peduncle Depth (cm)** | 0.097 | -0.121 | 0.512 | 0.172 | -0.184 | 0.918 |
| **Dorsal fin base Length (cm)** | 0.51 | -0.68 | 0.859 | 0.179 | 0.213 | 0.894 |
| **Eye Diameter (cm)** | 0.038 | 0.371 | 0.426 | 0.036 | 0.403 | 0.695 |
| **Head Length (cm)** | 0.276 | -0.128 | 0.772 | 0.275 | 0.379 | 0.743 |
| **Pectoral Length (cm)** | 0.389 | -2.4448 | 0.151 | 0.147 | -0.107 | 0.887 |
| **Peduncle depth(cm)** | 0.12 | -0.01 | 0.256 | 0.13 | -0.15 | 0.942 |
| **Pelvic fin base Length (cm)** | 0.064 | -0.07 | 0.36 | 0.07 | -0.016 | 0.838 |
| **Post-orbital Length** | 0.132 | -0.413 | 0.397 | 0.085 | 0.942 | 0.24 |
| **Pre-dorsal Length (cm)** | 0.297 | -0.148 | 0.7 | 0.379 | 0.087 | 0.986 |
| **Pre-orbital Length (cm)** | 0.127 | -0.478 | 0.531 | 0.142 | -0.8 | 0.429 |
| **Pre-pelvic Length (cm)** | 0.297 | 0.182 | 0.766 | 0.287 | 0.146 | 0.975 |
| **Standard Length (cm)** | 0.779 | 0.241 | 0.902 | 0.835 | 0.303 | 0.986 |

a =intercept or constant, b= slope, r = coefficient of correlation, n = Number of fish sample

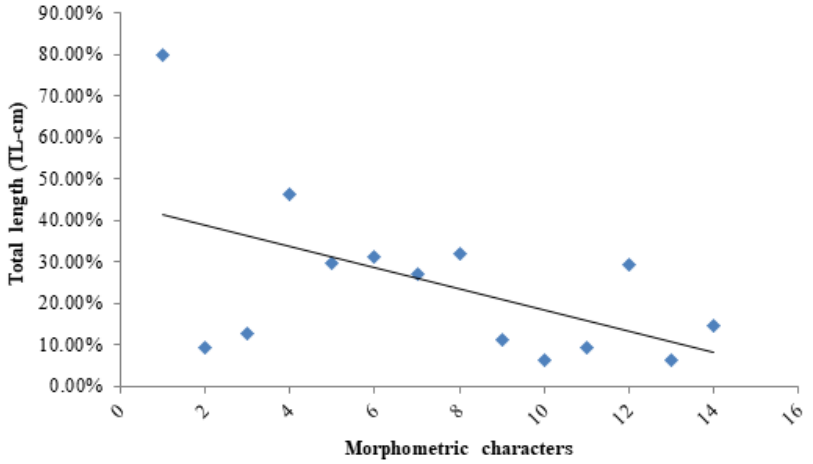



**Fig. 2.** Length- Morphometric relationship of Cichlidae Family from Challawa George Dam

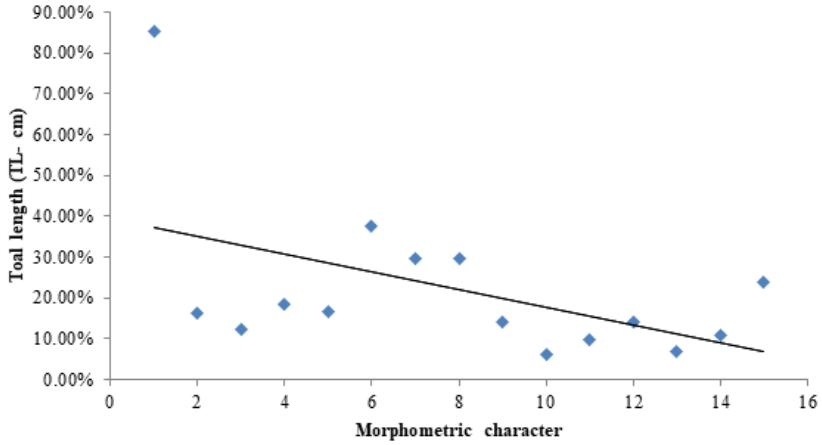



**Figure 3:** Length- Morphometric relationship of Latidae Family from Challawa George Dam

## DISCUSSION

Morphometric techniques remain the most straightforward and direct approach for species identification, as supported by previous research (Kwikiriza *et al.*, 2023). Morphometric traits continue to be reliable, practical tools for characterizing fish species in field studies (Traverso *et al.*, 2024). The result obtained from this study showed that morphometric characters of Cichlids including total length, standard length, head length, body depth, eye diameter, anal fin base length, dorsal fin length, pelvic fin base length and pectoral length were within the range reported by Olufeagba *et al.*, (2015); Adediji *et al.*, (2019) Felix *et al.*, (2021) for the same family from Asejire, Jebba, Kainji, Oyan, Geriyo Lakes and lake Komadugu in Nigeria respectively. Findings of this study for morphometric characters of Cichlids is also similar to report of Idowu *et al.* (2017) who conducted a preliminary study on Cichlids caught from Oyan dam in Nigeria. Our findings is also similar to that of Jawad *et al.* (2018) for Cichlid collected from Shatt al-Arab River, Basrah, Iraq. Desforges *et al.* (2023) noted that morphometric traits help detect differences between fish of the same species from different locations. This study aligns with Idowu *et al.* (2017), who found no significant meristic or morphometric differences in cichlids from Nigerian and other African waters. Jawad *et al.* (2018) suggest environmental plasticity and genetic variation explain why fish populations don't homogenize. Morphometric traits can reveal how fish populations respond to their environments (Oyebola *et al.*, 2024).

The morphometric differences observed from the family Cichlidae and Latidae in this study when compared to other studies could be attributed to environmental fluctuations especially water temperature (Akinrotimi and Ukwe 2018). Environmental conditions such as water temperature, spawning habitat, sex, stress, depth of water and food abundance have been highlighted as the reason for high morphological plasticity in fish (Felix *et al.*, 2021; Shen *et al.*, 2023; Nagelkerken *et al.*, 2023; Agarwal *et al.*, 2024) and Akinrotimi Ukwe (2018) on fin rays of the tilapiine group followed the same trend. Length-morphometric relationship with the total length (TL) which indicate a linear relationship, this relationship has been reported by several researchers including (Piya *et al.*, 2014 and Shariar *et al.*, 2011). Higher ($r^2$ 0.986), ($r^2$ 0.986) mean value which was recorded for Latidae in standard length and pre-dorsal length respectively compared to family Cichlids, meanwhile higher ($r^2$ 0.859) mean value of dorsal fin base Length were also recorded in Cichlidae. The superiority exhibited by Latidae is a result of its genetic attributes. This is similar to the work of Yakubu and Okunsebur (2011) who also recorded higher mean value in some of the morphometric characters in Latidae than in Cichlids. Lower mean value of total length (TL) recorded in both the species compared to their genetic potential might be attributed to low quality and quantity of available feeding materials since the fishes only feed on whatever they come across in the Reservoir, other factors include poor maintenance of physico-chemical water quality parameters, insufficient regulation of fishing and fishing gear practices, lack of public enlightenment and low enforcement of law by relevant authorities.

## CONCLUSION

The study revealed that some morphometric features of the family Cichlidae varied including total length, standard length, head length, body depth, eye diameter, anal fin base length, dorsal fin length, pelvic fin base length and pectoral length while some were constant. So also, total length in all the families shows a linear relationship with the rest of the morphometric features, as they all increase with increase in total length where they showed a high value of r, meaning these parameters were highly correlated with total length. A lower mean value of total length was recorded in both the species compared to their genetic potential therefore, variation exist within the species in each family. There is a need to carry out meristic counts, length-weight relationship and condition factor these natural populaces to evaluating the relative well-being and growth patterns these two families.

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# EVALUATION OF MORINGA (*Moringa oleifera)* SEEDS EXTRACT EFFICIENCY IN THE PRODUCTION OF ALL MALE NILE TILAPIA (*Oreochromis niloticus*)

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**ABSTRACT**
*This study was conducted to evaluate the efficiency of Moringa oleifera seeds extract in the production of all male Nile tilapia (Oreochromis niloticus) for a period of six months (March to September, 2023) using standard methods and procedures. A total of four hundred and eighty (480) newly hatched tilapia were collected. Moringa oleifera seeds were collected and extracted with methanol and hexane using a Soxhlet apparatus. 17α-Methyltestosterone hormone was also purchased. The experiment consisted of a control and 7 treatments in triplicates labeled as; Control, 17α-MT, 20mlMOM (20ml Moringa oleifera extracted with methanol per kg diet), 40MOM (40ml Moringa oleifera extracted with methanol per kg diet), 60mlMOM (60ml Moringa oleifera extracted with methanol per kg diet), 20mlMOH (20ml Moringa oleifera extracted with Hexane per kg diet), 40mlMOH (40ml Moringa oleifera extracted with Hexane per kg diet), 60mlMOH (60ml Moringa oleifera extracted with Hexane per kg diet), making a total of 24 aquaria, each consisting of 20 hatchlings. The treatments involved mixing the hormone and various concentrations of Moringa oleifera seeds extract per kilogram of the fish diet. The result of sex ratios in the various treatments shows that the negative control group (Control) which was fed with the basal diet only, had the lowest male to female sex ratio (M:F) of 2:1. There was significantly higher ($p<0.05$) males to female ratio of 7:1 in the positive control group fed with feed mixed with 17α-MT hormone. 40mlMOM has the highest ratio of 2:1 following the standard.*

**Keywords:** Nile tilapia, 17α-Methyltestosterone, methanol, hexane, *Moringa oleifera*, all male, seed extract

## INTRODUCTION

Aquaculture, the cultivation of aquatic species, is a crucial industry for providing protein to human diets (FAO, 2020). Nile tilapia (*Oreochromis niloticus*) is a popular species in aquaculture due to its rapid growth, adaptability, and high market demand (El-Sayed, 2006). However, the expansion of tilapia farming faces challenges, particularly related to sex ratios and growth rates. Female tilapia, which reproduce prolifically and grow slower in high densities, can hinder production, while male tilapia exhibits faster growth and are preferred for monosex aquaculture (Guerrero, 2007).

Synthetic hormones are commonly used to induce sex reversal in tilapia, but their use raises environmental and health concerns due to potential contamination and adverse effects on consumers. Consequently, there is growing interest in finding environmentally friendly alternatives (Kristesen, 2017). Phytochemicals, such as those from *Moringa oleifera* seeds, offer a promising solution. *Moringa oleifera* seeds contain androgenic properties that may induce sex reversal in fish. The seeds are inexpensive, readily available, and non-toxic, making them an attractive alternative to synthetic hormones (Raji, 2018).

As regulations on chemical use in aquaculture increase, exploring safe, natural alternatives becomes essential. This study was aimed at assessing the effectiveness of *Moringa oleifera* seed extracts in producing all-male Nile tilapia (*Oreochromis niloticus*).

## MATERIALS AND METHOD

### Study Area, Sources of Seeds, Feeds, Hormone and Fishes

This study was conducted at the Fisheries Department of the National Biotechnology Development Agency (NABDA) in Katsina, Nigeria, from March to September 2023. *Moringa oleifera* seeds were collected from local markets and plantations in Katsina, while 17α-Methyltestosterone hormone was obtained from the Federal University, Dutsin-ma (FUDMA) Katsina State. Commercial fish feed was purchased in Katsina town. A total of four hundred and eighty (480) newly hatched *Oreochromis niloticus* were collected from the fish hatchery of National Biotechnology Development Agency, Katsina.

### Seeds and Feeds Processing

The *Moringa oleifera* seeds were washed, dried, and ground into powder, and then extracted with Methanol and Hexane using a soxhlet apparatus according to the procedure of Hussain *et al*. (2009). The 17α-Methyltestosterone was prepared by dissolving it in 95% ethyl alcohol to create a stock solution according to procedure described by Vinarukwong *et al*. (2018). The treatments involved mixing the various concentrations of *Moringa oleifera* seed extracts with the fish feed as follows: 20ml *Moringa oleifera* extracted with methanol per kg diet, 40ml *Moringa oleifera* extracted with methanol per kg diet, 60ml *Moringa oleifera* extracted with methanol per kg diet, 20ml *Moringa oleifera* extracted with Hexane per kg diet, 40ml *Moringa oleifera* extracted with Hexane per kg diet, and 60ml *Moringa oleifera* extracted with Hexane per kg diet.

### Experimental Design

The experiment was conducted in two phases. The first phase lasted for 60 days and involved treating the fish with the hormone and plant extracts. The second phase extended for 130 days and focused on rearing the fish on untreated feed to assess the long-term effects of the treatments. The fish were distributed into 24 ponds, with 20 fish per pond and three replicates for each treatment.

### Feeding and Water Change

During the rearing period, the fish were fed twice daily at 5% of their body weight, and the ponds were filled with de-chlorinated water, which was changed daily to ensure optimal conditions.

### Gonads Examination

Gonads were analysed by using the standard acetocarmine squash technique as described by Suman (2016).

### Data Analysis

The data was presented using a bar chart. One-way Analysis of Variance (ANOVA) was used to compare the means at 5% significance level. The analysis was performed using Graph pad instant (Version 3.0).

## RESULTS

The identification of gender by means of acetocarmine squash method was performed with ease at the end of the 180 days trial period. At the end of the 180 days trial, in the negative control group (Control) which was fed with the basal diet only, the male to female (M: F) sex ratio of 2.3:1 had the lowest sex ratio

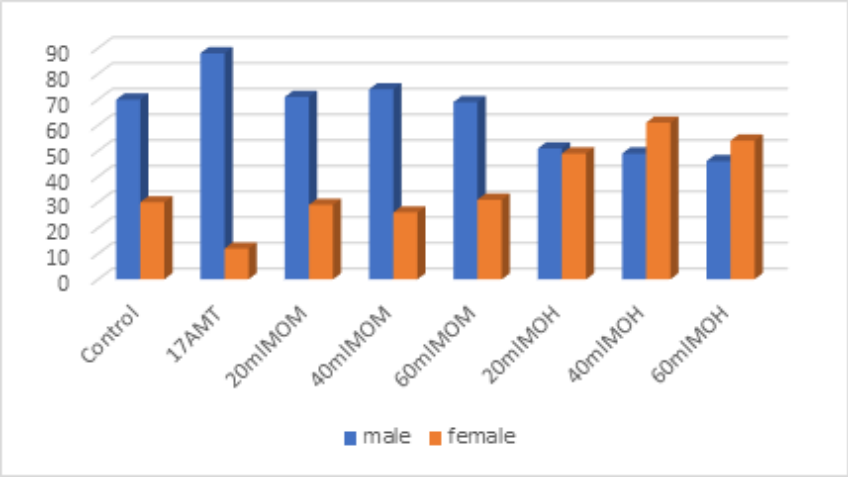



Figure 1. shows sex ratios of O*reochromis niloticus* treated with 17α-MT hormone and *Moringa oleifera* seeds extract after a 180 days trial

(MOM: *Moringa oleifera* extracted with methanol; MOH: *Moringa oleifera* extracted with hexane)

### Gonad histology

The male gonads were differentiated by fine granular-like structure of spermatogonia and the female gonads were characterized by having a structure with pre-vitellogenic oocytes (Fig. 2 and 3).



Figure. 2. Male gonads differentiated by fine granular-like structure of spermatogonia. Mg x 100

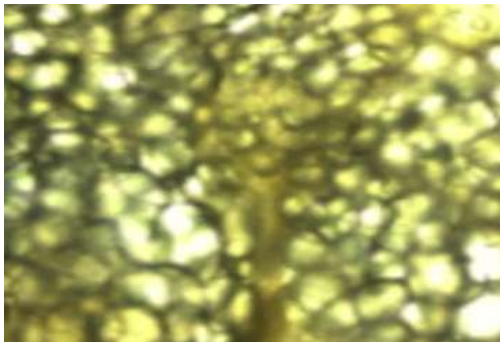


Figure:3 Female gonads differentiated by previtellogenic oocytes. Mg x 100

## DISCUSSION

The result of sex ratios in the various treatments shows that, the negative control group (Control) which was fed with the basal diet only, had the lowest male to female sex ratio (M:F) of 2:1. There was significantly ($p<0.05$) higher males to female ratio of 7:1 in the positive control group (17α-MT) which were fed with feed mixed with 17α-MT hormone. 40mlMOM has the highest ratio of 2:1 following the standard. This is in accordance with the result of Onyia *et al*., (2022) who reported high male to female ratio.

## CONCLUSION

The use of phytochemicals as viable alternative to 17-α-methyl testosterone in the production of monosex tilapia an economically important food fish holds a great prospect. From this study, it shows that *Moringa oleifera* seeds extract has the potential to induce sex reversal in tilapia. The study highlights the potential of using *Moringa oleifera* seed extracts as an alternative to 17α-Methyltestosterone for producing monosex tilapia, a key food fish. This method offers an environmentally friendly approach that could enhance profitability and reduce environmental degradation. It also minimizes health risks associated with synthetic steroids. In developing countries like Nigeria, where natural water systems are

abundant, this phytochemical-based approach can provide a cost-effective and sustainable solution for aquaculture. The research suggests that using plant extracts for sex reversal in tilapia can benefit fish farmers, aquaculture scientists, and consumers by offering a safer, more affordable alternative to synthetic hormones.

## RECOMMENDATION

Although *Moringa oleifera* seeds extract are reported to skew the sex ratio in favor of males in this study, the percentage masculinization may not be idle since as little as 4% females in a culture facility can reproduce indiscriminately thereby mitigating the benefit inherent in monoculture tilapia production. Therefore, there is need for further research to increase the percentage of masculinization.

Although Phytochemicals are viewed as relatively cheap and readily available alternative to synthetic hormones, no much study has sufficiently described the economic viability of utilizing plant extracts in aquaculture. As such, information on the cost effectiveness of plant-based products for commercial application in tilapia culture is limited. Therefore, research to determine the benefit–cost ratio of utilizing plant extracts is needed to guide recommendations for an economically feasible alternative to synthetic hormones.

The commercial application of plant extracts in masculinization of tilapia is also limited by inadequate information regarding the long-term effects of the extracts on the quality of fish's flesh and other physiological processes. Plant extracts may either positively or negatively modulate the physiological functioning of fish, depending on plant type and the administered dose. Besides reproduction control, plant extracts such as saponins also enhance the immune system and subsequently growth performance of fish. However, a specific dosage of the extracts that is effective in controlling unwanted breeding may trigger negative growth response in the same fish. Some plant extracts also contain antinutritional factors such as gossypol in cotton, which interfere with feed utilization, hence adversely affecting health and growth of fish.

## ACKNOWLEDGEMENT

My outmost appreciation goes to the entire staff of the Department of Biology, Faculty of Natural and Applied Sciences, Umaru Musa Yaradua University, Katsina, the management of National Bioresources Development Agency (NABDA), Katsina and the Department of Fisheries and Aquaculture, Faculty of Agriculture, Federal University, Dutsinma, for providing the necessary resources that made this research possible.

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# BLUE ECONOMY, TRADE, MARKETING AND VALUE CHAIN DEVELOPMENT - BETMV

# SOCIOECONOMIC IMPACT OF FISHERFOLKS IN THREE FISHING COMMUNITIES IN DOMA LOCAL GOVERNMENT AREA OF NASARAWA STATE, NIGERIA

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**ABSTRACT**

*The study on socio-economic characteristics of fisherfolksin three fishing communities in Doma Local Government Area of Nasarawa State, Nigeria was carried out between July and October 2024. A well-structured questionnaire was administered to sixty (60) fisherfolks selected randomly in three fishing communities in Doma (Yelwa, Ohinna and Agbashi). Twenty questionnaires were purposively distributed in each fishing communities to collect data through interview schedule. Data were analyzed using descriptive statistics expressed in percentages to evaluate the socio-economic factors and hygienic practices. The study showed that women (66.67%) were actively involved in fish business than men (33.33%).. Most of the fish business were carried out by married people (66.67%) while 8.33% of the activities were carried out by single. Majority (48.33%) were in their productive years between the age bracket of 36-45 years. Majority (63.33%) of the respondents were slightly literate (SSCE). They usually obtained their fish from the wild (75.00%) and they use traditional smoking kiln with firewood (78.33%) to smoke their fish. The study observe that the respondents had poor hygienic handling of their fish products from the source of water to smoking of the fish. Government should come to the aid of the people in the study area by supplying them with modern equipment to increase artisanal practices which will improve food security in the area and will cut down the cost of obtaining protein resources for their livelihood.*

**Keywords:**
Socioeconomic, Fishery, Communities, Fisherfolks

## INTRODUCTION

Fish is major source of animal protein with a high level of Vitamins (Fiedler *et al.*, 2015); thus, making fish a good alternative of meeting the domestic demand for protein rich animal source of food. The continued rise in fish import bill is unstainable especially in an economy dependent on revenue from unstable prices of crude oil export. In order to mitigate this alarming situation, Adeosun *et al.* (2019) proposed on the investment in fisheries for the improvement of livelihoods and the protein requirement of people.

The socio-economic characteristics of fisherfolks is a key indicator of profitability analysis of the fishery sector. Social factors such as gender, age, education level and household characteristics have been recognized to play an important role in sustainable fishery (Kundu, 2010). Omeje *et al.* (2020) opined that fisherfolks within the economically active age possess the potentials to expand for higher income while Onyekuru *et al.* (2019) gave an insightful thought that fish farmers with longer years of experience are expected to be more productive than those with shorter years of experience; and Adeosun *et al.* (2019) reported that the years of experience in fish business is a positive determinant of net farm income. Understanding of socioeconomic factors is important as it reflect the needs and aspirations of the people concerned. Hence, this study provides information on the socio-economic characteristics and fish smoking hygienic practices involved in handling fish production in Yelwa, Doma Local Government Area of Nasarawa State, Nigeria.

## METHODOLOGY

### Description of Study Area

Doma is a populated place located in Nasarawa State Nigeria located approximately 26 kilometers from Lafia. Doma is located between latitude 8° 16' 59"N and longitude 8° 19' 0"E. Doma Local Government Area is a region characterized by its agricultural prominence, rich agricultural heritage and significant landmarks such as the Doma Dam and a forest reserve. The town has an area of 2,714km2 and a population of 139,607 in 2006.

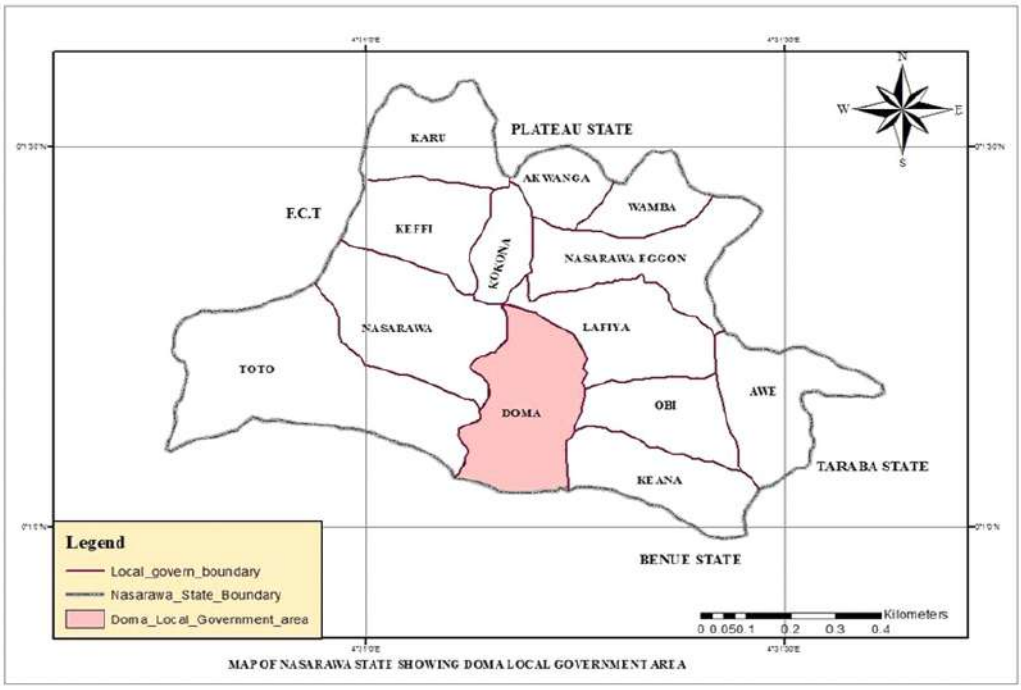



**Figure 1:** Map of Nasarawa State showing Doma Local Government Area

### Collection of Data

A well-structured questionnaire was administered to sixty (60) fisherfolks selected randomly in three fishing communities in Doma (Yelwa, Ohinna and Agbashi). Twenty questionnaires were purposively distributed in each fishing communities to collect data through interview schedule. The study was carried out between July to October of 2024, season where fishing activities were at its peak in the three fishing communities.

### Data Analysis

Data were analyzed using descriptive statistics expressed in percentage to evaluate the socio-economic factors and hygienic practices.

## RESULTS

### Demographic Information of the Respondents

The results presented in Table 1 showed the demographic information of the respondents in the study. The results showed that women were the majority (66.67%) in the business of fish in the study area. Majority of the respondents engaged in fish business are married (66.67%), divorced (8.33%), widow (16.67%), while single (8.33%) are the least respectively. The age range of the respondents in fish business showed that 48.33% were between 36-45 years which are the majority, followed by those between the ages of 26-35 years (21.67%), while 19-25 years (15%), and 46-55 years (15%) were the least. The level of education obtained in the study showed that majority had SSCE (38%), followed by those who obtained primary education (30%), however very few had tertiary education (4%) while

0.00% had no formal education. Fish selling is the major occupation (75%) of the respondents in the study while civil servant are the least (8.33%) respectively. Majority of the household (50%) had between 6-10 members followed by those having 16 and above (40%) members while the respondent with household size between 1-5 members were the least (10%) respectively. In terms of years of experience in fish business, 41.67% of the respondents reported that they had between 11-15 years of experiences in the business, followed by those between 16 years and above, only 8.33% had between 1-5 years.

**Table 1:** Demographic Information of the Respondents

| Items | Frequency | % |
|---|---|---|
| **Gender of the respondents** | | |
| Male | 20 | 33.33 |
| Female | 40 | 66.67 |
| Total | 60 | 100.00 |
| **Marital Status** | | |
| Single | 5 | 8.33 |
| Married | 40 | 66.67 |
| Divorced | 5 | 8.33 |
| Widowed | 10 | 16.67 |
| Total | 60 | 100.00 |
| **Age range of Respondents** | | |
| 18-25yrs | 9 | 15.00 |
| 26-35yrs | 13 | 21.67 |
| 36-45yrs | 29 | 48.33 |
| 46-55yrs | 9 | 15.00 |
| Total | 60 | 100.00 |
| **Higher level of education obtained** | | |
| No formal Education | 0 | 0.00 |
| Primary education | 18 | 30.00 |
| SSCE | 38 | 63.33 |
| Tertiary Education | 4 | 6.67 |
| Total | 60 | 100.00 |
| **Occupation** | | |
| Civil servant | 5 | 8.33 |
| Fish seller | 45 | 75.00 |
| Others | 10 | 16.67 |
| Total | 60 | 100.00 |
| **Household size** | | |
| 1-5 | 6 | 10.00 |
| 6-10 | 30 | 50.00 |
| 15 and above | 24 | 40.00 |
| Total | 60 | 100.00 |
| **Years of experience in fish selling** | | |
| 1-5 | 5 | 8.33 |
| 6-10 | 17 | 28.33 |
| 11-15 | 25 | 41.67 |
| 16 and above | 13 | 21.67 |
| Total | 60 | 100.00 |

**Hygienic practices involved in handling smoked fish product**

The Table 2 below showed the hygienic practices of fisherfolks involved in smoked fish handling in the study area. Most of the respondents used methods of fish smoking (21.67%), was traditional methods (21.67%) while modern methods involving modified smoking kiln (78%)) was the less used smoking methods of fish smoking. The study recorded that firewood was the highest (75.00%) utilized source of heat during heat smoking followed by charcoal (25.00%) while gas (0%) was not used at all in the study area. Majority of the respondent use well water (58.33%) as source of water for washing their fish during smoking, followed by 21.67% of borehole users while 20% of the respondents obtained water from the nearby rivers. Majority of the fish sold in the study area were caught from the wild (95.00%) meanwhile 5% source their fish from Aquaculture. Most of the fish sellers in the study area do not degut their fish before smoking. Majority of the respondents (91.67%) are crop farmers while few of them are civil servants (8.33%) respectively. the study showed that 100% of the respondents expressed that fish business is profitable in the study area.

**Table 2:** Fish Smoking Practices in the Study Area

| Items | Frequency | % |
|---|---|---|
| **Methods used in smoking of the fish** | | |
| Modern | 13 | 21.67 |
| Traditional | 47 | 78.33 |
| Total | 60 | 100.00 |
| **Source of heat for fish smoking** | | |
| Gas | 0 | 0.00 |
| Firewood | 45 | 75.00 |
| Charcoal | 15 | 25.00 |
| Total | 60 | 100.00 |
| **Sources of water for washing the fish** | | |
| River | 12 | 20.00 |
| Borehole | 13 | 21.67 |
| Well | 35 | 58.33 |
| Total | 60 | 100.00 |
| **Sources of Fish** | | |
| Culture | 03 | 05.00 |
| Wild | 57 | 95.00 |
| Total | 60 | 100.00 |
| **Process of degut the fi sh before smoking ?** | | |
| Yes | 17 | 28.33 |
| No | 43 | 71.67 |
| Total | 60 | 100.00 |
| **Other occupation apart from fish business** | | |
| Crop farming | 55 | 91.67 |
| Civil service | 5 | 8.33 |
| Total | 60 | 100.00 |
| **Profitability?** | | |
| Yes | 60 | 100 |
| No | 0 | 0.00 |
| Total | 60 | 100.00 |

## DISCUSSION

The women contribution to fish business in the study area gave higher percentage than men. This implies that majority of the women are unemployed and they had to engage in fish selling to support their families. This result deviated from the study reported by Oluwasola and Ige (2015) who indicated 80% of fish farmers were men in Ibadan Nigeria. Another reason why men have less concern for fish business could be due to series of activities carried out by men such as cultivating farm or fishing, selling of the farm produce, administering of income, and making of the decisions (Ukpe *et al.*, 2017). Majority of the respondents are married, and this is because married couples often have access to financial support, land, and labor which may contribute largely to fisheries. Marital status can also provide access to social network in the society (Zacharia *et al.*, 2013). Most of the people engaged in the fish business are between the ages of 36-45 years. Studies have shown that people who fall within this age bracket are refers to as youth in their economic age. They are agile, and engaged in various roles within the fisheries values chain from production and processing to distribution and marketing therefore provide diverse opportunities for livelihood and income generation (Omeje *et al.*, 2020). Omeje, *et al.* (2020) also reported higher participation of fish farmers between the age brackets of 31-40years in Kainji Lake Niger State Nigeria. In terms of educational qualification, the study showed that majority of the respondents are slightly educated indicating a higher percentage for SSCE. Low literacy rate in western education is a general characteristic of the rural population in Nigeria. Education plays crucial role in impacting various aspects of fish value chain from production to consumption. However, the most important reason of recording majority of the respondents with moderate educational qualification could be probably attached to lack of sponsors (Akarue and Aregbor, 2015), lack of Agricultural Institutions, inadequate financial support and their quest for promoting fish and fish products through practices. Fish business is the major occupation among the respondents which could be due to low level of education attained. The size of household in the study showed that majority had between 6-10 members. Household members serve as source of labour in fish farming operation such as feeding, environmental sanitation as well as entry point to fish farming enterprise (Ogunmefun and Achike, 2017). Over 41.67% of the respondents have between 11-15years experience in fish business in the study area. This is a good sign which shows that the fish farmers have a good number of years of experience in managing risks and others shocks that can possibly affect the business.

Traditional method of smoking is the most commonly used method in the study area. This involved the use of mud smoking chambers where firewood is used to generate heat during smoking and by doing so, the fish quality is improved hygienically (Jimoh and Oni, 2022). The major source of heat in fish smoking was derived from firewood. Charcoal usage was low which could be due to high cost of purchasing the charcoal. The respondents stated that they prefer to use firewood because the smoke produced during combustion add color, flavor and prevent the fish from spoilage. Their preferences of heat source is in line with the report of Sutikno *et al.* (2019) who stated that smoke from incomplete combustion of wood help to suppress bacterial growth. Well water is the most utilized source of water owing to the fact that geographical locations affect water table hence hindering easy access of water.

Most of the fish sold in the study were obtained from the wild. Only few respondents raise their fish through aquaculture. The low level of aquaculture practices in the study areas could be due to epileptic power supply, high cost of fish feed and lack of constant source of water that is why they prefer to purchase the fish from artisanal fisherfolks. During fish processing stages, majority of the respondents do not engage in degutting fish before smoking. The behavior of the respondents toward fish smoking will encourage fish deterioration over time. Engaging in fish business had earn income to a lot of the respondents because majority of them agreed that the business is profitable. Omeje *et al.* (2021) stated that fish farming is a viable business with high level of turnover in a study conducted in Kainji Lake Niger State Nigeria.

## CONCLUSION

The women contribution to fish business in the study area gave higher percentage than men. This implies that majority of the women are unemployed and they had to engage in fish selling to support their families. Majority of the respondents are married, and this is because married couples often have access to financial support, land, and labor which may contribute largely to fisheries. Education plays crucial role in impacting various aspects of fish value chain from production to consumption. However, the most important reason of recording majority of the respondents with moderate educational qualification could be probably attached to lack of sponsors. Household members serve as source of labour in fish farming operation such as feeding, environmental sanitation as well as entry point to fish farming enterprise. Most of the fish sold in the study were obtained from the wild. Only few respondents raise their fish through aquaculture.

## RECOMMENDATION

Government should come to the aid of the people in the study area by supplying them with modern equipment to increase artisanal practices by doing so, it will improve food security in the area and will cut down the cost of obtaining protein resources for their livelihood.

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# MARINE ENVIRONMENT AND BLUE ECONOMY IN COASTAL COMMUNITIES IN NIGERIA

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**ABSTRACT**
*This paper critically examines the relationship between the marine environment and the blue economy in coastal communities in Nigeria. The paper obtains its data from secondary sources of data including books, notes, journals, official publications, and the internet. The paper notes that unsustainable human activities, such as pollution (oil, domestic, and industrial), overfishing, dredging, land reclamation, and climate change, pose significant threats to the health and biodiversity of marine ecosystems and coastal communities. Multiple pressures, including habitat loss and degradation, pollution, overexploitation of fish stocks, climate change and natural hazards impact the coastal ecosystems negatively. It posits that protecting marine ecosystems through sustainable practices and conservation efforts is very crucial for ensuring the long-term health of the planet and the well-being of future generations. The paper concluded that the future of blue economy in Nigeria looks bright, with significant opportunities in sustainable practices, technological innovation, renewable energy, circular economy principles, sustainable tourism, and blue finance to promote sustainable development, while preserving the ocean's health. It recommended the full implementation of the National Policy on Marine and Blue Economy and the strengthening of other relevant policy and strategic frameworks to manage the impact of the marine environment on the blue economy of Nigeria's coastal communities (and vice versa).*

**Keywords**: Marine Environment, Blue Economy, Climate Change, Sustainable Development, Sustainable Livelihoods

## INTRODUCTION

The marine environment encompasses all saltwater ecosystems, including oceans, seas, coral reefs, estuaries, and coastal areas, and is characterized by its high salt content and diverse habitats. It is a vital part of the planet's life-supporting systems, providing essential resources like food and oxygen, sustaining livelihoods, regulating the climate, and sustaining a vast array of species. Marine ecosystems are incredibly diverse, ranging from the open ocean and deep sea to coastal areas like coral reefs, estuaries, mangroves, and salt marshes. It also plays a crucial role in global ecosystems, acting as a major carbon sink.
Blue economy, or the ocean or maritime economy, refers to the sustainable use of ocean resources for economic growth, improved livelihoods, and ocean health. It also encompasses a range of sectors, such as fisheries, aquaculture, shipping, energy, tourism, and marine biotechnology. Its potential to contribute to sustainable development, and poverty reduction has gained attention from policymakers, scholars, and stakeholders worldwide (Smith-Godfrey, 2016). Climate change, overfishing, pollution, and habitat destruction, among others, are significant threats to the health of oceans and their resources. These challenges affect the environment and have economic and social consequences, such as losing biodiversity, livelihoods, and cultural heritage (Bari, 2017).

Coastal communities refer to groups of people living in areas bordering the sea or ocean, often heavily reliant on coastal resources for their livelihoods and way of life including, fishing, aquaculture (mariculture), boat building, tourism, sand dredging, marine transportation, trading, etc. Their lifestyles, traditions, and social structures are often shaped by their proximity to the coast. Coastal communities are often more vulnerable to natural disasters like storms, floods, and rising sea levels. The health of coastal ecosystems directly impacts the well-being and livelihoods of these communities.

## METHOD OF DATA COLLECTION

This is done through secondary sources of data from books, notes, journals, speeches, conference reports, newspapers, magazines, official publications, seminars, published and unpublished materials, and the internet.

### Marine Environment

There is gross underutilization of the resources, opportunities and gains of the marine environment provided by the Atlantic Ocean, the lagoons. the creeks, and the mangroves in the coastal communities of Nigeria. This has affected the development of these coastal communities and the livelihoods of the residents of the communities. The coastline along the Atlantic seaboard has receded greatly over the past years due to a combination of unchecked coastal erosion, rising sea levels, and human activities. The increasing rise in sea level along the state coastline pose a significant threat to existing infrastructure, agriculture, and businesses. The tourism, leisure, and entertainment industries, which contribute greatly to the national GDP face significant threats from coastal damage and rising sea levels. Increasing urban development has led to the degradation and reclamation of vital ecosystems like floodplains, wetlands, and grasslands, severely diminishing their capacity to regulate floodwaters. Pollution from solid waste also contribute immensely to the degradation of the marine environment in the coastal communities of Nigeria.

### Blue Economy Dimensions and Challenges

Blue economy has six main dimensions, namely economic dimension, social dimension, environmental dimension, technological dimension, cultural dimension, and governance dimension. Each dimension is characterised by principles and practices that aim to ensure the sustainable use of ocean resources for the benefit of present and future generations (Lee et al., 2021; Sarwat, 2022). Studies on the blue economy seek to explore the interconnections between these dimensions and to identify pathways for promoting sustainable development that balances economic growth with environmental and social sustainability. Key study areas include ocean governance, marine policy, ecosystem services, climate change adaptation, and sustainable business models. Modern blue economy research aims to create a comprehensive framework that supports the sustainable use of ocean resources for the benefit of both present and future generations.

The Nigerian marine and blue economy sectors and sub-sectors are as follows:

- Marine Trade and Transportation - Marine Transport, Port Infrastructure and Services, Shipbuilding and Repair, Maritime Security, and Maritime Safety;
- Fisheries and Aquaculture - Artisanal, Coastal and Deep-Sea Fisheries, Mariculture, Aquaculture, Fisheries, and Seafood Processing;
- Marine Resources and Industries - Marine Minerals, Blue Technology, Water Desalination, and Laying of Underwater Cables and Pipes;
- Energy and Marine Environmental Sustainability - Blue Energy and Renewables, Marine Pollution and Waste Management, Blue Carbon, and Green Shipping;
- Blue Tourism and Recreation - Coastal and Marine Tourism and Coastal Development

While the blue economy offers many opportunities, it also presents several challenges that must be addressed to ensure its sustainable development. These include: environmental degradation, inadequate or lack of regulation and governance, limited access to finance, limited infrastructure, limited human capacity, and limited market access, (Bari, 2017).

Youssef (2023) concluded that the future of the Blue Economy looks promising as there is growing interest in sustainable ocean development, and as more attention is being paid to the value of the ocean as an economic asset.

**Climate Change and Coastal Erosion**

The Intergovernmental Panel on Climate Change (IPCC) in its Third Assessment Report (TAR), concluded that the globally averaged surface temperature increased 0.60C ± 0.2°C in the 20th century. This warming trend is expected to persist with a 1.40C to 5.8°C increase predicted for the current century. Warming will vary by region and be accompanied by significant changes in precipitation, sea level rise and changes in the frequency and intensity of some extreme events. These changes will impact natural and human systems directly or in synergy with other determinants to alter the productivity, diversity and functions of many ecosystems and livelihoods around the world. Yet these impacts will not be distributed or felt uniformly, as certain ecosystems and populations exhibit higher degrees of vulnerability. Settlements on marginal or unstable lands, such as steep slopes or floodplains, heighten their exposure to the impacts of climate hazards. Heavy dependence on ecosystem services can place their welfare and survival at the mercy of environmental conditions. As the availability and quality of natural resources decline due to natural and human-induced pressures, so does the viability and security of their livelihoods. Limited capacities and resources for responding to stresses such as droughts and floods, constrain their ability to meet basic needs and move out of poverty (IPCC, 2007).

In the hazard-prone areas, mitigation of negative impacts refers to actions that can be taken in advance of disaster events to reduce disaster impacts and losses, or to avoid them entirely. Hazard mitigation measures include the relocation of communities or parts of communities, land-use policies, building code adoption and enforcement, and the retrofitting of hazardous structures. Mitigation is viewed as one phase in the cycle of disaster management; the other three phases are preparedness, response and recovery. In the climate change field, the term mitigation refers to measures designed to reduce greenhouse gas emissions, while the term adaptation is used to describe activities that reduce the effects of climate change on the natural and built environment. From the perspective of hazards, the very broad use of the concept of adaptation by climate scientists serves to blur important distinctions among different types of adaptive strategies.

Climate change will redraw national coastlines, alter where food is grown, change where to find water, expose communities to fiercer storms or more severe droughts, and force large numbers of people to migrate to other locations. Climate change will affect the economic and agricultural base of many countries, particularly vulnerable developing countries, and may undermine their comparative advantage in world markets. It will stress existing mechanisms for sharing resources like trans-boundary rivers and lakes and migratory fish stocks (IPCC, 2007). Danladi et al. (2017) highlighted the vulnerability of the Nigerian coast to sea level rise owing to climate change and anthropogenic activities.

The effects of climate change could be devastating to vulnerable coastal and marine areas as well as to the function and structure of their ecosystems. Increasing sea level (1.7 mm/year) changes the shape of coastlines, contributes to coastal erosion and leads to flooding and more underground salt-water intrusion. Building up resilience to increasing climate variability is the most significant climate challenge facing all countries, including Nigeria. Countries will need to factor climate risks and climate change adaptation into their development planning, and consider the range of interventions that will increase their resilience to climate change (Eboh, 2009).

**National Policy on Marine and Blue Economy**

The National Policy on Marine and Blue Economy is a strategic framework aimed at harnessing Nigeria's vast marine and coastal resources to promote sustainable economic growth, environmental protection, and socio-economic development. It is aimed at transforming Nigeria to a global hub for sustainable marine and blue economy practices, promoting economic development, environmental stewardship, and social equity. It will engender the promotion of responsible utilization of marine resources, the protection

of biodiversity, and while supporting economic activities expanding and diversifying Nigeria's marine-based industries, including fisheries, tourism, and shipping. The policy highlights the need to mitigate the impacts of marine pollution and climate change, to preserve marine ecosystems for future generations, to enhance the livelihoods of coastal communities through inclusive and equitable opportunities in the blue economy, to foster innovation in marine technologies, and to support research initiatives that drive progress in the sector.

Furthermore, the policy addresses the need to implement sustainable fishing practices, protect marine biodiversity, and ensure sustainable exploration within the Exclusive Economic Zones (EEZ) and Areas Beyond National Jurisdiction (ABNJ). It will also restore degraded marine environments and promote marine tourism, development of port infrastructure, and support maritime industries including shipping and offshore oil and gas exploration. Nigeria has developed as a necessity, strategies to reduce marine pollution, address the impacts of climate change, enhance marine protected areas, involve local communities in decision-making processes, enhance their capacities, and provide economic opportunities linked to the blue economy. The policy has identified the need to establish a robust institutional structure for policy implementation, coordination among stakeholders, and enforcement of regulations that will emanate from this policy, it has also called for greater investment in research, technology development, and training programmes to support the growth of the Marine and Blue Economy sectors.

Lastly, the policy recognizes the need to establish mechanisms for tracking progress, assessing impact, and making necessary adjustments to ensure the its effectiveness. Consequently, the policy is expected to contribute to the diversification of the economy through job creation, thereby increasing Nigeria's GDP. The effective implementation of the policy will promote marine ecosystem health, reduce pollution, enhance resilience to climate change, enhance access to economic activities, improve the quality of life, and strengthen social equity among coastal and inland waterways communities.

## CONCLUSION AND RECOMMENDATIONS

The paper reviews the interrelationship between the marine environment and blue economy in coastal communities in Nigeria and concludes that the future of blue economy in Nigeria looks bright, with growing interest in sustainable practices, technological innovation, renewable energy, circular economy principles, sustainable tourism, and blue finance. Stakeholders must work together to promote sustainable development while preserving the ocean's health.

The paper therefore recommends that:

i. The implementation of the National Policy on Marine and Blue Economy and the strengthening of other relevant policy and strategic frameworks to manage the impact of the marine environment on the blue economy of Nigeria's coastal communities (and vice versa) should be carried out without delay.

ii. The Federal Ministry of Marine and Blue Economy should bring on board relevant stakeholders from the Public Sector and the Private Sector to develop the emerging sector.

iii. Necessary strategies should be adopted by stakeholders in the maritime and blue economy sector to ensure sustainable development and conservation of the living and non-living resources in Nigeria's marine environment.

iv. Global best practices on blue economy management and development should be adopted. Relevant United Nations Sustainable Development Goals (SDGs) should be domesticated along

with the implementation of other relevant national policies.

v. Lastly, innovations in science, technology, business, and education needed for social, environmental, and economic benefits in the marine and blue economy sector in Nigeria should be fully embraced.

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# ASSESSMENT OF CONSUMER PREFERENCE FOR SMOKED FISH SPECIES SOLD IN BAGA ROAD FISH MARKET, MAIDUGURI, BORNO STATE, NIGERIA

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**ABSTRACT**

*The study was conducted to determine the Consumer Preference of Smoked fish species sold in Baga road fish market, Maiduguri, Borno State, Nigeria. A community based descriptive study was used for the study. The data were randomly collected in the sampling site, 100 copies of a structured questionnaire were administered. The data gathered from the questionnaire was analysed using descriptive statistics such as frequency distribution and percentage. The highest age group of the respondents was 31-above (50%), followed by age group 21-30 (36%) and least age group (15 - 20) was 14%. It was observed that 35% had no formal education, 15% had primary education, 25% had secondary education and 22% of the respondents had higher level of education. 40% and 37% of the respondents preferred smoked and fresh fish respectively. Tilapia recorded 30% level of preference, while 35% was recorded for catfish and Heterotis niloticus recorded 13% preference.*

**Keywords:** Fresh fish, Marketers, Maiduguri Metropolitan Council, Insurgency

## INTRODUCTION

Fish is the most important source of animal protein available all over the world for human consumption. Fish among all other important protein food stuffs (such as eggs, milk, meat and other animal products), constitute an excellence source of protein (FAO, 2013).Kumar *et al*. (2015) showed that taste (54%) was the most important reason for purchasing catfish specifically C*larias gariepinus* more often than other fish because they are easy to fry (15%) and availability (10%) were the other main reason for preferring catfish (C*larias gariepinus*) to and over (*Heterobranchus bidorsalis, Hetorabranchus longifilis* and *clarias angularis*).African catfish, C*larias gariepinus* is an indigenous fish to Nigeria with good nutritional value and adequate market demand. In order to understand what drivers demand, it is argued that motive or value fulfilment in many situations is a major antecedent for decision making and choices (Brunso, 2009)..Health is a dimension that has become very important for many consumers, and consumers form preferences based on this dimension motivated by expectations of both longer life and are of higher quality (Roininen *et al.*, 2001; vannoppen *et al*., 2002), Taste of food has always been at high importance to most consumers. Food is a matter of pleasure, and few people eat things of which they do not like the taste (Grunert *et al.*, 2001; verbeker, 2016). To date, trend in consumer preference of fish species is a more complex matter than in the past and the idea about the choice of fish species is more dynamic and diversified. Some other consumers consider fish species as responsible for good health (Grunert *et al*., 2001). If consumers are able to understand fish species, characteristics, the introduction of new species in the market would be improved. In this context, there is need for information on fish species as food composition has grown (Brunso *et al*., 2012). Some developing countries mostly consider a future increase in fish species demand and consumption in view of the population increase, fisheries industries have evolved as a consequence of specific consumer demands both in developing and developed countries. According to Regni and Gehlh, 2005, wealthy people prefer time saving fish product and food having high healthy attributes quality and variety.

Local market consumers buying behaviour is a significant determinant of production and marketing decision made by the private and public sectors (Houston *et al*, 1996). Service data (Houston *et al*, 1996) show that consumers react differently to different attributes of fish species. Successful fish traders respond to customers' preferences. However, consumer's behaviour and choice attitude have significant bearing on markets development. Many approaches have been developed in the field of consumers' attitudes and purchasing choice. These are primarily aimed at identifying how behaviour factor might affect market dimension and development. They differ from traditional demand analysis that focused on explaining the relationship between the quantity demand and its determinants such as consumer income, taste and price and aimed primarily at determining consumers' response to income and price change. Operators who are confronted with these progressive changes and need to acquire information about consumer perception, so as to create a business that can withstand the difficulties of main customer purchasing behaviour and suggestion. The study was therefore designed to determine the consumer preference of fish species in Baga road Fish market in Maiduguri and factors that affects consumption pattern of different species of smoked fish in the study area.

## MATERIALS AND METHOD

### Study Area

The study area is Maiduguri the Capital of Borno State of Nigeria, It lies with latitude 11° 50" 48.91°Nand Longitude 13° 09°25,63°E. It occupies a total mass of 50, 7782km (Ministry of land and Survey Maiduguri, 2008). The sahelial climate is characterized with their distinct seasons: rainy and dry seasons. The rainy season starts on the average from June to October with mean annual rainfall ranging from 200mm to 500mm; dry season starts from November to April/May which is a period of very low temperature and dry harmattan wind. The dry hot season starts from March to June with temperature ranging from 27°C to 40°C making the driest period with intense heat (Adadu and Ochogwu, 2020)

### Sampling Site

The sampling site is Baga road fish market Maiduguri, Borno State Nigeria.

### Data Collections

The tools for data collection were structured questionnaire and oral interview. The data were randomly collected in the sampling site. 100 copies of the structured questionnaire were distributed to the respondents in the study area, retrieved and collated.

### Data Analysis

The data gathered from the questionnaire was analysed using descriptive statistics such as frequency distribution and percentage.

## RESULTS

The results of social demographic characteristics of respondents are as showed in Table 1. Age group (31 and above) of respondents has the highest frequency (50%) while (15 – 20) has the lowest (14%). Male gender participation was 71% while female was 29%. Educational qualification of respondents shows that primary education was 38% while none formal was 15%. Occupation of respondents shows that civil servants were 42, businessmen were 35, farmers 17, while others were 06 out of 100 respondents served the questionnaire.

**Table 1:** Social Demographic Characteristics of Respondents

| Variable | Frequency (N = 100) | | | Percentage (%) |
|---|---|---|---|---|
| **Age of the Respondents** | | **Male** | **Female** | |
| 15-20 | 14 | 7 | 7 | 14 |
| 21-30 | 36 | 24 | 12 | 36 |
| 31-and above | 50 | 40 | 10 | 50 |
| **Gender of the Respondents** | | | | |
| Male | 71 | | | 71 |
| Female | 29 | | | 29 |
| **Educational Level of the Respondents** | | **Male** | **Female** | |
| None Formal | 15 | 10 | 5 | 15 |
| Primary | 38 | 27 | 11 | 38 |
| Secondary | 29 | 20 | 9 | 29 |
| Tertiary | 18 | 14 | 4 | 18 |
| **Occupation of the Respondents** | | **Male** | **Female** | |
| Civil Servant | 42 | 30 | 12 | 42 |
| Farmer | 17 | 12 | 5 | 17 |
| Businessmen | 35 | 28 | 7 | 35 |
| Others | 06 | 1 | 5 | 06 |

***Source:*** *Field Survey, 2024*

The results of species of fish and fish form preference are shown in Table 2. Results show that 35% of respondents prefer Catfish, 30% prefer Tilapia, 15% (*Lates niloticus*), 13% (*Heterotis niloticus*) while 07% prefer other species of fish.

**Table 2:** Species of Fish and Form Preferred by Respondents

| Variables | Frequency (N = 100) | | | Percentage (%) |
|---|---|---|---|---|
| **Species of Fish Preferred by respondents** | | | | |
| Catfish | 35 | | | 35 |
| Tilapia | 30 | | | 30 |
| *Lates niloticus* | 15 | | | 15 |
| *Heterotis niloticus* | 13 | | | 13 |
| Others | 07 | | | 07 |
| **Form of Fish Preferred by respondents** | | **Male** | **Female** | |
| Smoked fish | 69 | 50 | 19 | 69 |
| Sun-dried | 31 | 21 | 10 | 31 |

***Source****: Field Survey, 2024*

## DISCUSSION

In this study, there was high frequency in fish consumption found between the age, gender, educational level and occupation of respondents. This is in agreement with Umar *et al.* (2018), who stated that fish preferences are affected by taste, behaviour, believed and personal characteristics. The consumption level of male (71.0%) was two times greater than that of female. The high level of male respondents could be attributed to the fact that they were the ones that visits the market most frequently to purchase food items. The consumption of age group 31and above was greater than other age groups in this study. This

age group consists mostly of youths that are strong and energetic, who can be sent to the market by their loved ones. In this study, consumers with formal education (primary, secondary and tertiary) put together, are greater (85%) than those with non-formal education (15%). Therefore, it can be opined that education and income level might have effects on the choice of smoked fish. Educational status has a great influence on the knowledge of so many events, including fish consumption. This is in agreement with myrland (2000), The study also revealed that civil servants have high level of fish consumption. This could be because they have more money compared to other respondents in this study.

The present study indicated that there was a clear difference between the species of smoked fish preferred by the respondents. 30% of the respondents preferred tilapia, while 13% of the respondents preferred *Heterotis niloticus*. According to the report of this study, respondents' most preferred fish species is catfish (35%). Public fish consumption was low in Baga road fish market Maiduguri. This will not be unconnected with the impact of the Nigerian economy on the citizens. This is in agreement with reported work of Cevger *et al*. (2018) on Antakya, a coastal city. Fish consumption preference in the study was quite below the average of European Union (EU) (48.00%) and the world (36.00%) (FAO/UN, 2013). The high percentage of Tilapia preferred by consumers in this study could be attributed to affordability. However, catfish and *Heterotis niloticus* are in high demand even though their prices are higher than Tilapia. Catfishes are being transported to other parts of Nigeria because of its protein content and the fact that they are easily smoked unlike *L. niloticus* and *H. niloticus* that are too expensive and not many consumers can afford them. Smoked fish and freshness are two other important factors affecting fish consumption. In this study, 69.0% and 31.0% of the respondents preferred smoked and sundried fish respectively. Smoked fish can be transported to far places and can be preserved for a long period of time with same pleasant taste.

## CONCLUSION

Fish consumption and preference are affected by consumers' geographic, social and cultural characteristics. The findings of this study reveal that fish preferences are affected by taste, behaviour, believed and personal characteristics in the study area. People prefer Catfish to other fish species in the study area. Most respondents have formal education which could inform their choice/ preference.

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# ECONOMIC VIABILITY OF FRUIT WASTE IN ENHANCING PROFITABILITY OF AQUACULTURE

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**ABSTRACT**

*The global fruit production generates substantial agro-industrial waste, which offers a sustainable alternative to conventional fish feed ingredients. This study assesses the impact of incorporating dietary fruit waste on the economic profitability of hybrid red tilapia. The study compared the cost-benefit analysis of diets containing jackfruit pulp, grated coconut, jackfruit peel, pineapple peel, and pineapple crown with a control diet of cornmeal. The bioeconomic analysis showed that Jackfruit pulp yielded the highest profit of $0.72 per tank, representing a significant improvement over the control ($0.42) per tank. However, the data from the cost-benefit analysis from the post-challenge test revealed that Jackfruit pulp remained the top performer, generating a positive profit ($0.35) with a return on investment (55.56%), followed by Coconut waste and Pineapple peel. The control recorded the lowest ROI (23.44%) after the bacterial challenge, which was attributed to the low survival rate. This could result in significant losses for farmers. These findings suggest that fruit waste is a resilient, cost-effective, and sustainable feed additive option with potential applications in commercial aquaculture production.*

**Keywords**: Cost-benefit, resilient, waste management, cost efficiency, profit,

## INTRODUCTION

The global demand for seafood has been increasing, accompanied by a significant rise in aquaculture production (Mahari et al., 2022; J. Wang et al., 2023). However, the industry faces several challenges, including the cost of feed ingredients and disease outbreaks (Akpoilih, 2023). Effective techniques must be used to mitigate the intensifying stress as fish and crustaceans are vulnerable to stress and diseases during intensive culture (Lumsangkul et al., 2022). Alternative substances, such as fruit waste, are recommended because they not only contain acceptable nutritional value but are lower in cost and have been used with proven effectiveness (Sulaiman et al., 2022). They are rich in carbohydrates, fibre, vitamins, and minerals, which can be used as a replacement for some traditional ingredients in aquafeed (Kawata et al., 2021). Fruit waste-based diets are less expensive than traditional feeds, which makes them more accessible to farmers in developing economies (Sampathkumar & Loo, 2023). Several studies have investigated the use of fruit waste in aquafeed and its impacts on growth performance. In 2023, the world produced approximately 952 million tonnes of fruit, accounting for a combined total of 2.1 billion tonnes of fruit and vegetables (FAO, 2024). Fruit processing typically generates about 25–30% by-products from the peels, pomace and seeds, implying roughly 230–280 million tonnes of solid processing

waste annually from fruit alone (Argun & Ates, 2025). Recent syntheses estimate that the fruit-processing industry generates more than 190 million tonnes of solid waste per year, and when wastewater streams are included, the total waste generated by the fruit industry is approximately 0.5 billion tonnes annually (Shahkoomahally et al., 2021). About 75% of all fruits are wasted worldwide during production and processing (Błaszczyk et al., 2024; Esparza et al., 2020). A review by Greff et al. (2023), fruit by-products contain 20,000 bioactive compounds that have potential industrial uses such as food additives and medicines. These compounds include but are not limited to polyphenols, pectins, and carotenoids (Plaskova & Mlcek, 2023). These bioactive compounds help boost the immune system in aquatic species (Sulaiman et al., 2022). For instance, fruit waste is rich in polysaccharides, which are important prebiotic additives that help maintain the balance of bacterial flora in the intestines, thereby improving digestion and intestinal immunity (Bhatt & Gupta, 2023; Gao et al., 2023).

Tilapia, particularly hybrid red tilapia (O*reochromis niloticus* × O. mossambicus), has significant growth potential; however, traditional farming methods are becoming unsustainable. The hybrid red tilapia is derived from the selective breeding of O*reochromis niloticus* x O. *mossambicus*, exhibiting enhanced growth rates, appealing vibrant colouration and resilience (Yang *et al*., 2024). They are good for commercial production with rapid growth performance, tolerance, and adaptation to change in water quality parameters, making it an excellent candidate for commercial production as a food and animal protein source (Hilsdorf *et al*., 2022; El-Dakar *et al*., 2024). However, the cost of feed ingredients and nutritionally related disease outbreaks results in reduced production. These are among the primary culprits affecting hybrid growth, production, and resulting in a significant loss to farmers (Jones, Le Anh, & Priyambodo, 2019; Saputra & Fotedar, 2023). The use of fruit waste in aquafeed may reduce pressure on feed ingredients and lower the cost of aquaculture production. This study assesses the impact of incorporating dietary fruit waste on the economic profitability of hybrid red tilapia. The research will assess the potential cost-benefit analysis associated with supplementing fruit waste. The findings of this research could have significant implications for the aquaculture industry by providing valuable insights into the utilisation of fruit waste as a sustainable feed additive. This may improve food security, enhance waste management, promote a circular economy, and support sustainable fish production.

## MATERIALS AND METHODS

### Economic analysis

This cost analysis was based on the data published on the growth and biological effects of fruit waste according to Sulaiman et al. (2022), where cost analysis data were not included for publication. The experimental diets were economically evaluated by calculating the cost of feed in USD required to produce 1 kg of live fish weight. Total costs and net profits of the feeding trial (S1) and after the challenge test (S2) were calculated as follows:

$$\text{Feed cost/kg fish} = \text{Feed cost/kg feed} \times \text{FCR}$$

$$\text{Total costs} = \text{Feed cost} + \text{Juvenile cost}$$

$$\text{Net Profit (NP)} = \text{Total income} - \text{total cost}$$

$$\text{Profit ratio (\%)} = 100 \times (\text{profit/total cost})$$

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Total sales}}{\text{Total cost}}$$

$$\text{Return on Investment (ROI)} = \frac{\text{Profit}}{\text{Total cost}} \times 100$$

$$\text{Weight Gain (WG)} = \frac{(\text{Final weight} - \text{Initial weight})}{\text{Initial weight}}$$

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Total Feed Intake}}{\text{Weight gain}}$$

$$\text{Survival (\%) after challenge} = \frac{\text{Initial stocking} - \text{Dead fish}}{\text{Initial stocking}} \times 100$$

**Data analysis**

All data from each trial were subjected to one-way analysis of variance (ANOVA) after prior confirmation of data homogeneity using Statistical Analysis System 9.5 for Windows (SAS Inc., USA). Differences among dietary treatments were determined using Tukey's test.

## RESULTS

**Economic analysis**

The cost-benefit analysis of hybrid tilapia pre-challenged showed significant variation ($p < 0.05$)**.** Net profit was highest in fish fed JP and GC, with values of $ 0.72 and $ 0.62, which correspond to 3,573,00 $/ha and 3,101,000 $/ha, respectively, followed by PS at $ 0.59 (2,961,000 $/ha). Meanwhile, the control at $ 0.42 (2,129,000 $/ha) and PC at $ 0.25 (1,240,000 $/ha) had the lowest positive values **(Table 2)**. Benefit Cost Ratio values were significantly higher ($p < 0.05$) in JP (2.14), GC (1.98) and PS (1.94) when compared to CN (1.66) and PC (1.40). The return on investment ROI exceeded 100% in JP (114.29%), then GC (98.41%), 93.65% in PS, and 65.63% in CN, while PC returned 39.68%. Cost per kilogram of biomass was lowest in JP and GC (1.97 and 2.12 $/kg), not significant with PS (2.17 $/kg), although the highest was observed in CN (2.52 $/kg) and PC (3.01 $/kg).

The cost-benefit analysis of hybrid red tilapia after a 15-day *Aeromonas hydrophila* challenge test showed significant variation ($p < 0.05$)**.** The net profit was highest in JP at $0.35, corresponding to $1,751,000/ha, followed by GC and PS at $0.26. Meanwhile, the control (CN) and PC recorded negative values of -$0.15 (-$750,000/ha) and -$0.14 (-$712,000/ha), respectively **(Table 3)**. Benefit Cost Ratio values were significantly higher ($p < 0.05$) in JP (1.56), GC (1.41) and PS (1.41) when compared to CN (0.77) and PC (0.74). The ROI was less than 100% in JP (55.56%), 41.27% in GC and PS, while CN had the lowest return, 23.44%.

**Table 2**: Economic analysis of hybrid red tilapia fed with different fruit-wastes (PRE S1)

| | Fruit Wastes | | | | | |
|---|---|---|---|---|---|---|
| | Control (CN) | Pineapple Peel (PS) | Pineapple Crown (PC) | Jackfruit Peel (JS) | Jackfruit Pulp (JP) | Grated Coconut (GC) |
| Total cost ($) | $0.64 \pm 0.06^{a}$ | $0.63 \pm 0.07^{a}$ | $0.63 \pm 0.07^{b}$ | $0.63 \pm 0.10^{b}$ | $0.63 \pm 0.19^{b}$ | $0.63 \pm 0.10^{b}$ |
| Revenue ($) | $1.06 \pm 0.08^{c}$ | $1.22 \pm 0.08^{a}$ | $0.88 \pm 0.08^{a}$ | $0.97 \pm 0.08^{b}$ | $1.35 \pm 0.08^{a}$ | $1.25 \pm 0.06^{a}$ |
| Net profit ($) | $0.42 \pm 0.14^{d}$ | $0.59 \pm 0.15^{c}$ | $0.25 \pm 0.14^{a}$ | $0.34 \pm 0.14^{b}$ | $0.72 \pm 0.16^{a}$ | $0.62 \pm 0.17^{a}$ |
| BCR | $1.66 \pm 0.09^{d}$ | $1.94 \pm 0.09^{c}$ | $1.40 \pm 0.06^{b}$ | $1.54 \pm 0.12^{b}$ | $2.14 \pm 0.07^{a}$ | $1.98 \pm 0.05^{a}$ |
| ROI per cycle (%) | $65.63 \pm 0.05^{d}$ | $93.65 \pm 0.12^{c}$ | $39.68 \pm 0.15^{a}$ | $53.97 \pm 0.08^{b}$ | $114.29 \pm 0.14^{a}$ | $98.41 \pm 0.06^{a}$ |
| FCR | $1.71 \pm 0.11^{c}$ | $1.37 \pm 0.06^{a}$ | $1.62 \pm 0.09^{a}$ | $1.64 \pm 0.09^{a}$ | $1.15 \pm 0.05^{a}$ | $1.21 \pm 0.07^{a}$ |
| Cost per kg ($/kg) | $2.517 \pm 0.08^{c}$ | $2.166 \pm 0.07^{b}$ | $3.014 \pm 0.10^{c}$ | $2.722 \pm 0.11^{c}$ | $1.969 \pm 0.08^{c}$ | $2.117 \pm 0.09^{c}$ |
| Production (kg/ha) | $1265000 \pm 0.06^{d}$ | $1456000 \pm 0.12^{b}$ | $1046000 \pm 0.18^{b}$ | $1158000 \pm 0.14^{c}$ | $1601000 \pm 0.18^{a}$ | $1489000 \pm 0.18^{a}$ |
| Revenue ($/ha) | $5313000 \pm 0.08^{d}$ | $6114000 \pm 0.08^{b}$ | $4392000 \pm 0.16^{b}$ | $4865000 \pm 0.10^{c}$ | $6725000 \pm 0.12^{a}$ | $6254000 \pm 0.05^{a}$ |
| Net profit ($/ha) | $2129000 \pm 0.15^{c}$ | $2961000 \pm 0.09^{d}$ | $1240000 \pm 0.18^{b}$ | $1712000 \pm 0.12^{c}$ | $3573000 \pm 0.21^{a}$ | $3101000 \pm 0.14^{a}$ |

Values are means ± SE (n = 4). Different superscripts in the same row indicate significant differences ($P < 0.05$). BCR = Benefit cost ratio; $ = United States dollar; ha = hectare.

**Table 3**: Economic analysis of hybrid red tilapia fed with different fruit-wastes (POST S2)

| | Fruit Wastes | | | | | |
|---|---|---|---|---|---|---|
| **Nutrient** | **Control** | **Pineapple Peel** | **Pineapple Crown** | **Jackfruit Peel** | **Jackfruit Pulp** | **Grated Coconut** |
| Total cost ($) | $0.64 \pm 0.07^{a}$ | $0.63 \pm 0.04^{a}$ | $0.63 \pm 0.07^{b}$ | $0.63 \pm 0.13^{b}$ | $0.63 \pm 0.05^{b}$ | $0.63 \pm 0.06^{b}$ |
| Revenue ($) | $0.49 \pm 0.15^{c}$ | $0.89 \pm 0.06^{a}$ | $0.49 \pm 0.08^{a}$ | $0.67 \pm 0.21^{b}$ | $0.98 \pm 0.10^{a}$ | $0.89 \pm 0.13^{a}$ |
| Net profit ($) | $-0.15 \pm 0.06^{d}$ | $0.26 \pm 0.11^{c}$ | $-0.14 \pm 0.04^{a}$ | $0.04 \pm 0.10^{b}$ | $0.35 \pm 0.11^{a}$ | $0.26 \pm 0.07^{a}$ |
| BCR | $0.77 \pm 0.12^{d}$ | $1.41 \pm 0.09^{c}$ | $0.74 \pm 0.05^{b}$ | $1.06 \pm 0.02^{b}$ | $1.56 \pm 0.07^{a}$ | $1.41 \pm 0.13^{a}$ |
| ROI per cycle (%) | $-23.44 \pm 0.05^{d}$ | $41.27 \pm 0.14^{c}$ | $-22.22 \pm 0.03^{a}$ | $6.35 \pm 0.07^{b}$ | $55.56 \pm 0.06^{a}$ | $41.27 \pm 0.06^{a}$ |
| Cost per kg ($/kg) | $2.517 \pm 0.07^{a}$ | $2.166 \pm 0.06^{b}$ | $3.014 \pm 0.12^{c}$ | $2.722 \pm 0.04^{c}$ | $1.969 \pm 0.08^{c}$ | $2.117 \pm 0.08^{c}$ |
| Production (kg/ha) | $580000 \pm 0.04^{d}$ | $1054000 \pm 0.15^{b}$ | $581000 \pm 0.08^{b}$ | $8000 \pm 0.15^{c}$ | $1168000 \pm 0.18^{a}$ | $1055000 \pm 0.13^{a}$ |
| Revenue ($/ha) | $2434000 \pm 0.08^{d}$ | $4428000 \pm 0.13^{b}$ | $2440000 \pm 0.10^{b}$ | $3360000 \pm 0.11^{c}$ | $4904000 \pm 0.07^{a}$ | $4430000 \pm 0.07^{a}$ |
| Net profit ($/ha) | $-750000 \pm 0.017^{c}$ | $1275000 \pm 0.11^{d}$ | $-712000 \pm 0.18^{b}$ | $208000 \pm 0.07^{c}$ | $1751000 \pm 0.13^{a}$ | $1277000 \pm 0.13^{a}$ |

Values are means ± SE (n = 4). Different superscripts in the same row indicate significant differences ($P < 0.05$). BCR = Benefit cost ratio; $ = United States dollar; ha = hectare.

## DISCUSSION

Global commercial fruit farming has expanded significantly, leading to increased fruit production and corresponding waste generation (Caipang et al., 2019; Md Nor & Ding, 2020). Improper disposal of fruit waste into rivers or landfills poses significant environmental risks, including organic pollution (Galintin et al., 2021). However, this by-product holds potential as a valuable feed ingredient for aquaculture (Kawata et al., 2021). The inclusion of specific fruit wastes in the diet significantly improved growth rate and weight gain in hybrid red tilapia (Sulaiman et al., 2022; Van Doan et al., 2021). Incorporating fruit waste into aquafeed offers significant cost-saving potential. The economic evaluation from the current study revealed substantial profit increases in tilapia farming when compared to the control group using conventional cornmeal. Jackfruit pulp yielded the highest profit increase, with a gain of $0.72 per tank equivalent, equivalent to $3,573,000 per hectare, representing a significant improvement over the control, which yielded $0.42 ($2,129,000/ha). Grated waste achieved a comparable profit increase of $0.62 ($3,101,000/ha), while pineapple peel (PS) provided a $0.59 ($2,961,000/ha) in earnings. Jackfruit peel demonstrated a $0.34 ($1712000/ha) profit enhancement and pineapple crown, although less impactful, still showed a significant $0.25 ($1240000/ha). Therefore, Jackfruit pulp and Coconut waste provided the strongest margins and cost efficiency before the disease challenge test (Sulaiman et al., 2025). Post-challenge showed disease stress compressed profitability across all diets, but fruit-waste treatments were more resilient. Jackfruit pulp remained the top performer with a positive profit of $0.35 per tank ($1,751000/ha), whereas Coconut waste and Pineapple peel retained smaller yet positive profits ($0.26 each). In contrast, Control and Pineapple Crown became less productive. BCRs stay above 1.0 for JP (1.56), GC (1.41), and PS (1.41), but fell below 1.0 for CN (0.77) and Pineapple crown (0.74), indicating costs outweighed benefits in Control and Pineapple crown (Wang et al., 2025). The ROI declined under challengee, yet remained positive for JP (55.56%) and moderate for Coconut waste and pineapple (41.27%), while Control returned the lowest (23.44%). These outcomes highlight the economic protection conferred by fruit waste diets when mortality risks rise (Sulaiman et al., 2025). These results are consistent with follow-up feeding trials involving *Tor tambroides*, further supporting the economic feasibility of integrating fruit waste into aquaculture diets. The use of by-products, such as pineapple peel, jackfruit pulp, and coconut waste, enables farmers to reduce production expenses without compromising feed quality. This economic advantage stems from the reduced dependency on expensive conventional ingredients, such as corn, cassava and soybean meal (Goren et al., 2024). Finally, the BCR values follow standard cost-benefit analysis; BCR > 1 indicates that benefits exceed costs whereas BCR < 1 indicates economic infeasibility matching the post-challenge results where Control and Pineapple Crown fell below unity (Wang et al., 2025). This approach underscores the importance of optimizing resource use in aquaculture through sustainable feed practices, with long-term ecological and financial gains.

## CONCLUSION

The findings of this study highlight the potential of utilizing fruit waste as a sustainable and cost-effective feed alternative in aquaculture. Jackfruit Pulp and Coconut waste deliver the best cost efficiency and returns. Under disease pressure, they also maintain positive margins and a BCR greater than 1. Pineapple peel is competitive in both contexts and notably resilient after the challenge. Additionally, the environmental benefits of reducing organic waste further enhance the sustainability of aquaculture systems. Future research should focus on large-scale applications and optimizing formulations to maximise the potential of fruit waste in commercial aquafeed production.

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## CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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# CLIMATE CHANGE AND GENDERS IN FISHERIES AND AQUACULTURE – CCGFA

# THE EFFECTS OF CLIMATE CHANGE ON FISH PRODUCTION IN NIGERIA

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**ABSTRACT**
*The fisheries and aquaculture sectors in Nigeria are increasingly vulnerable to the multifaceted impacts of climate change. As environmental conditions shift, rising temperatures, irregular rainfall patterns, and ocean acidification are reshaping aquatic ecosystems and threatening fish productivity. The ecological and socioeconomic consequences of these changes extend to reduced biodiversity, declining yields, and heightened risks to food security and livelihoods. The paper advocates for integration of conventional mitigation approaches, negative emission technologies, and renewable energy innovations which remains imperative to achieving long term climate stability and safeguarding Nigeria's fisheries sector.*

**Keywords:** Climate Change, Fisheries, Aquaculture, acidification, climate resilience.

## INTRODUCTION

Climate change refers to significant and lasting changes in weather patterns caused largely by greenhouse gas emissions from human activities such as fossil fuel combustion, deforestation, and industrialization (IPCC, 2007; Eboh, 2009). These changes influence temperature, rainfall, and water availability, resulting in droughts, floods, and other extreme weather events that threaten agriculture and fisheries (NEST, 2011). Variations in temperature and ocean conditions alter fish migration, breeding, and survival, leading to reduced fish biodiversity and productivity (Brander, 2010). Developing countries, particularly in Africa, are most vulnerable due to low adaptive capacities and dependence on climate sensitive livelihoods like rain fed agriculture (Nwafor, 2007). In Nigeria, where fish contributes significantly to food security and livelihoods, climate induced production declines have widened the gap between local supply (1.12 million metric tons) and demand (3.32 million metric tons) (FAO, 2014). The deficit is met largely through imports, which strain the economy. Thus, while climate change poses global threats, its impacts are more severe in Nigeria's fisheries sector, where reduced yields, habitat loss, and economic instability are evident (Akintola *et al.*, 2015).

## OVERVIEW OF FISH PRODUCTION IN NIGERIA

Aquaculture in Nigeria has developed remarkably from its colonial origins to a major agricultural sector today. Modern fish culture began around 1941 when the colonial authorities established a fishery organization in Lagos to evaluate aquatic resources in Nigeria (Adewumi *et al.*, 2010). By 1945, the organization merged with the Department of Commerce and Industries and was later renamed the Federal Fisheries Services in 1950. The first industrial scale fish farm was established at Panyam near Jos in 1951 for the culture of carp (Ajayi *et al.*, 2022).

Fish culture intensified in the mid 1960s through cooperation with the Food and Agriculture Organisation (FAO, 1969). During this period, various species such as the African catfish (*Clarias gariepinus*), sharptooth catfish (*Heterobranchus longifilis*), tilapia (*Oreochromis niloticus*), and common carp (*Cyprinus carpio*) were introduced and farmed either singly or in combination (Oboh, 2022). The hybrid "Heteroclarias" also became popular, while the African bonytongue (*Heterotis niloticus*) emerged as a promising aquaculture species (Ozigbo, *et al.*, 2014).

From 1960 to 1970, fish production increased tenfold, giving confidence to more Nigerians to invest in aquaculture (Kaleem & Sabi, 2021). Production rose from about 2,000 tonnes in 1960 to over 300,000 tonnes by 2015, though it slightly declined to 275,645 tonnes in 2019 and 260,000 tonnes in 2020 due to the COVID-19 impact (FAO, 2022). Nigeria is now ranked as the leading aquaculture-producing nation in Sub-Saharan Africa (Ajayi *et al.*, 2022), with the African catfish contributing over 65% of national production (FAO, 2023). The species' adaptability, market value, and growth performance have made fish farming one of the fastest-growing agricultural businesses in the country (FAO, 2022).

## IMPACT OF CLIMATE CHANGE ON FISH PRODUCTION IN NIGERIA

The impacts of climate change on fish populations are multifaceted and far-reaching, with significant consequences for the health, productivity, and sustainability of marine ecosystems. These include but not limited to the following:

### 1. Rising Temperatures and Species Distribution

Increasing global and regional temperatures have altered aquatic ecosystems in Nigeria, affecting both wild and cultured fish species. Warmer waters are causing fish to migrate toward cooler regions, which disrupts traditional fishing areas and reduces species diversity (Nuon *et al.*, 2024). Temperature changes also influence the growth, reproduction, and survival of fish. While slightly warmer waters can accelerate growth, excessive heat reduces oxygen concentration, impairing fish metabolism and leading to stress and higher mortality rates (Hochachka & Somero, 2002). Furthermore, elevated temperatures increase the prevalence of pathogens and parasites in aquaculture systems, exposing fish to diseases and weakening their overall productivity.

### 2. Rainfall Variability and Water Availability

Erratic rainfall patterns caused by climate change have a significant impact on fish farming and natural water bodies. Frequent flooding and prolonged droughts alter pond water levels and degrade water quality, both of which are vital for aquaculture productivity. Inconsistencies in rainfall affect fish growth rates and can destroy hatcheries and other infrastructure necessary for production (Ezeh *et al.*, 2020). Wahab and Iyiola (2023) observed that unpredictable rainfall modifies river flows and wetlands, disrupting fish breeding cycles and leading to habitat loss. These fluctuations make fish production increasingly unstable across different regions of Nigeria.

### 3. Ocean Acidification and Aquatic Biodiversity

The rising concentration of carbon dioxide ($CO_2$) in the atmosphere contributes to ocean acidification, which reduces pH levels in aquatic environments. Acidified waters pose a serious threat to species with calcium carbonate shells or structures, such as shellfish, thereby weakening marine food webs and lowering fish yields (Griggs & Reguero, 2021). According to Ezenwa (2022), this phenomenon may significantly alter marine ecosystems and reduce the availability of key fish species in Nigerian coastal waters.

### 4. Socioeconomic Consequences

Beyond the ecological disruptions, climate change has serious social and economic implications. Declining fish stocks, combined with reduced aquaculture output, limit the protein supply for millions of Nigerians while threatening the livelihoods of fishing communities. These losses contribute to food insecurity, declining household incomes, and growing competition over limited aquatic resources (Ezenwa, 2022). The continued decline of fisheries and aquaculture could endanger Nigeria's progress toward achieving the Sustainable Development Goals related to hunger and poverty reduction.

## MITIGATING STRATEGIES OF CLIMATE CHANGE

Mitigating climate change requires coordinated strategies to reduce greenhouse gas emissions and stabilize global temperatures. There are three main approaches to this: conventional mitigation, negative emissions technologies (NETs), and radiative forcing geoengineering.

Conventional mitigation focuses on reducing fossil fuel-based carbon dioxide emissions through renewable energy, energy efficiency, fuel switching, nuclear power, and carbon capture, storage, and utilization (CCSU). Studies such as Mathy et al. (2018) and Hache (2015) highlight the importance of renewable energy solar, wind, and bioenergy in decarbonization, while Pitelis et al. (2019) and Shivakumar et al. (2019) stress the role of supportive policies and social acceptance in their deployment.
Negative emissions technologies aim to capture and store atmospheric carbon dioxide. Key examples include bioenergy with carbon capture and storage (BECCS), afforestation and reforestation, biochar, soil carbon sequestration, and ocean-based carbon removal. According to Gasser et al. (2015) and Fuss et al. (2018), achieving the Paris Agreement's 1.5 to 2 °C target will require integrating NETs alongside conventional methods. However, large scale deployment may lead to land use conflicts (Heck *et al.*, 2018), ecosystem disruption (Harper *et al.*, 2018), and high implementation costs (Fuss *et al.*, 2018).
Radiative forcing geoengineering represents a third approach techniques such as stratospheric aerosol injection and marine cloud brightening aim to reduce global temperatures by reflecting solar radiation. Yet, as Lawrence et al. (2018) warn, these remain experimental and carry considerable environmental and ethical risks.

## CONCLUSION

Climate change has emerged as a critical driver of decline in Nigeria's fisheries and aquaculture sectors. Its manifestations rising temperatures, variable rainfall, and increasing acidification disrupt aquatic ecosystems and threaten the sustainability of fish production. As this review underscores, effective adaptation must focus on building resilience through sustainable aquaculture practices, technological innovation, and supportive policy interventions. In parallel, national and global mitigation efforts aimed at reducing greenhouse gas emissions remain vital. Strengthening institutional capacity, research, and stakeholder collaboration will be key to safeguarding Nigeria's fisheries and ensuring the sector's contribution to food security and economic stability in a changing climate.

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# SUSTAINABLE FISH FARMING IN A CHANGING CLIMATE, AN ANALYSIS OF COPING STRATEGIES IN ENUGU STATE, NIGERIA

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**ABSTRACT**
*This study analyzed climate change and fish farming, an analysis of coping strategies in Enugu State, Nigeria. Muiti-stage sampling technique and descriptive statistics were all employed for this study. Results on socio-economic characteristics of the respondents showed that the age range of 41-50 years had the highest percentage with 34.4% showing that most of the fish farmers were in their active age range. Most of the fish farmers were married with 51.6%, while 39.1% of the respondents had secondary school level of education as their highest level of education, meaning that ideas and innovations introduced to these fish farmers will easily be adopted, also about 37.5% of the fish farmers had household size of 1-5 persons showing they have fairly available labour in the rearing of fishes in the study area while 36.0% of the respondents have between 7-19 years of fish farming and climate change mitigating experience. Furthermore, the result showed that the most felt effect of climate change was high incidence of drought with a mean of 2.48, followed by high temperatures/increased heat waves with mean of 2.42. The study showed that the most coping strategies adopted by the fish farmers were, rearing of fishes that are highly resistant to climate change, adoption of ideas and innovations introduced to them by extension agents, followed by digging of boreholes and wells for water during drought, also with stocking of quick maturing species of fishes and construction of ponds close to water sources in the study area.*

**Keywords**: Fish farming, climate change, impact, coping, strategies

## INTRODUCTION

Climate change has led to the vulnerability of countries producing fishes and countries dependent on fish production (Allison *et al*., 2009). Fishing population variables such as stability, utilization, access and availability are been altered by climate change (Garcia 2010). Climate change had led to sea-level rise resulting in temperature increase and low-oxygen content in seawater which can lead to aquatic animals' extinction (Portner and Knust, 2007). This situation is a serious concern to poorest countries nutrition as about three billion persons depend on the fish protein (World Fish Centre, 2008). Considering Nigeria's enormous water resources, human capital and other natural endowments, the Federal Department of Fisheries estimated fish production of over 1.7mmt comprising 201,300mt (offshore fisheries), 288,200mt (inland fisheries) and 1,180,215mt (aquaculture) (Aphunu and Nwabeze, 2012). Climate change requires the development of natural resources management strategies that ensures the sustainable use of soil and water, halt biodiversity decline and deal with emerging issues such as demand for renewable energy (Aphunu and Nwabeze, 2012), therefore, efforts must be put into reducing human activities enhancing climate change and also improving on ways to adapt to the consequences of the change. In lieu of this, this study was aimed at analyzing climate change and fish farming in Enugu State with the following objectives; to describe the socio-economic characteristics, identify the source of climate change information, examine the impact of climate change on fish farming and to examine the coping strategies of fish farmers to climate change in the study area.

## METHODOLOGY

### Study Area

This research was carried out in Enugu State, Nigeria. The State covers a total of 7,161square kilometers of land mass and it is bounded in the South by Abia State and in the North by Kogi State. To the West, it is bounded by Anambra State while in the East it is bounded partly by Benue State and partly by Ebonyi State. Enugu State is found on latitude $6.5000^0$N and longitude $7.5000^0$E. The State is made up of seventeen (17) Local Governments Areas (LGAs). According to the (City Population, 2022), Enugu State population stood at 5,590,513 people thus making it rank among the most populous states in the country. The major occupations of the people living in the State are farming and trading while a few work as civil servants. Both cash crops and food crops including fruits and vegetables are produced in Enugu State. There are two distinct seasons namely wet and dry seasons.

### Sampling procedure and sample size

The study was conducted in two local government areas of Enugu State, Nigeria. The targeted sample size were fish farmers in two selected local government areas namely; Oji-River and Achi LGAs. Multi-stage random sampling technique was employed. In the first stage, two local government areas were purposively selected due to their high rate of climate change and fish farming. In the second stage, four communities per local government area were randomly selected, totaling 8 communities. In the final stage, eight respondents were randomly selected from each community resulting in a sample size of sixty-four (64) respondents.

Analytical tools used were descriptive statistics; frequency, percentages and likert scale. Descriptive statistics were used to analyze all the objectives of the study. A three point likert scale was used to capture the perception of the fish farmers on climate change, to obtain the mean cut off point, the scored responses were multiplied by each weight and divided by the responses pooled together with the decision being (3+2+1 =6/3 =2). Implying that any impact with mean score of 2.0 and above was a major impact and any with mean score of less than 2.0 was not a major impact in the study area.

## RESULTS AND DISCUSSION

### Socio-economic Characteristics

Results from Table 1, shows that the majority of respondents (34.4%) were between the ages of 41 and 50 years, with a mean age of 29 years. These findings suggest that those in the 31–50 age range were likely to be more resilient to fatigue from the arduous work and effort required to rear fishes and adapt to climate change in the study area. According to the study by Anugwo and Egwue, (2024) in high cost of feed among poultry farmers in Enugu State, Nigeria, observed that majority of the poultry farmers were middle-aged and these findings are consistent with this study. Table 1 revealed that males (67.2%) were rearing more fishes than females (32.8%) in the study area, indicating that the male fish farmers have the strength to engage all coping strategies on fish rearing in the study area. Table 1 results, revealed that (51.6%) were married suggesting that the majority of respondents would have enough family workers to complete some of the labor-intensive activities associated with rearing fishes and adjusting to the changing climate in the study area. Additionally, results from Table 1, also revealed that the respondents average households was 7 persons with secondary school being their highest level of education and 6.8 years mean farming experience with climate change coping strategies for fish rearing in the study area. This result is in line with the work of (Nwilo, *et al*. 2018), who asserted that many of the respondents have a significant amount of expertise with coping mechanisms, which will assist to mitigate the impact of climate change on fish farming on their farms.

**Table 1:** Socio-economic Characteristics of the Respondents

| Variables | Frequency | Percentages | Mean/Mode |
|---|---|---|---|
| Age of Respondents | | | |
| <30 | 14 | 21.8 | |
| 31-40 | 16 | 25 | |
| 41-50 | 22 | 34.4 | 29 years |
| >51 | 12 | 18.8 | |
| Sex | | | |
| Males | 43 | 67.2 | Males |
| Females | 21 | 32.8 | |
| Marital Status | | | |
| Single | 17 | 26.6 | |
| Married | 33 | 51.6 | Married |
| Divorced | 14 | 21.8 | |
| Household size | | | |
| 1-5 | 24 | 37.5 | |
| 6-10 | 18 | 28.1 | 7 persons |
| 11-15 | 12 | 18.8 | |
| >16 | 10 | 15.6 | |
| Educational Level | | | |
| No formal education | 11 | 17.2 | |
| Primary school | 15 | 23.4 | |
| Secondary school | 25 | 39.1 | Secondary school |
| Tertiary school | 13 | 20.3 | |
| Farming Experience | | | |
| 1-3 | 14 | 21.8 | |
| 4-6 | 17 | 26.6 | |
| 7-9 | 23 | 36.0 | 6.8 years |
| >10 | 10 | 15.6 | |
| Total | 64 | 100 | |

*Source: Field Survey, 2025.*

**Sources of Information on Climate Change**

Results from Table 2, shows that (15.6%) of respondents indicated that radio/television were the source of their information about climate change, (14.0%) said that they learned about it from the internet, and (11.0%) came from newspaper. The results also showed that (7.8%) of respondents derived their own information from their personal experience in the study area, while (9.4%) of respondents obtained their information about climate change from friends/neighbors, while the majority of the respondents (26.6%) got their information about climate change from extension agents, it is evident that the primary source of information about climate change for these farmers came from their extension agents. This outcome is consistent with the study by Dhakal *et al.* (2021), which found that farmers viewed their interpersonal and group methods as the most common ways to obtain climate change information.

**Table 2:** Sources of Information on Climate Change

| Sources of Information | Frequency | Percentages | Mean/Mode |
|---|---|---|---|
| Radio/Television | 10 | 15.6 | |
| Internet | 9 | 14.0 | |
| Newspaper | 7 | 11.0 | |
| Personal experience | 5 | 7.8 | |
| Friends/neighbors | 6 | 9.4 | |
| Extension agents | 17 | 26.6 | Extension agents |
| None of the above | 10 | 15.6 | |
| Total | 64 | 100 | |

*Source: Field Survey, 2025*

**Perception of the Effects of Climate Change on Fish Farming**

The results in Table 3, the perception question of about high incidence of drought, had a mean of 2.48 and was ranked 1st, the highest felt effect of climate change as perceived by the respondents in the study area. The perception question about high temperature and increased heat waves had a mean of 2.42 and was ranked the 2nd most felt effect of climate change on fish farming in the study area. The perception question about high cost of fish production had a mean of 2.31 and was ranked the 3rd highest felt effect of climate change in the study area. The perception question about high incidence of flooding had a mean of 2.29 and was ranked the 4th most felt effect of climate change in the study area. The perception question on high food insecurity had a mean of 2.25 and was ranked the 5th most felt effect on climate change by the respondents in the study area while the perception question about unpredictable changes in weather conditions had a mean of 2.20 and was ranked the 6th most felt effect of climate change in the study area and the perception question about increased level of sunshine was ranked the 7$^{th}$ least most felt effect on climate change in the study area. This result shows that the fish farmers were relatively aware of the whims and vagaries on climate change on their fish farms and as such ideas and innovations introduced to them as coping strategies will easily be adopted, this result conforms to the work of (Ayisi, *et al*. 2024), who worked on perception of climate change and adoption of climate smart fisheries among artisanal fishers.

**Table 3:** Perception of Impact of Climate Change on Fish Farming

| Perception questions on Impact of Climate Change | Very serious | Not serious | Serious | Mean | Ranking |
|---|---|---|---|---|---|
| High incidence of drought | 31 | 18 | 15 | 2.48 | 1$^{st}$ |
| High incidence of flooding | 33 | 17 | 14 | 2.29 | 4$^{th}$ |
| High temperatures and increased heat waves | 38 | 15 | 11 | 2.42 | 2$^{nd}$ |
| High intensity of sunshine | 24 | 18 | 22 | 2.03 | 7$^{th}$ |
| High cost of fish production | 33 | 14 | 17 | 2.25 | 5$^{th}$ |
| High level of food insecurity | 34 | 16 | 14 | 2.31 | 3$^{rd}$ |
| High unpredictable changes in weather conditions | 26 | 25 | 13 | 2.20 | 6$^{th}$ |

*Source: Field Survey, 2025*

**Coping Strategies to Climate Change employed by fish farmers**.

Table 4 results shows that many of the fish farmers in the study area (18.8%) used high-resistant fish species to rear their fishes and another (18.8%) of the respondents learned from their extension agents,

new ideas, innovations and techniques on how to rear their fishes to avoid the vagaries of climate change during flooding, drought and excessive temperatures in the study area. This suggests that the majority of these farmers used fish species that are resistant to the whims of climate change as a major coping strategy in the study area, meaning they won't lose many their fish stock due to the new ideas, innovations and techniques learned from the extension agents. Additionally, Table 4 revealed that (15.6%) of respondents stocked quick maturing fish species in the study area as a coping strategy against climate change, also (17.2%) of the respondents provided portable water during droughts for the fishes on their farms by digging boreholes and wells. This suggests that fish farmers were conscious of the effects of water scarcity on their farms and as a result, many of them provided water for their fishes rather than depending on natural resources that may dry up due to climate change, meanwhile (15.6%) of the respondents constructed their fish ponds close to water sources and another (14.0%) constructed fences to prevent flood water from sweeping away their fish farms during high flooding. This result demonstrates that the fish farmers in the study area possess extensive knowledge of the coping mechanisms employed to lessen the impact of climate change on fish rearing. This result conforms to the work of (Ayisi, *et al*. 2024), who worked on perception of climate change and adoption of climate smart fisheries among artisanal fishers.

**Table 4: Coping Strategies of Fish Farmers to Climate Change**

| Coping Strategies | Frequency | Percentage | Mean/Mode |
|---|---|---|---|
| Rearing of fishes highly resistant to climate change | 12 | 18.8 | 18.8 |
| Stocking of quick maturing fish species | 10 | 15.6 | |
| Digging of boreholes/wells to supply water during drought | 11 | 17.2 | |
| Construction of ponds close to water sources | 10 | 15.6 | |
| Construction of fence to prevent flood water | 9 | 14.0 | |
| Learning of new ideas/innovations/techniques from extension agents | 12 | 18.8 | 18,8 |
| Total | 64 | 100 | |

*Source: Field Survey, 2025*

## CONCLUSION

Results from the study showed that from the socio-economic characteristics of the respondents the age range of 41-50 years had the highest percentage with 34.4% showing that most of the fish farmers were in their active age range. Most of the fish farmers were married with 51.6%, while 39.1% of the respondents had secondary school level of education as their highest level of education. Furthermore, the result shows that the most felt effect on climate change was high incidence of drought with a mean of 2.48, followed by high temperatures and increased heat waves with mean of 2.42. The study showed that the most coping strategies adopted by the fish farmers were, rearing of fishes highly resistant to climate change and adoption of ideas and innovations introduced to them by extension agents in the study area.

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# EFFECTIVENESS ANALYSIS OF CLIMATE CHANGE ADAPTATION STRATEGIES AMONG FISH FARMERS IN SOME LOCAL GOVERNMENT AREAS OF ANAMBRA STATE, NIGERIA

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**ABSTRACT**
*This study analyzed climate change adaptation strategies among fish farmers in Anambra-West and Ogbaru LGAs of Anambra State, Nigeria. Muiti-stage sampling technique, descriptive and regression analysis were employed for this study. Results showed that the age range of 41-50 years had the highest percentage with 32.5% with a mean age of 33years. Many of the fish farmers were married 47.5% with a mean household size of 7 persons. Secondary school level of education was the highest level of education, meaning that ideas and innovations introduced to these fish farmers will easily be adopted. Loss of fishes (36.2%) and Loss of livelihood (33.7%) were the major effects of climate change in the study area while mean annual income was ₦528,541.10k. The $R^2$ value was 0.682, this implies that the regression analysis explained 68.2% of the total variation in the model, while the remaining 31.8% was shown in the error term. The regression variables of age, access to extension agents and ownership of fish production were all positive and significant at 1% level, while marital status was significant at 5% with household size being significant at 10%. This implies that as each of these variables were increased, they increased the level of fish production in the study area. Fish farmers are encouraged to form cooperative societies so that they can have access to professionals and extension agents and be taught new ideas innovations and techniques of high reproductive success and quick growth rate of fish farming.*

**Keywords**: Climate change, adaptation, effects, strategies, fish farming

## INTRODUCTION

Nigeria is Africa's most populous country and ranks second in production of farmed fish in the continent (Oyebola *et al*., 2018). The country faces varying degrees of climate risk of which rising temperature, changing rainfall pattern, distribution and volume, and extreme climate events have been reported as the principal shocks (BNRCC 2011). These risks affect the production of farmed fish in the country and also threaten the objective of meeting the daily protein requirements of Africa's largest nation. In lieu of this therefore, understanding the adaptation decisions of fish farmers on climate change in Anambra State, Nigeria and their effectiveness is very important if Nigeria is to feed her growing population. The specific objectives of the study were to describe the socio-economic characteristics of the respondents, examine the annual income level of the respondents, examine the effects of climate change on fish farming in the study area and determine the factors affecting adaptation strategies of the respondents in the study area.

## METHODOLOGY

### Study Area

This research was carried out in Anambra-West and Ogbaru local government areas of Anambra State, Nigeria. The State covers a total of 4,844 square kilometers of land mass and it is bounded in the South by Imo, Abia and Rivers States and in the North by Kogi State. To the West, it is bounded by Delta and Edo

States while in the East it is bounded by Enugu State. Anambra State is found on latitude $5^0 82`$ and $6^0$ 45`N and longitude $6^0 43`$ and $7^0 22`$ E. The State is made up of twenty-one (21) Local Governments Areas (LGAs). According to the (City Population, 2022), Anambra State population stood at 4,177,821 people thus making it rank among the most populous states in the country. Major occupations of the people are farming and trading while a few work as civil servants. Both cash crops and food crops including fruits and vegetables are produced in the State. There are two distinct seasons namely wet and dry seasons.

**Sampling procedure and sample size**

The targeted sample size were fish farmers in the two selected local government areas namely; Anambra West and Ogbaru LGAs. Multi-stage sampling technique was employed. In the first stage, two local government areas were purposively selected due to the adverse effects of climate change and fish farming. In the second stage, four communities per local government area were randomly selected, totaling eight (8) communities. In the final stage, ten respondents were randomly selected from each community resulting in a sample size of eighty (80) respondents.

**Analytical tools**

Analytical tools used were descriptive statistics and regression analysis. Descriptive statistics used were; frequency, percentages mean and mode. Descriptive statistics were used to analyze objectives I, II, and III. Regression analysis was used to analyze objective IV; factors affecting adaptation strategies fish farmers on climate change. A dependent dichotomous variable which assumes just two values (one and zero) were used to estimate the likelihood of events using the regression model estimated as follows; $b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + e$. Where Y is a binary response variable defined as; Y =1 if fish farmers participate in climate change coping strategies and Y = 0 if they do not participate. $X_1$= Age, $X_2$=Household size, $X_3$= Marital status, $X_4$= Access to extension agents, $X_5$= Climate change awareness, $X_6$=ownership of fish produced, $X_7$=pond owner. $b_1$ - $b_7$ = parameter estimates, $b_0$= intercepts, e =error term.

## RESULTS AND DISCUSSION

**Socio-economic Characteristics**

Table 1 shows that in the study area, the average age and household size of the respondents were 33 years and 7 persons respectively, indicating that the fish farmers were young and agile with a relatively large household size to engage in fish farming. Most of the respondents were married (47.5%) and males dominated (65.0%) the fish farming business in the study area, this result conforms to the work of (Anugwo and Egwue, 2024), who posited that most respondents were married and as such will have enough hands on labour in their enterprise. Furthermore many of the respondents had secondary school level of education with (36.2%) and those with primary school level of education were just (23.8%), respondents with tertiary level of education were (21.2%) and just (18.8%) had no formal education while the average farming years of experience was 7.2 years in the study area. This finding is in line with the work of Ume, *et al*. (2016) who worked on Economic Analysis of Catfish Production in Anambra State, Nigeria.

**Table 1:** Socio-economic Characteristics of the Respondents

| Variables | Frequency | Percentages | Mode |
|---|---|---|---|
| Age of respondents | | | |
| <30 | 18 | 22.5 | |
| 31-40 | 20 | 25.0 | 33 years |
| 41-50 | 26 | 32.5 | |
| >50 | 16 | 20.0 | |
| Marital status | | | |
| Single | 22 | 27.5 | |
| Married | 38 | 47.5 | Married |
| Divorced | 20 | 25.0 | |
| Sex | | | |
| Males | 52 | 65.0 | Males |
| Females | 28 | 35.0 | |
| Household size | | | |
| 1-5 | 28 | 35.0 | |
| 6-10 | 22 | 27.5 | 7 persons |
| 11-15 | 16 | 20.0 | |
| >15 | 14 | 17.5 | |
| Educational level | | | |
| No formal education | 15 | 18.8 | |
| Primary school | 19 | 23.8 | |
| Secondary school | 29 | 36.2 | Secondary school |
| Tertiary school | 17 | 21.2 | |
| Farming experience | | | |
| 1-4 | 18 | 22.5 | |
| 5-8 | 21 | 26.2 | 7.2 years |
| 9-12 | 27 | 33.8 | |
| >13 | 14 | 17.5 | |
| Total | 80 | 100 | |

*Source: Field Survey, 2025*

**Annual Income Level of Fish Farmers**

Table 2 result shows that the respondents with annual income level of ₦250,000 – ₦450,000 were (22.5%), those with annual income level of ₦451,000 – ₦651,000 were (18.8%) while those with ₦652,000 - ₦852,000 were (25.0%). Respondents with income level of ₦853,000 – ₦1,053,000 were (17.5%) and just (16.2%) had annual income level above ₦1,054,000 with a mean annual income of ₦528,541.10, indicating that this is ₦1448.05 per day which is $0.90/day, using the $1 per day poverty line index. This shows that fish farming in the study area was greatly affected by climate change as the respondents remained below the poverty line. This collaborated with the work of Emaziye (2020) that rural households' annual income on fish farming was very low.

**Table 2:** Annual Income Level of Fish Farmers

| Income (₦) | Frequency | Percentage % | Mode/mean |
|---|---|---|---|
| 250,000-450,000 | 18 | 22.5 | |
| 451,000-651,000 | 15 | 18.8 | ₦528,541.10 |
| 652,000-852,000 | 20 | 25.0 | |
| 853,000-1,053,000 | 14 | 17.5 | |
| >1,053,000 | 13 | 16.2 | |
| Total | 80 | | |

*Source: Field Survey, 2025*

**Effects of Climate Change on Fish Farmers**

From the results in Table 3, the perceived effects of climate change on fish farming in the study area showed that loss of fish stock (36.2%), loss of livelihoods of fish farmers(33.7%), altered rainfall patterns (32.5%) and low reproductive success of stocked fishes (32.5%) were the most perceived effects of climate change in the study area by the respondents. Slow metabolism/growth rate (27.5%), increased frequency of extreme weather events (26.2%), changes in distribution/abundance of fingerlings (23.7%), high floods (21.2%), rising/high temperatures and high CO2 absorption/acidification of ponds with (20.0%) respectively and high droughts (17.5%) were other perceived effects of climate change in the study area. Implying that in the study area many of the respondents lost their fish stock and as such their livelihoods in the study area. This collaborated with the findings of (Owoade, *et al*. 2025) that fish farmers were seriously affected negatively which led to income losses and the collapse of fisheries business.

**Table 3:** Effects of Climate Change on Fish Farmers

| Effects | Frequency | Percentage % | Mode |
|---|---|---|---|
| Loss of fish stock | 29 | 36.2 | 36.2 |
| Loss of livelihood by fish farmers | 27 | 33.7 | |
| Rising/high temperatures | 16 | 20.0 | |
| Altered rainfall pattern | 26 | 32.5 | |
| Increased frequency of extreme weather events | 21 | 26.2 | |
| Changes in distribution/abundance of fishes | 19 | 23.7 | |
| Slow metabolism/growth rates | 22 | 27.5 | |
| Low reproductive success of fish stock | 26 | 32.5 | |
| High CO2 absorption/acidification of ponds | 16 | 20 | |
| High droughts | 14 | 17.5 | |
| High floods | 17 | 21.2 | |

*Source: Field Survey, 2025. Multiple responses allowed*

**Factors Affecting Adaptation Strategies on Climate Change**

The regression result in Table 4; revealed the $R^2$ value was 0.682, this implies that the regression analysis explained 68.2% of the total variation in the model, while the remaining 31.8% were shown in the error term. The regression variables of age, access to extension agents and ownership of fish production were all positive and significant at 1% level, while marital status was significant at 5% with household size being significant at 10%. This implies that as each of these variables are increased, they increased the level of fish production in the study area. Increase in age and household size helps in providing expertise and knowledge with labor needed in fish farming, while access to extension agents and ownership of fish production helps with learning of new ideas and innovations about fish farming while marital status helps with enough hands on labor in making sure all of the basic knowledge learnt in the cause of the years of fish farming translates into high fish output, thereby increasing the quantity of fish produced in the study area. The result is in line with the work of Okezie, *et al.* (2021), who posited that marital status (5%), member of cooperative society (10%) and extension services (1%) were positively related to number of mitigation strategies used by artisanal fishermen in their fishing communities. The study also, recommended that extension workers should be continuously trained and educated on current information about climate change to enable them enlighten and disseminate to fish farmers and will enable update and synchronization of ideas with the artisanal fishermen.

**Table 4:** Factors Affecting Adaptation Strategies on Climate Change

| Variables | Estimated Coefficients | Standard Error | T-values |
|---|---|---|---|
| Constants | 2.872 | 1.022 | 2.810*** |
| Age | 0.146 | 0.071 | 2.056* |
| Household size | 0.159 | 0.056 | 2.839*** |
| Marital size | 1.717 | 0.726 | 2.365** |
| Access to extension agents | 1.232 | 0.589 | 2.091* |
| Climate change awareness | 0.854 | 0.645 | 1.324 |
| Ownership of fish production | 1.019 | 0.459 | 2.220* |
| Pond ownership | 0.701 | 0.532 | 1.317 |
| Model | R2=0.682 | Adjusted R2=0.594 | |

*Source: Field Survey, 2025* **1%, **5%, ***10%*

## CONCLUSION AND RECOMMENDATION

This study analyzed climate change adaptation strategies among fish farmers in Anambra State, Nigeria. Results showed that the age range of 41-50 years had the highest percentage with 32.5% with a mean age of 33years showing that most of the fish farmers were young and agile. Many of the fish farmers were married with 47.5% and a mean household size of 7 persons, and secondary school level of education as their highest level of education, meaning that ideas and innovations introduced to these fish farmers will easily be adopted. It is recommended that the government of Anambra State should implement programs that will help mitigate the effect of climate change on fish farming in the study area so these farmers can have easy production of fishes in the study area. Fish farmers are encouraged to form cooperative societies so that they can have access to professionals and extension agents and be taught new ideas innovations and techniques of high reproductive success and quick growth rate of fish farming so as to avoid huge losses of fish stock and hence their livelihoods as a result of the vagaries of climate change.

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# CLIMATE CHANGE AND GENDERS IN FISHERIES AND AQUACULTURE IN DOMA LOCAL GOVERNMENT AREA, NASARAWA STATE, NIGERIA

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**ABSTRACT**

*Climate change is a reality that is experienced in different parts of the world. Climate change is a global phenomenon undermining the achievement of the Millennium Development Goals (MDGs) and efforts to reduce extreme poverty in Doma Local Government Area, Nasarawa State, Nigeria. A study was conducted to understand how fisheries and aquaculture can be promoted using climate and gender-inclusive techniques measures. This study examines the gender-specific impacts of climate change on fisheries and aquaculture in Doma Local Government Area, Nasarawa State, Nigeria. The study employed a mixed-methods approach, combining survey data from 100 respondents with focus group discussions and key informant interviews. The findings reveal that climate change exacerbates existing gender inequalities, affecting women's and men's livelihoods, food security, and community resilience. Women are more vulnerable to climate-related shocks, with limited access to resources, decision-making power, and adaptive capacities. The study recommends gender-sensitive adaptation strategies, capacity building, and climate information services to promote sustainable, encourage women's full participation in fisheries and aquaculture and promote climate-smart aquaculture practices. The findings have implications for policymakers, practitioners, and researchers seeking to address the intersectionality of climate change, gender, and fisheries/aquaculture in Nasarawa and beyond.*

**Keywords:** Climate Change, Gender, Fisheries, Aquaculture, Food, Nasarawa

## INTRODUCTION

Fisheries and aquaculture have very important roles for food supply, food security, and income generation from local to global level. Some 42 million people work directly in the sector, with the great majority in developing countries. Adding those who work in associated processing, making distribution and supply industries. Aquatic foods have high nutritional quality, contributing 20 percent or more of average per capita animal intake for more than 2.8 billion people, monthly from developing countries. *Allison, et al (2009)*.

The fisheries and aquaculture sector is a very important component of the food production systems in every society striving towards achieving the UN sustainable Development Goal on food security. This article is significant to the achievement of six goals within the sustainable Development Goals (SDGs). The time is tickling based on the fact that 2030 is very close and there is the need to speed up with the actions that will lead to the achievement of the goals.

Climate change is projected to impact broadly across ecosystem, societies and economics, increasing pressure on environment and food supplies, including those in the fisheries and aquaculture sector. Food quality will have a more pivotal role as food resources come under greater pressure and availability and access to fish supplies will become an increasingly critical development issue (FAO, 2008). Therefore, programs and initiatives geared ecosystem restoration and food security have the imperative of inclusion

of some aspect of fisheries and (or) aquaculture to be holistic and cost effective. Under circular economy, the sector is very useful in the transformation of some agricultural and food processing waste into useful resources further food production while its own waste becomes useful in agriculture *(Bosma and Verdegen, 2011; Dawood et al, 2018)*.

Fish provides not only protein of high value but are source to a wide range of essential fatty acids (Highly Unsaturated Fatty Acid – HUFAs) very essential for human health (FAO, 2012). Fish is readily digestible and utilizable by human body, making it suitable for complimenting the high carbohydrate diets in most developing countries (FAO, 2016). Fish have all the essential amino acids required by the body. On the average, it provides 20-30 kilocalorie per person per day (WHO, 2011). The fisheries sector contributes 3-3.5% of the gross domestic product (GDP) in Nigeria and constitutes 50% of animal protein consumption (Federal Ministry of Agriculture and Rural Development (FMARD), 2008: Onada and Ogunlola, 2016). Fish consumption per capita is 7.5kg in Nigeria (FMARD, 2008) while the global average is 20.2kg (FAO, 2022). Nigeria.

Climate – smart fisheries refers to sustainable fishing practice and management approaches that help fisheries adapt to climate change, while also reducing their contribution to greenhouse gas emissions intensities (Ari and Dogo, 2023). Gender- sensitive approach consider the different needs, experiences and perspective of women, men, and non-binary individuals in various contexts of both male and female genders in the fisheries and aquaculture sub-sector. This becomes necessary given earlier reports indicating that different parts of both the fisheries and aquaculture value chain are being dominated by the male gender (Giwa et al, 2017; Unah et al., 2017; Sub single et al., 2021).
Climate change is the alteration of the pattern of the climate of a place over a period of time; usually ten years and above. Recent weather events like changes in hydrological regime, drastic change in weather condition, reduction water levels, heavy windstorms, excessive sunshine, increased incidents of flooding and draught are being linked to climate change (Onada and Ogunlola, 2016).

## CLIMATE-SMART FISHERIES APPROACH

Federal Development of Fisheries (FDF, 2021) noted that climate change will affect fisheries strongly given that it will have impact in fishes on which fisheries depend. It is envisaged that artisanal fisheries which currently accounts for 80% of local production (Obasi et al. 2017) will be affected through multiple weather events like windstorms rising sea level, warning that lead to migration and (or) extinction of some economic species (Evulobi, 2015) near the coast which may impede the capacities of the communities to operate. Warning is also expected to lead to more satiation of inland takes leading to anoxic hypolimnion and ultimate fish kills (FDF, 2021). These challenges are expected to be exacerbated by the impact of climate change; but can be addressed if some climate-smart measures are taken.

Climate – Smart approach to fisheries is based on the ecosystem Approach to Fisheries (CCRF). It outlines the following principles in relation to the ecosystem.

1. States should facilitate consultation and effective participation of all stakeholders.
2. Management measures should not only ensure the conservation of target species but also species belonging to the same ecosystem.
3. States should ensure that fisheries interest are taken into account in the multiple uses of coastal zones and are integrated into coastal area management.
4. All critical habitats such as wetlands, mangroves, reefs, lagoons, nursery and spawning areas should be protected and rehabilitated.
5. States should promote responsible development of aquaculture including evaluation of the effects on genetic diversity and ecosystem integrity.

6. States should establish effective procedures to undertake appreciate environmental assessment and monitoring with the aim of maintaining adverse ecological changes and related economic and social consequences (staples and fungi-smith, 2009).

The term "gender" refers to socially ascribed roles, responsibilities and opportunities associated with women and men as well as the hidden power structures that govern relationships between them. Gender issues focus not only on women but on the relationship among men, women and Children and their roles, access to and Control over resources and division of labour in meeting needs (Anyanwu-Akeredolu, B. 2005).

Gender Concerns in the fishery Sector can only be identified and addressed by identifying the participation of male and female in fish farming as well as the factors hindering their participation.
Both male and female fish farmers are engaged in the production of aquaculture activities essential to household welfare (Anyanwu-Akeredolu, B. 2005). Women contribution continues to be marginalized while male contribution continues to remain the sole focus of attention (Food Agriculture Organization FAO, 2005). It is presumed that male fish farmers participated in fish farming system more than female fish farmers.

This study focused on the climate change and genders in fisheries and aquaculture i.e involvement of male and female fish farmers. The study aimed to know how climate affects genders participation in fish farming in the study area.

## MATERIALS AND METHODS

### Study Area

The Study was carried out in Doma Local Government Area of Nasarawa State. The area has a total land area of 5640km. The Population Census of (1971) gave its Population of about 50,000 and that of (2006) Population Census is 138,991. The Local Government Area is made up of three districts are Doma, Rukubi and Agbashi. Doma districts Cover a land of about 138,991 people according to 2006 Census. Doma Local Government Area is situated between Latitude 8.24.N and 8.5'N and Longitude 6.E and 6.30'E.

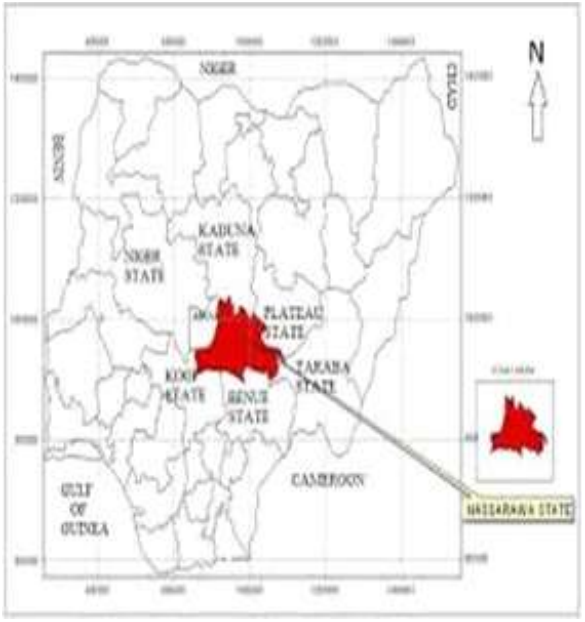



***Figure 1:*** *Map of Nigeria Showing Nasarawa State*

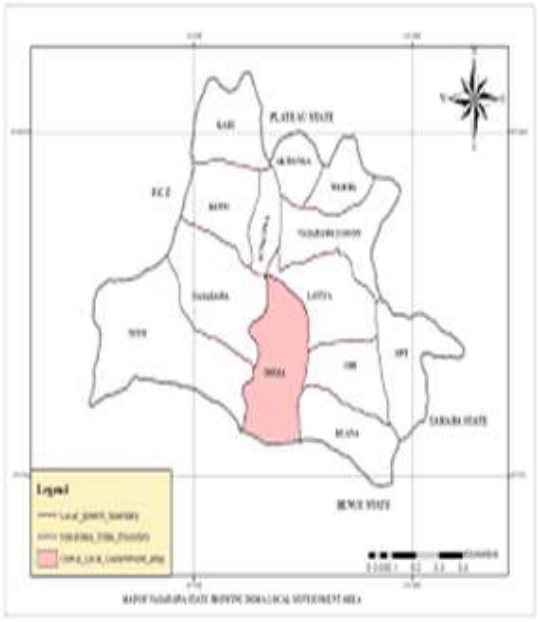



***Figure 2:*** *Map of Nasarawa Showing Doma Local Government Area*

The Local Government share boundaries with Lafia the State Capital in the West and Nasarawa Eggon Local Government in the West. The major occupations of the people in the area include fishing, trading Hunting, Crop Production, Livestock production and farming. The religion practiced in the area are Christianity and Islamic while the language spoken include Agatu, Hausa, Tarok, Jukun, Eggon and Alago. The ethic group that can be found in the area include Agatu, Alago, Tiv, Bassa and which are Galadima, Madaki, Madauchi, SabonGari, Alagye, SarkiDawaki, Agbashi, Doka, Rukubi and Akpanaja. These Communities were selected because of the high concentration of fish farmers in the communities. A percentage of the total estimated numbers of fish farmers were randomly Selected in each of the Selected Community to give Eighty-Seven (87) fish farmers irrespective of the sex.

Primary data were used in the Study. The data were collected from the selected male and female farmers in the study area. Other relevant information for the study was obtained from internet, journals and textbooks. Data Collected were analyzed using descriptive statistics such as frequency, percentages and means.

## RESULT AND DISCUSSION

### Personal Characteristics of the Male and Female Fish Farmers.

The distribution of respondents by gender (Table1) Showed, that (81.6%) were males while (18.4%) were female an indication that more males were engaged in fish farming than the female (Table 1). This finding agreed with the report of George (2010) and Ogunlade (2007) who found that more males were involved in fish farming than women in their study areas. The male dominance implies the laborious nature of fish farming operations which may be very tedious for the opposite sex (females) to handle as well as the involvement/participation of the female in the domestic affairs of the household. The mean ages of the male and female fish farmers were 34 and 35 years respectively indicating that they were still young and active people. Koledoye and Deji (2013) found that majority of the age Category 31-60 years. Majority (57.7%) and (56.3%) of male and female respondents were married. This shows that gender roles in fish farming practice can be effectively distributed among the men and women. Almost all the male and female farmers had one level of education or the other. Agwu and Anyanwu (1996) showed that increase in educational status of farmers positively influenced the adoption of improved technologies and practices of fish farming.

Majority (40.9%) and (50.0%) of the male and female respondents respectively had family size of 6-10 persons implying a fairly large family size. Larger proportions (40.9%) and (50.0%) of the male and female respondents respectively received less than #250,000.00 as their monthly from fish farming. The mean monthly incomes were #270952.50 and #147,500.00 for male and female farmers respectively. This implies that majority of the respondents were low income earners and also, the male fish farmers earn more than the female. A difference in income between male female fish farmers was also reported by Deji and Koledoye (2013) where they observed that 45.0% of male fish farmers earn annual income of #200,000-#400,000 from fish production, while in the female category, 40% earned an annual income of #200,000 and below.

**Table 1:** Personal Characteristics of Male and Female Fish Farmers

| Variable | Male (n=70) Frequency (%) | Percentage | Female (n=16) Frequency (%) | Percentage |
|---|---|---|---|---|
| **Age (years)** | | | | |
| <30 | 30 | 42.2 | 6 | 37.5 |
| 30-50 | 34 | 47.9 | 8 | 50.0 |
| >50 | 7 | 9.9 | 2 | 12.5 |
| **Mean** | 33.0 | | 35.3 | |
| **Standard Deviation** | 11.2 | | 12.4 | |
| **Marital Status** | | | | |
| Single | 30 | 43,7 | 7 | 43.7 |
| Married | 41 | 57.7 | 9 | 56.3 |
| **Educational level** | | | | |
| No formal | - | - | 1 | 6.3 |
| education | 3 | 4.2 | - | - |
| Primary education | 20 | 28.2 | 4 | 25.0 |
| Secondary | 48 | 67.6 | 11 | 68.7 |
| education | | | | |
| Tertiary education | 26 | 36.6 | 4 | 28.6 |
| **Family Size** | 29 | 40.9 | 7 | 50.0 |
| **(persons)** | 4 | 5.6 | 2 | 14.3 |
| 1-5 | - | - | 1 | 7.1 |
| 6-10 | 12 | 16.9 | - | - |
| 11-15 | | | | |
| ≥ 20 | 48 | 67.6 | 14 | 87.4 |
| No response | 9 | 12.7 | 1 | 6.3 |
| **Monthly Income** | 3 | 4.2 | 1 | 6.3 |
| **(naira)** | 1 | 1.4 | - | - |
| ≤250000 | 2 | 2,8 | - | - |
| 25001-500000 | 8 | 11.3 | - | - |
| 5000001 – 750000 | - | 270952.5 | | 147500.0 |
| 7500001 – 1000000 | - | 596082.0 | - | 166633.0 |
| >1000000 | | | | |
| No response | | | | |
| **Mean** | | | | |
| **Standard Deviation** | | | | |

*Source: Field Survey, 2025*

**Source of Capital and information of the fish harmers**

Table 2 Showed that majority (45.6%) and (3.7.5%) of male and female fish farmers respectively got information on fish farming through other fish farmers suggesting how important members in the same profession or trade could be as effective sources of useful information. A fewer proportion (18.8%) of the female compared to the male (26.8) farmers had access to extension agents indicating that the female compared to the male (26.8) farmers had access to extension agents indicating that the female farmers do not access to extension agents as the male farmers. This finding corroborates that of Osuman (1997) who observed that male farmers have more access to agricultural information through extension agents than the female farmers do. Majority (32.4%) and (43.8%) of the male and female farmers respectively got their capital from personal savings. Although the finding indicated that these farmers relied mainly on their personal savings their investment in fish farming, the female farmers had more access to credit from personal savings. This finding is consistent with *Jeiyol et al, (2013)* the report of who opined that female rural farmers in Benue State, Nigeria obtained credit from local savings. Cultural factors may be responsible for the non-dominance of friends and relatives' sources of credit for the female farmers as also observed by Kachina E.I and Hiam A. *(2025)*. However, 21.7% and 18.8% of the male and female farmers respectively obtained capital from agricultural banks indicating that the financial institution is

playing an important role in the financing of fish farming in the area. In the study area, majority of female farmers devoted their time in processing Smoked fish rather than marketing the fish fresh from the stream or river.

**Table 2:** Sources of Capital and information of the fish farmers

| | Male | | Female | |
|---|---|---|---|---|
| Variable | Frequency | Percentage (%) | Frequency | Percentage (%) |
| **Sources of information** | 34 | 45.6 | 6 | 37.5 |
| Other fish farmers | 7 | 9.9 | 2 | 12.5 |
| Television and | 11 | 15.5 | 3 | 18.8 |
| Radio | 19 | 26.8 | 3 | 18.8 |
| Newspaper and Magazine | 13 | 18.3 | 3 | 18.8 |
| Extension agents | 15 | 21.1 | 3 | 18.8 |
| **Sources of Capital** | 12 | 16.9 | 1 | 6.3 |
| Commercial Bank | 23 | 32.4 | 7 | 43.8 |
| loan | 7 | 9.9 | 2 | 12.5 |
| Agricultural Bank loan | 1 | 1.4 | - | - |
| Friend and | 65 | 91.5 | 11 | 68.6 |
| Relatives | 6 | 8.5 | 5 | 31.3 |
| Personal Savings | 4.31 | - | 3.06 | - |
| Corporative Organization | 3.89 | - | 2.89 | - |
| Money Lender | | | | |
| **Mode of Marketing Fish** | | | | |
| Fresh from stream/ River | | | | |
| Processed into smoked fish | | | | |
| Mean | | | | |
| Stadard | | | | |

*Source: Field Survey, (2025)*

**Table 3:** Factors responsible constraints to Climate change and genders in fisheries and aquaculture

| | Male (n=71) | | Female (n=16) | |
|---|---|---|---|---|
| Constraints to fish farming | Mean | Rank | Mean | Rank |
| Poor marketing of fish | 1.50* | 2nd | 1.00 | 6th |
| product | 1.37 | 4th | 1.17 | 5th |
| Inaccessibility of market | 1.18 | 5th | 1.54* | 1st |
| Inadequate Capital | 1.64* | 1st | 1.44* | 3rd |
| Flood | | | | |
| Insufficient Information on | 1.44* | 3rd | 11.50* | 2nd |
| Fish Farming | 1.15 | 6th | 1.40 | 4th: |
| Disease and Pest | | | | |

*Source: Field Survey, 2025*

Poor marketing and distribution of fish production (X = 1.50) was ranked 5th, followed by insufficient information on harvesting and practices ranked (X=1.44) (3rd) and Inaccessibility of market was ranked (X=1.37) (4th) because male hardly sell fish in the market. These findings are consistent with Oyinbo and Mohammed (2015) who reported high turnout in the marketing of fish among female fish farmers in Doma, Nasarawa State, Nigeria. This knowledge gap in the male can be trained through training. This suggests the need for the male fish farmers to acquire need skills in fish processing. While inadequate capital ranked 6th for the male farmers, in was ranked 4th for the female farmers suggesting that capital was more of a constraint to the female than the male farmers. Flood was ranked the 1st constraint (X =167*) while disease and pest (X =1.64) was ranked 2nd (Table 3) Studies by Kusakabe, 2003. Have found out that women have less access than men to formed sources of credit, such a banks or credit unions. They rarely have the collateral required, usually land tittle. Therefore, women rely mostly on family, their savings, or money lenders.

## CONCLUSION

In conclusion, the study highlights the critical intersectionality of climate change, gender, and fisheries/aquaculture in Doma Local Government Area, Nasarawa State, Nigeria. The findings underscore the disproportionate impacts of climate change on women and men in the sector, exacerbating existing gender inequalities and affecting livelihoods, food security, and community resilience. To address these challenges, we recommend a multi-faceted approach that integrates gender-sensitive adaptation strategies, capacity building, and climate information services. This includes promoting climate-smart aquaculture practices, encouraging women's full participation in fisheries and aquaculture, and ensuring equal access to resources and decision-making power. By adopting a gender-sensitive approach to climate change mitigation and adaptation, we can promote sustainable and equitable fisheries and aquaculture practices, enhancing community resilience and contributing to the achievement of the Sustainable Development Goals (SDGs).

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# GENDER GAPS IN THE AQUACULTURE VALUE CHAIN: EXPLORING GENDER CONSTRAINTS, ECONOMIC OUTCOMES AND IMPACT FOR WOMEN'S EMPOWERMENT IN EDO STATE, NIGERIA

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**ABSTRACT**
*In achieving sustainable change in the aquaculture value chain, there is need for deliberate efforts which are critical for a gendered food security, improvement of livelihoods and economic empowerment of individuals. Aquaculture are hindered by inequalities among men and women in the sector which affected evenly distribution of benefits, access to and control over resources among the actors which limits the empowerment of women in the value chain. This present study employed data driven strategies to reveal gender gaps in the aquaculture value chain and explore gender constraints, economic outcomes and impact for women's empowerment in the value chain in Edo state, Nigeria. A gender sensitive quantitative household survey was conducted among 305 randomly selected farmers using well-structured questionnaires in three districts in Edo State. Results of the study revealed gender participation at different nodes of the value chain with women having a representation of 31% compared to men with 69%. Gender constraints limiting women from benefiting from the fish value chain include, access to productive resources and control over the resources, lack of capital, lack of decision making power and limited mobility. The result revealed aquaculture improved the livelihoods of both gender in the value chain. The study concludes that building the capacity of women in the production value chain, curbing the discriminatory social norms that hinder women from participating in the value chain, providing access to credit are the deliberate actions that can close the gender gaps and empower women in the aquatic food system in Edo State, Nigeria.*

**Keywords:** Gender, Aquaculture, Women's empowerment, Edo state, inequalities, Value chain.

## INTRODUCTION

According to Food and Agriculture organization of the United Nation, FAO, (2024) on the State of World Fisheries and Aquaculture, total fisheries and aquaculture production attained an all-time record of 223.2 million tonnes in 2022 with 185.4 million tonnes of aquatic animals' production indicating an increase in these sectors. Malhotra *et al.*, (2024) stated that while women play an important role in aquaculture and fisheries, their involvement are tailored to the least-valued sections of the value chain that have the lowest economic returns. This present study employed data driven strategies to comprehend how the aquaculture value chain functions employing a gender responsive value chain analysis. The study explores this gender lens impacting women's involvement in the sector, particularly within the framework of sustainable aquatic food system practices. In order to get a sufficient and evidenced based data and knowledge on gendered dimension in aquaculture value chain, this research focused on two analytical approaches which are:

1. The rapid assessment approach developed by Kruijssen *et al.*, (2016) into nine components and later modified by Kruijssen *et al.*, (2018) into three variables which are independent variables (socio demographic characteristics), intervening variables and dependent variables (gender constraints, economic outcomes and impact).
2. Integrating Gender into Agricultural Value Chains (INGIA-VC) developed by Rubin *et al.*, (2009). Thus this study adopted gender value chain composition according Kruijssen *et al.*, (2018) and was detailed by Kruijssen *et al.*, (2021).

The main objective of the study was to understand how the fish value chain functions and reveal the differences in men and women in terms constraints, opportunities and economic outcomes and impact. However, the specific objectives were to:

1. Explore the gender constraints hindering and limiting women from participating fully in the aquaculture value chain.
2. Ascertain if aquaculture promotes economic outcomes of actors (men and women) in the value chain and impacted on their livelihoods in Edo State, Nigeria.

**Research question**

1. What are the gender constraints affecting women from participating fully in the aquaculture value chain in Edo State, Nigeria?
2. Does aquaculture improve livelihoods and economic outcomes of actors (men and women) in Edo State Nigeria?

## MATERIALS AND METHODS

### Study Area

This study was conducted in three senatorial districts: Edo South, Edo North and Edo Central which cut across the seventeen (17) local government areas of Edo State where fisheries and aquaculture play a significant role in livelihoods and food security. Edo State is a coastal region with diverse fish species and various stakeholders involved in the fish value chain, including fishers, processors, traders, and consumers.

### Sample Selection

This study employed a quantitative research design to gain a comprehensive understanding of the aquaculture fish value chain and gender-based differences within it. Survey design and purposive sampling method were employed to select sub-district in each of the three districts based on fish production statistics. Respondents within each senatorial district were randomly selected to ensure a representative sample of men and women across different nodes of the fish value chain (e.g., fishers, processors, and traders). The sample size included a total of 305 farmers that were interviewed using structured questionnaires according to Krejcie and Morgan, (1970). A reconnaissance survey was undertaken before the actual data collection to assess the type of responses expected from the field.

### Data Collection

Structured questionnaires in Google forms app were administered to participants to gather quantitative data on intervening variables and dependent variables according to Kruijssen *et al*., (2018). Secondary data, including government reports, policy documents, and relevant literature, were collected to support the primary data and offer additional insights into the structural context of the fisheries sector in Edo State. This data helped in understanding broader trends and policies that may affect men and women differently in the value chain.

### Quantitative Data Analysis

Survey data was analyzed using SPSS statistical software (version 27) to generate descriptive statistics, such as frequencies, means, and standard deviations in order to assess differences between men and women in terms of roles, socio-economic factors, gender constraints and economic outcomes and impact as described by Hejase and Hejase, (2013). Statistical significance was considered when $\alpha = 0.05$ while Microsoft excel was used in data arrangement.

### Ethical Considerations

Ethical approval was obtained from the appropriate institutional body prior to data collection. All

participants were informed of the study's purpose and provided written consent before participating. The confidentiality and anonymity of all respondents were maintained throughout the study, and participants had the option to withdraw from the study at any time without penalty according to Alcser *et al*., (2011).

## RESULTS AND DISCUSSION

### Socio-demographic characteristics of respondents

This reveals gender participation at different nodes of the value chain with women having a representation of 31% compared to men with 69% as detailed in Table 1.

### Gender constraints in Aquaculture Value Chain: Roles, Norms and Perceptions

Among the respondents, 128 respondents (124% both male and female) revealed that men take leadership position in their cluster. Furthermore, results showed that 174 (58.39%) agreed that there is disparity in the amount of salary earned for work by men and women which revealed men earning more than women in the aquaculture value chain. 73.00% respondents agreed that men make more decision compared to women which revealed lack of decision making power of women in the value chain. Also, 53.72% of the total respondents reported the existence of gender norms (in terms of labour, interaction, and mobility). Results also showed that farmers (male and female) 61.29% of the respondents agreed that women's mobility is limited compared to men's.

### Economic Outcomes and Impact of Aquaculture

This provided an analysis of the economic impact of aquaculture by examining several variables across gender, focusing on reasons for entering fish farming, assistance from the government, livelihood improvement, and ownership of equipment, land ownership, and source of capital. Each category's statistical significance by gender is determined by p-values from Analysis of Variance (ANOVA). Males are slightly more motivated by "source of income" (48.75%) compared to females (37.5%), while a higher percentage of females (25%) report venturing into aquaculture out of "passion" compared to males (15%). A majority of both males (90.24%) and females (97.62%) reported receiving government assistance (training and financial support), with slightly more females benefiting. Both genders report high levels of livelihood improvement from aquaculture, with females at 88.64% and males at 85.54%.

**Table 1:** Socio-demographic Features of Farmers by Gender

| Variable | Categories | Female n (%) | Male n (%) | Total N (%) | P-value |
|---|---|---|---|---|---|
| | | 74 (0.31) | 211 (0.69) | n=305 | |
| | Edo Central | 10(10.6) | 33(15.7) | 43(14.1) | |
| Senatorial District | Edo North | 32(34.1) | 75(35.5) | 107(35.1) | 0.42 |
| | Edo South | 52(55.3) | 103(48.8) | 155(50.8) | |
| | 18 – 29 | 13(13.83) | 32(15.17) | 45(14.75) | |
| Age | 30 – 40 | 39(41.49) | 69(32.7) | 108(35.41) | 0.343 |
| | 41 – 49 | 18(19.15) | 58(27.49) | 76(24.92) | |
| | 50 and above | 24(25.53) | 52(24.64) | 76(24.92) | |
| | Divorced | 6(6.38) | 3(1.42) | 9(2.95) | |
| | Married | 53(56.38) | 152(72.04) | 205(67.21) | |
| Marital status | Separated | 3(3.19) | 7(3.32) | 10(3.28) | 0.004 |
| | Single | 25(26.6) | 46(21.8) | 71(23.28) | |
| | Widowed | 7(7.45) | 3(1.42) | 10(3.28) | |
| Physical | No | 93(98.94) | 196(92.89) | 289(94.75) | 0.029 |
| Challenge | Yes | 1(1.06) | 15(7.11) | 16(5.25) | |
| | Informal | 4(4.26) | 11(5.21) | 15(4.92) | |

| | | | | | |
|---|---|---|---|---|---|
| Educational Level | Primary | 3(3.19) | 15(7.11) | 18(5.9) | 0.525 |
| | Secondary | 27(28.72) | 52(24.64) | 79(25.9) | |
| | Tertiary | 60(63.83) | 133(63.03) | 193(63.28) | |
| Years of Experience | 0 - 4 years | 30(31.91) | 42(19.91) | 72(23.61) | 0.119 |
| | 10 - 14 years | 16(17.02) | 51(24.17) | 67(21.97) | |
| | 15 and above | 10(10.64) | 27(12.8) | 37(12.13) | |
| | 5 -9 years | 38(40.43) | 91(43.13) | 129(42.3) | |
| Household Size | 0 to 4 | 29(30.85) | 66(31.28) | 95(31.15) | 0.541 |
| | 5 to 9 | 61(64.89) | 128(60.66) | 189(61.97) | |
| | 15 and above | 0(0) | 3(1.42) | 3(0.98) | |
| | 10 to 14 | 4(4.26) | 14(6.64) | 18(5.9) | |

Women in the aquatic food system face numerous barriers that hinder their participation and empowerment (Adeyeye, 2019; FAO, 2024), hence this study therefore revealed these barriers and recommended strategies to increase women's participation in the aquaculture value chain. Furthermore, most National statistics particularly in Edo state often overlook the engagement of women in aquaculture value chain (Gopal *et al*., 2020; FAO 2020), thus, this research therefore, considered integrating gender considerations and participation into national statistics and policy interventions to deliver productivity for both men and particularly women within households.

## CONCLUSION

Hence, in an effort to close the gender gap for gender equality in the aquaculture value chain, there is need for a data –driven advocacy, thus these findings emphasized the need for gender sensitive interventions in the Edo state Fisheries Policy and Law: capacity building for women in production value chain node, give women agency and provides access to resources and credit and curb discriminatory social and cultural norms that hinders women from participating fully and unlock the full potential of the aquaculture value chain, contributing to sustainable livelihoods and a resilient aquatic food system in the state.

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# RELEVANCE OF WOMEN IN SMALL-SCALE FISH FARMING IN KANO STATE, NIGERIA

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**ABSTRAT**
*The study provides a future picture of fish farming sector in Kano State by projecting the dynamics of fish demand and supply responses through involvement of women small scale fish farming. To ensure women potentials in profitable fish farming is to provide capacity building support which would eventually lead to poverty alleviation and increase production. The research revealed, out of 51 respondents 16(31.4%) are female fish farmers which imply more women are involved and operates fish farming in Kano State despite male 35(68.6%) dominance in fish production. Thus, women fish farmers in Kano State have shown an unprecedented growth in terms of production and sustainability. Aside that fish farming sub-sector contributes to financial development, eliminating poverty, and improving the quality of life for marginalized women.*

**Keywords:** Small scale, Women, Fish farming, Kano State.

## INTRODUCTION

Fish farmers are rapidly developing fish production in Kano State, Nigeria, indicating the capacity for sustainable food security, livelihoods and job creation. In recent years women particularly in the urban/peri urban communities of Kano State are actively involved in fish culture to an unprecedented growth in terms of number and quantity of fish production. This is due to acceptability of fish consumption as a result of awareness on its health benefit, source of rich protein and economic benefits from farmed fishes. FAO (2023) reports that 47 million women and an unknown number in fisheries and aquaculture make up nearly half of the workers in production, processing, trading, and marketing globally.

Although, religion, culture and tradition may have continued to put Kano State women at a disadvantage manner. However, Fish farming is positively progressing among urban and peri urban women of the state, making it one of the states in North West Nigeria where women are actively involved in every sector of fish farming (breeding, stocking, sorting, feeding, medication, harvesting, and marketing). Besides, the inequalities in social, cultural and economic factors, alternatively this can be referred to as the gender norms and practices (Omeje et al., 2021 and Gbigbi, 2021). Women fish farmers in Kano State are enormous contributors to food fish, income and job creations to numerous households and also empowering and encouraging women within and outside Kano States of Nigeria.

## MATERIALS AND METHODS

The research was conducted in Kano State, Nigeria. Kano is the commercial nerve center of Northern Nigeria. The 2006 National census reported that Kano is the most populous state in Nigeria, with population of about 9,383,682 million people. The State lies within geographical coordinate's 12.0000° N latitude and 8.5167° E longitude. Temperature in Kano typically ranges from 25°C (77°F) to 40°C (104°F), with the hottest period between March and May. Kano State is bordered by four States (Bauchi, Jigawa, Kaduna, and Katsina). Structured questionnaires were administered directly for the purpose of speed and accuracy. Observations of fifty-one (51) active fish farms from (Fagge, Gwale, Kano Municipal, Kumbotso, and Tarauni) through simple random sampling technique were selected for the research. The results using SPSS statistical 26, narrative, descriptive, table, and pictorial formats are used

for the presentation.

**RESULT**

Broadly, social-cultural norms intertwine in fish farming activities and women receive lower profits than men who are in the same business (Umunna et al., 2020 and Omi, 2021). However, women in Kano State are increasingly involved in fish farming industry, probably due to ownership of tanks within their household and the dynamics of fish demand and supply in the state. These paradigm shifts from tradition and religion which reduces women from participating in distribution of fish produce and direct sales of the final produce to whole/retail markets is giving way for active control and decision making by the women. Plate 1 shows a woman fish farmer in Kano State feeding fish in plastic tanks. Although in a small scale, but women fish farmers are playing crucial role in terms of production due to quest towards improving economic status. The FAO, (2020) reported 19% of African women, are mostly using small-scale systems.



**Plate 1:** A woman fish farmer feeding.
*Source: Field survey, 2025.*

**Table 1:** Socio-economic characteristics of fish farmers

| Gender | Frequency | Percentage |
|---|---|---|
| Male | 35 | 68.6 |
| Female | 16 | 31.4 |
| Total | 51 | 100.0 |
| **Age** | | |
| 20-30 | 22 | 43.1 |
| 31-40 | 14 | 27.5 |
| 41-50 | 14 | 27.5 |
| 51-60 | 1 | 2.0 |
| Total | 51 | 100.0 |
| **Education** | | |
| No education | 5 | 9.8 |
| Primary | 4 | 7.8 |
| Secondary | 6 | 11.8 |
| Vocational | 6 | 11.8 |
| Tertiary | 28 | 57.1 |
| Total | 49 | 96.1 |
| Missing systems | 2 | 3.9 |
| **Resource** | | |
| Own land | 13 | 25.5 |
| Rent | 17 | 33.3 |
| Family | 14 | 27.5 |
| Government | 1 | 2.0 |
| Squatting | 4 | 7.8 |
| Total | 49 | 100.0 |
| Missing | 2 | |

*Field survey, 2025*

Table 1 shows male dominance in fish farming industry with 35(68.6%) while 16(31.4%) are female in Kano State. This is in line with the findings of Githukia et al. (2020), that gender inequality in fisheries and aquaculture is a significant barrier to women's participation in these sectors. Age distribution of the respondents shows that 22(43.1%) are between 20-30 years, 14(27.5%) are between the ages of 31- 40 years while 14(27.5%) are 40 years and above and one respondent 1(2.0%) 51-60 years. This means majority of the respondents are between the ages of 20-40 years which falls within the bracket of active employment level. Educational qualification of the respondents revealed 5(9.8%) had no formal education, 6(11.8%) holds SSCE. 6(11.8%) received vocational education, this is very important in Kano State, different organizations at different times trained fish farmers on stocking, processing, harvesting, marketing and general farm management, and how to reduce cost of productions. 28(57.1%) hold degrees at tertiary level indicating majority of the respondents are enlightened. The distribution of resource issues reveals that, 13(25.5%) owned land, 17(33.3%) rent the ponds, 14(27.5%) are family own land, 1(2.0%) one of the respondent uses government property and 4(7.8%) squatting which is typical to Burrow Pits systems of fish farming in the state. Therefore, land ownership is the most constrain in terms of resource issues this could be as a result of the state fish farmers' lack easily assessable financial support (loan, subsidy or any financial assistance) from any organization.

## DISCUSSION AND CONCLUSION

Food security and poverty reduction has been central to the world developmental agenda, but local and international crisis (war, religion, boko haram, kidnapping etc), growing population, changes in the world economy, adoptions of new technology, and state of the environment combined to reduce quantity of fish production. The study highlights gender equality and poverty reduction which requires positive policies that can bridge up demand and supply of fish productions in Nigeria. Women's empowerment should be a

focus towards achieving more small-scale fish farms in the state. The gender value chain composition of the fish value chain has been extensively, focusing on gender division of labor, social and gender norms, access to resources, and control over resources and benefits (Kruijssen et al., 2021).

The critical success factors driving fish farming production output in Kano State were high per capita consumption of fish due to awareness on fish health benefits, profitability of the fishing industry, huge population (market), infrastructure, technology, commercialization, provision of an enabling environment and skill development. Thus, in a small scale and at comfort of their home's women fish farmers increases productions despite the fact they disproportionately suffer from unequal distribution of resources, time allocation due to time spent on house hold works, and benefits, which limits their involvement and perpetuates the widening gender gap. According to FAO (2024), global fisheries and aquaculture production reached an all-time high of 223.2 million tons in 2022, with 185.4 million tons of aquatic animals' production, indicating significant growth in these sectors. However, the major constraints plaguing the pace of fish farming development in Kano State are land ownership (fish farm), access to credit facilities, adequate supply of required quantity and quality of inputs and marketing. In any case, to achieving fish farming value chain, women empowerment should be a focus, the women respondents realize that indulging in fish farming activities is very beneficial not only as an individual but source of livelihood and employment generation.

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# A REVIEW ON CLIMATE CHANGE AND SMART AQUACULTURE

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**ABSTRACT**

*This study reviewed the impacts of climate change on fish production and smart aquaculture technology in other to provide various adaptation strategies in smart aquaculture which leverage on data-driven decision-making tools for site selection, species selection, and operational management. The study reviewed that by utilizing automated monitoring systems and predictive models, aquaculture operations can proactively manage risks associated with climate change. The study further reviewed mitigation opportunities in smart aquaculture such as: minimizing the sector's carbon footprint through optimized feed utilization, reducing waste, and integrating renewable energy sources into operations. In conclusion, smart aquaculture can contribute to fish production by boosting aquaculture system, reducing environmental impacts, and ensuring sustainable fish production. Therefore, harnessing smart aquacultural technologies, the aquaculture sector can adapt to the climate change, mitigating environmental impacts and contributing to sustainable fish production and food security.*

**Keywords:** Climate Change, Smart Aquaculture, Potential Impacts, Adaptation, and Mitigation

## INTRODUCTION

Aquaculture is one of the fastest-growing sectors in the global food production system, currently supplying more than half of the fish consumed worldwide (FAO, 2022). However, the industry is facing significant risks associated with climate change, which can create adverse conditions for fish farming, including changes in water quality, disease outbreaks, and changing habitats for aquatic organisms. As aquaculture continues to grow, the adoption of "smart" aquaculture technologies such as Internet of Things (IoT) devices, automated feeding systems, and climate monitoring tools presents an opportunity to enhance resilience and sustainability in the face of climate change. (Zhuhua *et al.*, 2019. These technologies can help monitor environmental conditions, optimize resource use, and improve fish health and welfare. Moreover, the incorporation of eco-friendly practices, such as integrated multi-trophic aquaculture (IMTA) and better feed management, can mitigate the environmental impacts of aquaculture operations and contribute to broader climate mitigation goals. This review paper explores these areas in depth, focusing on how smart aquaculture can serve as both a solution to the challenges posed by climate change and a pathway to achieving sustainable aquaculture practices.

### Causes of Climate Change in an Ecosystem

Climate can change due to natural processes (bio-geographical) and human activities (anthropogenic). Human activities that emit large amounts of greenhouse gases include industrialization, burning of fossil fuel, gas flaring, urbanization, and agriculture (Cunningham and Cunningham, 2004). Climate change can also be influenced by the astronomical processes such as the extraterrestrial factors and volcanic eruption. The astronomical factors include the changes in the eccentricity of the earth's orbit, the way the continents are arranged, changes in the obliquity of the plane of ecliptic and changes in orbital procession,

while the extra-terrestrial factors are solar radiation quantity and quality among others. On the other hand, the anthropogenic factor in climate change involves human activities that either emit large amount of greenhouse gases (GHG); carbon (IV) oxide ($CO_2$), methane ($CH_4$), chlorofluorocarbons (CFC) and nitrous oxide ($N_2O$) among others into the atmosphere that depletes the ozone layer or activities that reduce the number of carbons absorbed from the atmosphere (Cunningham and Cunningham, 2004). The human factors that emit large amounts of greenhouse gases include industrialization, burning of fossil fuel, gas flaring, urbanization and agriculture. Also, human activities that reduce the amount of carbon sinks are deforestation, alterations in land use, water pollution and agricultural practices. In light of these challenges, integrating smart technologies and practices into aquaculture systems can enhance their resilience and productivity, thereby contributing to sustainable food systems.

**Impacts of Climate Change on Aquaculture**

Reduction of Fish Yields: Rising water temperatures can reduce oxygen levels, alter metabolism, and disrupt breeding cycles, ultimately affecting fish yields. Sudden rise in temperature on water bodies can significantly influence aquatic ecosystems thereby affecting dissolved oxygen levels, species distribution, metabolic rates of organisms, and the overall health of water bodies, with warmer temperatures often leading to decreased oxygen availability and altered food webs, which can disrupt the balance of aquatic life. Increased temperature and altered precipitation patterns can lead to decreased water quality, affecting fish health and productivity. Higher inland water temperatures may reduce the abundance and distribution of wild fish stocks in lakes by reducing water quality, longer dry seasons, fish mortality, introduction of new predators and pathogens, and changes in the prey abundance for fish. There is also a shift in species distribution and abundance. Climate change can alter the distribution of fish species, potentially disrupting ecosystems and impacting fisheries.

**Adaptation Strategies to climate change impacts in aquaculture**

Selecting Climate-Resilient Species like; Such as; C*larias gariepinus* (African catfish), O*reochromis niloticus* (Nile Tilapia), *Heterotis niloticus*, Zebrafish, Atlantic Salmo etc. Focusing on species that can withstand changing climatic conditions, such as temperature fluctuations and disease outbreaks. Also, improving Water management and enhancing water quality monitoring to maintain optimal growing conditions for aquatic organisms. Integrated Multi-Trophic Aquaculture (IMTA) is also a good adaptation strategy. This can be done by farming multiple species with different trophic levels in the same system to reduce environmental impact and enhance resilience.

**Mitigation for climate change**

Mitigations are essential for reducing these emissions and slowing the pace of global warming. This review explores various strategies for climate change mitigation, drawing on recent literature to provide insights into effective approaches. A crucial strategy for mitigating climate change is the transition from fossil fuels to renewable energy sources. Solar, wind, hydroelectric, and geothermal energy significantly reduce carbon footprints compared to traditional energy sources. A study by Jacobson *et al.*, (2017) highlights that a widespread transition to 100% renewable energy in the U.S. could prevent up to 4 million deaths and save the economy trillions through health benefits and reduced climate impacts. Improving energy efficiency in industries, buildings, and transportation is another vital mitigation measure. Rishabh *et al.*, (2019) discuss how implementing energy-efficient technologies can drastically reduce GHG emissions while maintaining economic growth. The authors emphasize the importance of government incentives and public awareness campaigns in promoting energy-efficient behaviours among consumers and businesses alike.

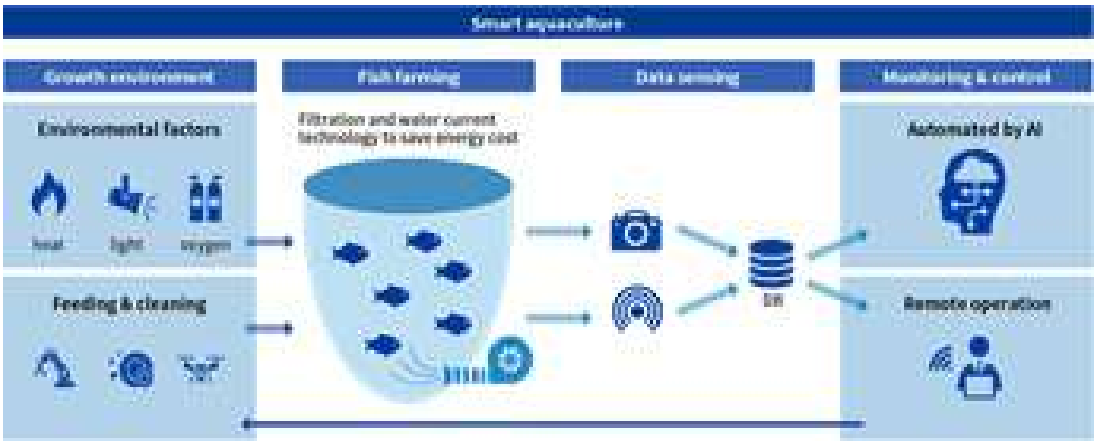
**Sustainable Agriculture Practices**

Agriculture is both a significant contributor to GHG emissions and a sector vulnerable to climate change

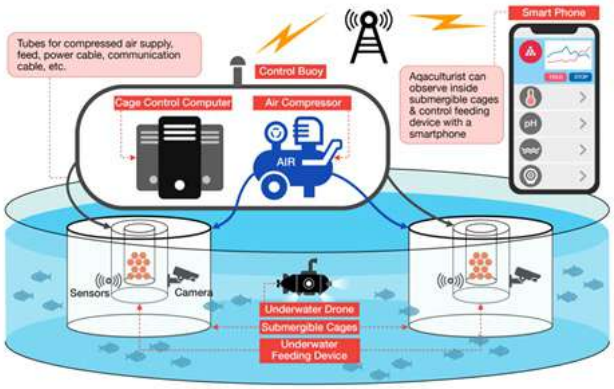
impacts. Implementing sustainable agricultural practices, such as agroforestry, cover cropping, and organic farming, can enhance carbon sequestration and reduce emissions. According to a meta-analysis by Smith *et al.*, (2014), sustainable practices can yield 20%-35% lower emissions per unit of agricultural output, contributing to food security while mitigating climate change. Reforestation and afforestation are complementary strategies that enhance carbon sinks, helping to offset emissions. Studies have shown that forest ecosystems can absorb substantial amounts of carbon dioxide from the atmosphere. Canadell and Raupach (2008) provide evidence that restoring and maintaining forests can play a critical role in global carbon management, indicating that a short-term increase in global forest cover could potentially limit climate change. The last mitigation measures are Smart Aquaculture practice and developing strategies that integrate climate change adaptation and mitigation measures to ensure the sector's sustainability. The principles of smart aquaculture include the use of technology to optimize resource usage, improve fish health monitoring, enhance feeding efficiency, and minimize environmental impacts. Key strategies involve the implementation of precision feeding techniques, automated monitoring systems, and data management platforms to make informed decisions that benefit fish welfare and productivity.

**Climate Smart Aquaculture (CSA)**

Climate-Smart Aquaculture is aim to support food security taking into account the need for adaptation and the potential for mitigation. CSA addresses the challenges of building synergies between the related objectives of climate change mitigation, adaptation and productivity and income increase, and minimizing their potential negative trade-offs. Climate-smart fisheries and aquaculture will require: improving efficiency in the use of natural resources to produce fish and aquatic foods; maintaining the resilience aquatic systems and the communities that rely on them to allow the sector to continue contributing to sustainable development; and gaining an understanding of the ways to reduce effectively the vulnerability of those most likely to be negatively impacted by climate change. (Zhuhua *et al.*, 2019). Examples of tactics for attaining CSA objectives in respect to fisheries include: the reduction of excess capacity and the implementation of fishing activities that are linked with improved fisheries management and healthy stocks; increased production efficiency through better integrated systems; improved feeding and reduced losses from disease in aquaculture.



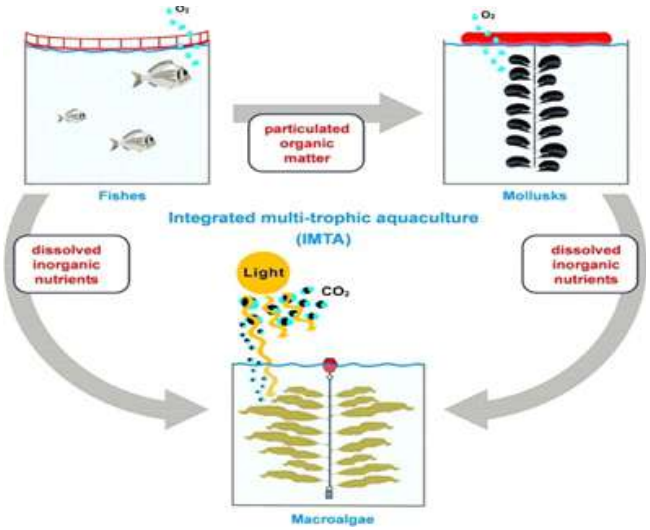

*Source: https://regional.fish/en/farming/*




*Source: https://www.mdpi.com/1370442*

**Smart Aquaculture Practices in Nigeria**

Smart aquaculture refers to the use of improved technologies, data analytics, and innovative methods to improve the efficiency, sustainability, and Aquaculture production. Integrated Multitrophic Aquaculture (IMTA): WorldFish is promoting IMTA in Nigeria, which involves farming multiple species together to improve efficiency and reduce waste.







*Source: https://seafoodnetworkbd.com/integrated-multi-trophic-aquaculture-imta-and-its-benefits*

Aquaponics: Researchers at the University of Ibadan have demonstrated the benefits of aquaponics, a system that combines fish farming with plant production, showing increased food production and investment profitability. Biofloc Fish Farming: J. Auwalu discusses the rise of Recirculating Aquaculture Systems (RAS): A feasibility study by Emmanuel O. Benjamin explores the potential of small-scale RAS for sustainable urban farming in Nigeria, emphasizing its benefits for water conservation and reduced environmental impact. Benjamin *et al.*, (2022)

**Environmental Sustainability in Smart Aquaculture**

Sustainability is one of the main challenges facing aquaculture. By implementing smart aquaculture practices, farmers can significantly reduce the environmental impacts of their operations. For instance, precision feeding techniques decrease feed wastage, which in turn reduces the phosphorus and nitrogen outputs from farms, mitigating the risks of eutrophication in surrounding water bodies (Zhuhua *et al.*, 2019). Smart practices can enhance resource efficiency. By optimizing water usage, minimizing energy consumption, and employing integrated multitrophic aquaculture (IMTA), farmers can create more sustainable systems that utilize environmental resources more effectively (Naylor *et al.*, 2021).

## CONCLUSION

Climate change is a serious threat to the global food security most especially in Africa. Impact of climate change limit sustainable production of fisheries and aquaculture. The adoption of climate smart approach enhances sustainable fisheries production in the face of climatic change and awareness on the climate smart approach is relatively low. Increased awareness on climate smart approaches in fisheries sector have potentials for enhancing food security and sustainable better livelihood for farmers.

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# FISHERIES BIOLOGY AND SMALL-SCALE FISHERIES MANAGEMENT - FBSFM

# LENGTH-WEIGHT RELATIONSHIP, CONDITION FACTOR AND SEX RATIO OF *Mormyrus rume* AND *Oreochromis niloticus* IN KAFIN GANA RESERVOIR, BIRNIN KUDU LOCAL GOVERNMENT AREA, JIGAWA STATE

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**ABSTRACT**

*This study appraised the Length-Weight Relationship, Condition Factor and Sex Ratio of Mormyrus rume and Oreochromis niloticus in Kafin Gana Reservoir, Jigawa State. 200 pieces of the fish samples were collected for a period of two months by local fishermen using diversified fishing gears. The samples were preserved and transported to the Laboratory for further analysis. Length and weight of the fish samples were measured for total length [TL], total weight [TW]. The condition factor (K) and sex ratio were also calculated using the conventional formulae while regression and correlation was carried out using SPSS computer software package. The results for the total length of M. rume and O. niloticus ranged from 13.6 to 25.3cm while the weights ranged from 20.9 to 130.9g. The females of M. rume had better b value of 3.139 than males (1.087) and combined sex (3.069), while, the male sex of O. niloticus had better b value of 0.730 indicating the possibility of better growth patterns than combined (0.563) and female (0.241). The condition factor (K) for M. rume is 0.760, 0.785, 0.876 for males, females and combined sexes, respectively. The fish sample was dominated by male fish for M. rume with Sex Ratio = 3:1 while O. niloticus fish sample was dominated by female with Sex Ratio = 1:5. The study contributes to the management of natural stocks of fish species which are economically and ecologically important.*

**Keywords:** Length-weight relationship; Sex ratio; freshwater fish; conservation; Management

## INTRODUCTION

Fish are high-quality food resources, apart from their protein contents; they are also rich in vitamins, minerals and varying amounts of essential fatty acids beneficial to human health. *Mormyrus rume* is a fresh water species of the family Mormyridae found in tropical Africa (Fawole, 2020). They occur in fast moving waters with demersal habits (Holden and Reed, 2014). Nile tilapia, *Oreochromis niloticus* is among leading farmed species around the world. They inhabit freshwaters and water bodies of low salinity, as is typical of most Tilapia species (Mortuza and Al-Misned, 2013). Length-weight relationships gives information on the condition and growth patterns of fish. Condition factor studies take into consideration the health and general well-being of a fish as related to its environment (Mortuza and Al-Misned, 2013). Various investigators (Kumar *et al*., 2017; Melaku *et al*., 2017) documented condition factor expressing the degree of wellbeing of fishes in their habitat. A sex ratio is the ratio of males to females in a population it provides basic information to assess the reproductive potential and to estimate stock size of fish populations. Length-weight relationship, condition factor and sex ratio are very important parameters for proper culture, exploitation and management of the population of fish. The present study aims at providing information on the length-weight relationship, condition factor and sex-ratio of *Mormyrus rume* and *Oreochromis niloticus* in Kafin Gana Reservoir in Birnin Kudu Local Government Area, Jigawa State to determine whether the fishes are in good condition or not.

## MATERIALS AND METHOD

### Study Area

Kafin Gana Reservoir is located at Kafin Gana town Birnin Kudu Local Government Area of Jigawa state.

Kafin Gana is located between Birnin Kudu and Dutse Local Government at latitudes $11^0 30^0$N and $9^0 21^0$E. It is in Sudan savannah as ecological zone of Nigeria. The dam was established primarily for irrigation purposes having a surface area of 121ha.

**Collection of Fish Sample**

The fish samples were collected from Kafin Gana Reservoir, preserved and transported to the Laboratory, Department of Fisheries and Aquaculture, Federal University Dutse for further analysis. A total of 200 samples of *M. rume* and O. *niloticus* (one hundred each from each specie) were collected for a period of two months. Samples were identified with the aid of fish identification guide.

**Length-Weight Relationship and Condition Factor**

The measurement of the fish was taken by placing it on a flat board. The parameters measured include the total length [TL], The weight of the sample was obtained using electric top loading balance.

Calculations for males and females fish species was done separately and also combined using the conventional formula described by Le-Cren (1951) as follows:

$W = al^b$ ---------- (1)

The above equation (1) and data were transformed in to logarithms. Therefore equation (1) becomes:

$\log W = \log a + b \log L$ ---------- (2)

Where W = weight of fish (grams); L = Total length of fish in centimeter; a = constant;
b = an exponent.

The 95% confidence interval, CI of 'b' was computed using the equation:

$CI = b \pm (1.96 \times SE)$ ---------- (3)

Where SE is the standard error of 'b'.

**Condition factor (K)**

The condition factors (K) were also calculated for individual fish species for each month using the conventional formulae described by Pauly (1983):

$$K = \frac{W \times 100}{L^3} \text{ ---------- (4)}$$

**Sex determination**

The gonads were examined with the naked eye in the case of sexually mature forms and a dissecting microscope was employed for examination of the sexually immature forms. The sex ratio was given as males: females (M: F), calculated using the formula: total number of males/ total number of females. The chi-square ($\chi^2$) was used to verify the existence of significant differences between the sex ratio of the study species and commonly expected 1:1 sex ratio (Oliveira *et al.*, 2012).

**Statistical Analysis**

Length-Weight relationship [LWR], were computed using linear regression model. The regression correlation was carried out using SPSS computer software package.

**RESULTS**

**Length-Weight Relationship, Regression analysis and Condition factor**

Length-Weight relationship, regression analysis and condition factor for the two fish species under study are presented in Table 1 and 2. The total lengths of 100 specimens each of *M. rume* and O. *niloticus* examined in this study ranged from 13.6 to 25.3cm and 9.2 to 15.0cm.

**Table 1:** Length-Weight Relationship and Condition Factor of *M. rume*

| Sex | No. of samples | Percentage | Weight | | Length | | a | b | $R^2$ | K |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | Min | Max | | | | |
| Both | 100 | 100 | 20.9 | 130.9 | 13.6 | 25.3 | 2.215 | 3.069 | 0.955 | 0.876 |
| Male | 76 | 76 | 24.3 | 50.7 | 15.0 | 19.2 | 0.172 | 1.087 | 0.928 | 0.760 |
| Female | 24 | 24 | 20.9 | 130.9 | 13.6 | 25.3 | 2.306 | 3.139 | 0.952 | 0.785 |

a = Intercept, b = Slope, $R^2$ = Regression coefficient, K = Condition factor
Sex Ratio = 3:1 for Male: Female

**Table 2:** Length-Weight Relationship and Condition Factor of O. *niloticus*

| Sex | No. of samples | Percentage | Weight | | Length | | a | b | $R^2$ | K |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | Min | Max | | | | |
| Both | 100 | 100 | 9.9 | 152.7 | 9.2 | 15.0 | 0.865 | 0.563 | 0.137 | 0.530 |
| Male | 18 | 18 | 9.9 | 152.7 | 9.2 | 15.0 | 0.60 | 0.730 | 0.733 | 0.825 |
| Female | 82 | 82 | 15.7 | 22.5 | 9.5 | 10.6 | 1.222 | 0.241 | 0.048 | 0.486 |

a = Intercept, b = Slope, $R^2$ = Regression coefficient, K = Condition factor
Sex Ratio = 1:5 for Male: Female

b- Values for females *M. rume* was 3.14 indicating a better growth pattern than the males with a value of 1.09 and combined sex with values of 3.07. While the b-values for O. *niloticus* was 0.73, indicating a better growth pattern than the female (0.24) and combined sex (0.56). condition factor (K) for *M. rume* is 0.76, 0.785, 0.876 for males, females and combined sexes respectively, that of O. *niloticus* are 0.825, 0.486, 0.530 for males, females and combined sexes respectively. Fish samples were dominated by male fish for *M. rume* with a ratio of 3:1 (male: female) indicating that males were significantly more in number than females, while, in O. *niloticus* the females were more numerous than the males in a ratio of 1:5 (male: female). Figure 1 and 2 shows the graphical representation of the length-weight relationship of the two fish species.

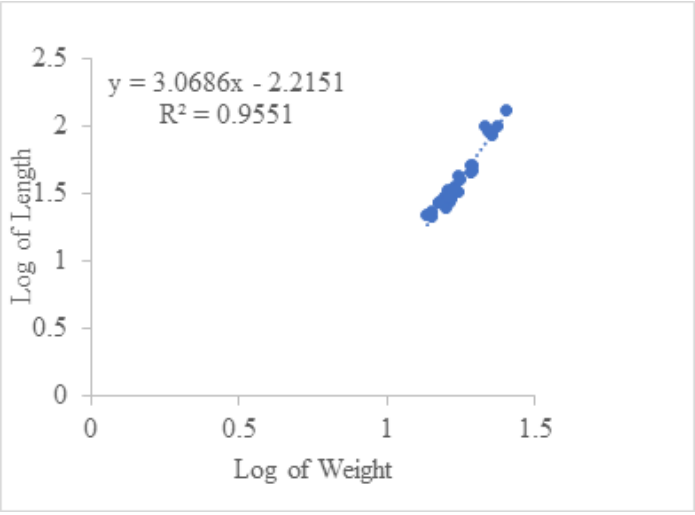



***Figure 1:*** *length-weight relationship of M. rume*

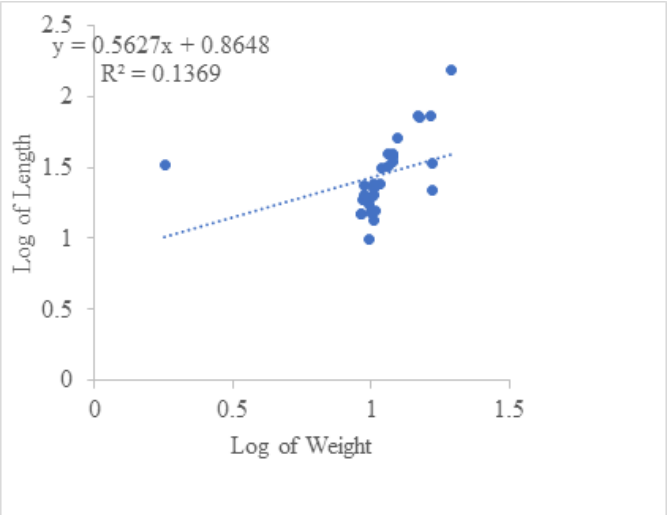



***Figure 2:*** *length -weight relationship of O. niloticus*

## DISCUSSION

Effective fishery management requires in-depth knowledge of population parameters such as length-weight relationship, this relationship allows estimation of average weight of given length group and provides valuable information on the habitat where the fish lives. The findings of the study revealed that

*M. rume* in kafin-Gana exhibited isometric growth since there was no significant difference between the b value (b = 3.069) in comparison with the ideal 'b' value for isometric growth (b = 3). O. *niloticus* expressed a negative allometric growth. The result obtained in this study agrees with the report of Kefas *et al*. (2020) that males of O. *niloticus* form lake Geriyo showed a negative allometric growth. It has been observed that certain factors such as increase in weight due to intake of food, season of the year and the time of the day when the fish was captured, loss of weight due to food regurgitation and spawning can among other things affecting 'b' values (Kefas *et al*., 2016). As values of 'b' increases the size of the fish also increases because the fish usually grows proportionally in all directions. Studies from (Getso *et al*., 2017; Kumar *et al*., 2017; Melaku *et al*., 2017) showed that the wellbeing of fishes is determined by length-weight structured data. The results obtained showed lower condition factor in O. *niloticus* indicating that the fish is not in good condition. The condition factor is a measure of various biological and ecological factors with regard to their feeding conditions (Nehemiah *et al.*, 2012). Total percentage of male and female ratio showed that the males of *M. rume* had a sex ratio of 3:1 while, the ratio of O. *niloticus* was 1:5; a different ratio was observed by Benedict *et al*. (2009) in tropical flood plain of Cross river who reported that *M. rume* and O. *niloticus* have equal sex ratio. In another study Cishahayo *et al*. (2022) reported that the male fish dominated females in nearly all the samples gotten from Lake Naivasha, Kenya. While, Waithaka *et al*. (2015) reported a sex ratio of 2:1 for O. *niloticus* from lake Naivasha.

## CONCLUSION

The length weight relationship and b-values indicate isometric growth of *M. rume* and negative allometric growth of O. *niloticus*. The *M. rume* examined were healthy and in good condition and can be used for commercial production. The male sex dominated in *M. rume* while female sex was predominant in O. *niloticus*. Therefore, proper management of water bodies is essential for sustainable fish stock exploitation in the country.

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# STOCK ASSESSMENT OF *Heterobranchus bidorsalis* (Geoffroy Saint-Hilaire 1809) FOR CONSERVATION AND MANAGEMENT IN RIVER IMO, NIGERIA

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**ABSTRACT**

*The Fish stock status (ages, growth rates, Mortality, Recruitment and Exploitation rate) of H. bidorsalis in River Imo were investigated from September 2023 to April, 2024. Standard lengths of 25,034 specimens were measured to the nearest centimeter (cm). The length data were analyzed with ELEFAN II of FiSAT (FAO-ICLARM) II software and fitted into the Von Bertalanffy Growth Model (VBGM). The estimated VBGM was* $L_{(t)} = 105[1 - e^{-0.24(t-0.945)}]$. *The maximum length* ($L_\infty$) *= 105cm, total mortality (Z) = 2.79 yr*$^{-1}$, *Natural Mortality (M) = 0.74 yr*$^{-1}$, *Fishing Mortality (F) = 2.05yr*$^{-1}$ *and Exploitation rate (E) = 0.72 yr*$^{-1}$. *Maximum predicted age was 15 years, while the length at first sexual maturity* ($L_m$) *= 70cm. H. bidorsalis is experiencing over exploitation and over-fishing in River Imo. Management strategies are Restriction on the use of small mesh sizes, restriction on the catching of sexually immature individuals (i.e those less than 70cm) and closure of fishing season of H. bidorsalis within the identified recruitment period of the month of May annually to ensure the species' conservation and avoid the collapse of its fishery in the river.*

**Keyword:**
*Heterobranchus bidorsalis*, Imo, status, conservation, management

## INTRODUCTION

Comprehensive knowledge of fish population dynamics (ages, growth rates, recruitment, mortality, exploitation rate, etc.) is crucial for setting sustainable harvest limits (El – sayed & Abd – El – Hady (2018)). *H. bidorsalis* is found in Northern and sub – Saharan Africa (Nelson 2006). The species by the International Union of Conservation of Nature (IUCN, 2024) is listed as 'Least concern'. However, Froese & Pauly in Fishbase (2024) noted that while the fish species as a whole is considered to be of 'Least Concern', local population may face threats such as habitat degradation, over-fishing or pollution as Adaka, (2016) reported catch from Njaba River. River Imo is ranked an important River in Nigeria. The significance of the river is highlighted in Afigbo (2005).

In spite of several works on *H. bidorsalis* (Agbebi *et. al.*, 2014, Eyo & Inyang, 2018, e.t.c) there are no published works on the stock status of *H. bidorsalis* in River Imo. This study, therefore, investigated the fishery parameters of the species in view of formulating management strategies for the conservation and sustainability of the fishery in River Imo.

## MATERIALS AND METHOD

Four sites along the main course of R. Imo were designated as sampling stations. Assorted fishing gears were used to catch fish by professional fishers fortnightly from September 2023 to April, 2024. Identification keys of Pauly (2003) and Adesulu & Sydenham (2007) were used to sort the different species. Standard length (SL) of specimens of *H. bidorsalis* was measured to the nearest centimeter (cm). The length data were analyzed by Electronic Length Frequency Analysis II (ELEFAN II) using FISAT (FAO – ICLARM) Tools II (Gayanilo *et. al.*, 2005) then fitted into Von Bertalanffy Growth Model

(VBGM):

$L_{(t)} = L_{\infty}[\ 1 - e^{-k(t-to)}]$

Where $L_{(t)}$ = Length at time, t,

$L_{\infty}$ = Length at infinity (i.e maximum length);

$t_o$ = time, length was zero

And K = growth coefficient.

The FISAT II software further estimated the total Mortality (Z), Natural Mortality (M), Fishing Mortality (F), Recruitment pattern and Exploitation rate (E) while the Length - at - first sexual maturity ($L_m$) was derived from

$L_m$ =

| Parameters | Values |
|---|---|
| Asymptotic Length ($L_\infty$) | 105cm |
| Total mortality(Z) | 2.79 $yr^{-1}$ |
| Natural Mortality(M) | 0.74 $yr^{-1}$ |
| Fishing Mortality(F) | 2.05 $yr^{-1}$ |
| Max. Predicted Age | 15 yrs |
| Length at first sexual maturity | 70cm |
| Exploitation rate(E) | 0.72 $yr^{-1}$ |

The maximum recorded length of *H. bidorsalis* is 150 – 160cm (Fishbase, 2024). In this study, the maximum length recorded was 105cm. The difference could be as a result of the different methods used and the difference in number of specimens examined. Total mortality in this study of 2.83$yr^{-1}$ is higher than that in Lake Kainji: (1.44$yr^{-1}$) (Adeyemi & Omitogon, 2018). River Imo is experiencing illegal, unregulated, unreported (IUU) fishery.

## CONCLUSION AND RECOMMENDATIONS

Fish is optimally exploited when F = E = 0.5$yr^{-1}$ (Hilborn & Walters, 2013). In River Imo, F = 2.05$yr^{-1}$ and E = 0.72$yr^{-1}$ which signified that *H.bidorsalis* is experiencing over – exploitation and being over – fished. The estimated length at first sexual maturity ($L_m$ = 70cm) suggests that most individuals are being caught before sexual maturity which in the long run will affect the reproductive capacity of the stock (Morgan 2008). The management strategies are:

1. Restriction on the use of small mesh sizes
2. Restriction on the capture of sexually immature individuals (that is those below 70cm)
3. Closure of fishing season of *H. bidorsalis* within the identified recruitment period in the month of May, annually to avoid the depletion of the stock which may lead to the collapse of the species' fishery in River Imo.

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# DISTRIBUTION, RELATIVE ABUNDANCE AND COMMUNITY STRUCTURE OF BENTHIC MACRO-INVERTEBRATES FROM SHAGARI RESERVOIR, SOKOTO, NIGERIA

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**ABSTRACT**

*Reservoirs have provided many benefits to host communities from employment opportunities, poverty reduction and rural population stabilization among others. This study assessed Distribution, relative abundance and community structure of Benthic macro-invertebrates of Shagari reservoir to determine the gravity of anthropogenic activities on the aquatic ecosystem. The reservoir was stratified into three sampling Stations (A, B and C) and samples were collected in triplicate per Station. The distribution and abundance of benthic macroinvertebrates (from sediment) were estimated. Pollution level was also estimated using "Shannon-Wiener" diversity index and "Margalef's" species richness. Data were subjected to multivariate statistical analysis using PRIMER$_{v7}$ software. Tarebia granifera (42.93%) was the most abundant macro-benthic invertebrate. "Shannon-Wiener diversity 0-1.07 and "Margalef's" species richness 0-0.43 indices were estimated for macro-benthic invertebrates. The study concluded that benthic macro invertebrates of Shagari reservoir were negatively affected by anthropogenic activities within and around the reservoir.*

**Keywords**: Benthic macro-invertebrates, species richness, diversity index

## INTRODUCTION

Benthic macroinvertebrates are among the most commonly used group of freshwater organisms for the biological assessment of water quality (Rosenberg and Resh, 1993; Thorne and Williams, 1997) because they offer many advantages as continuous biological indicators of the waters they inhabit. They are ubiquitous, diverse, abundant and represent a wide range of pollution sensitivity (Cairns and Dickson, 1971; Modde and Drews, 1990;). Their relatively long life cycle and sedentary nature makes them ideal organisms for spatial and temporal monitoring of the aquatic environment. In addition, sampling equipment is usually low in cost and relatively easy to use.

## MATERIALS AND METHOD

### Sampling design

Stratified random sampling was adopted. The reservoir was divided into transects based on activity level where benthic macro invertebrate were sampled randomly from each stratum following standard procedures.

### Determination of Macro-Invertebrates Abundance and Distribution

Sediment samples for benthic macro-invertebrates were obtained using a 0.1m$^2$ Van veen Grab and emptied into labelled polythene bags. The samples were washed through 0.5-1.0 mm sieve to collect the organisms, which were then placed for a few hours in magnesium chloride solution in order to relax the organisms prior to preservation. The organisms were fixed in 5% formalin thereafter as described by Davide and Marco (2010). Samples were then stained with Rose Bengal solution in the laboratory for ease of sorting (Holme and McIntyre, 1984). Large samples were subdivided into sub-samples of roughly equal size that can be sorted more comfortably. A small quantity of unsorted material was placed on a tray

for an initial general sorting for larger organisms with the help of a magnifying lens. Shell fragments, vegetal debris and coarse detritus in the sample were rinsed in a separate container and checked for the presence of invertebrates. Large organisms were placed immediately in appropriate containers making sure that no other smaller animals were attached to their bodies. Samples were spread onto a Petri dish and carefully examined to identify the organisms. Organisms were picked up and placed in different containers according to the main taxonomic groups using standard guides. The organisms were counted to determine the distribution and numerical abundance.

**RESULTS**

A total of 184 organisms from 3 species belonging to 2 families Thiaridae and Pleuroceridae, were encountered throughout the duration of the study (Table 2). Thiaridae were represented by *Tarebia granifera* and *Ancylus rivularis*, while Pleuroceridae, was represented by *Pleurocera acuta*. *Tarebia granifera* was most predominant accounting for about 42.93%, followed by *Pleurocera acuta* (35.17%) and the least was *Ancylus rivularis* (21.20%).

In Station A, no species was recorded (Table 3). Three (3) species were recorded in Station B where *Tarebia granifera* (22.83%) dominated followed by *Pleurocera acuta* (16.85%) and the least was *Ancylus rivularis* (13.04%). In Station C, all three species were recorded with *Tarebia granifera* accounting for 20.11% in terms of number

The highest number of species (3) was recorded in Station B and C followed by Station A with 0 species (Table 1). Station B and C had the same number (100) of individuals followed by Station A with none identified. In terms of species richness, Station B and C had the same (0.43). Evenness index ranged from 0.94 in Station C to 0.98 in Station B. Evenness index was not computed for Station A where no single species was recorded. Shannon diversity index ranged from 1.03 in Station C to 1.07 in Station B. Simpson dominance index was highest at station B (0.66) and lowest at station C (0.63). Diversity and dominance indexes were not computed for station A because no species was identified.

Figure 1 shows hierarchical cluster analysis of the stations based on the distribution of macro-benthic invertebrates in Shagari reservoir. The samples were separated into two clusters at a Bray-Curtis similarity level. Station A forms the first cluster while stations B and C formed the second cluster at a similarity level of 95.41. Similarity profile test (SIMPROP) however showed that the two clusters were not significantly ($P>0.05$) different.

**Table 1:** Diversity indices / community structure for macro-benthic invertebrates in Shagari Reservoir

| | Stations | | |
|---|---|---|---|
| Diversity indices | A | B | C |
| Number of species | 0 | 3 | 3 |
| Number of individuals | 0 | 100 | 100 |
| Margalef species richness (d) | 0 | 0.43 | 0.43 |
| Pielou's evenness index (J') | 0 | 0.98 | 0.94 |
| Shannon's diversity index (H') | 0 | 1.07 | 1.03 |
| Simpson's dominance index | 0 | 0.66 | 0.63 |

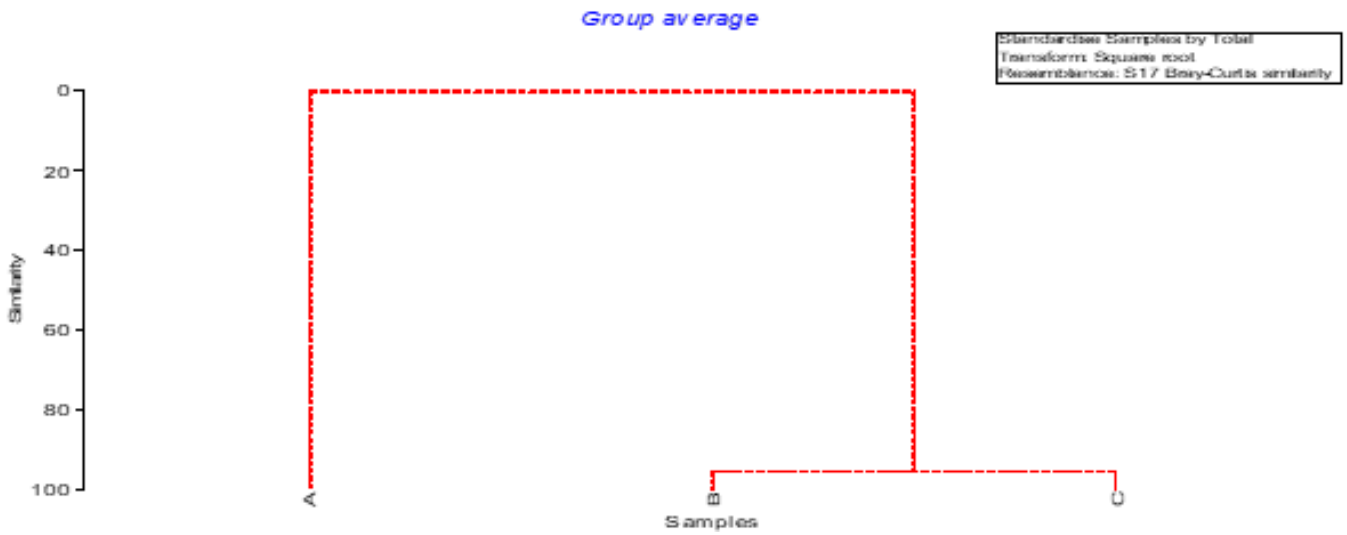



**Figure 1:** Cluster analysis of sampling stations based on the abundance and distribution of macro-benthic invertebrates in Shagari Reservoir.

**Table 2.** Temporal distribution and relative abundance of benthic macro-invertebrates in Shagari Reservoir (nos/ml)

| | | Months | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| FAMILY | SPECIES | SEPT. | OCT. | NOV. | DEC. | JAN. | FEB. | MAR. | TOTAL | RA |
| Thiaridae | | | | | | | | | | 64.13 |
| | *Tarebia granifera* | 11(5.98) | 9(4.89) | 8(4.35) | - | 12(6.52) | 17 (9.24) | 22 (11.96) | 79 | 42.93 |
| | *Ancylus rivularis* | 4 (2.17) | - | - | - | 6 (3.26) | 16 (8.70) | 13 (7.07) | 39 | 21.20 |
| Pleuroceridae | | | | | | | | | | 35.17 |
| | *Pleurocera acuta* | 9 (4.89) | 11 (5.98) | - | - | 14 (7.61) | 15 (8.15) | 17 (9.24) | 66 | 35.17 |
| | TOTAL | 24 | 20 | 8 | - | 32 | 48 | 52 | 184 | 100 |

**Table 3.** Spatial distribution and relative abundance of benthic macro-invertebrates in Shagari Reservoir

| | | Stations | | | | | |
|---|---|---|---|---|---|---|---|
| CLASS | FAMILY | SPECIES | A | B | C | TOTAL | RA% |
| Gastropoda | Thiaridae | | | | | | 64.13 |
| | | *Tarebia granifera* | (0.0) | 42 (22.83) | 37 (20.11) | 79 | |
| | | *Ancylus rivularis* | (0.0) | 24 (13.04) | 15 (8.15) | 39 | |
| | Pleuroceridae | | | | | | 35.17 |
| | | *Pleurocera acuta* | (0.0) | 31 (16.85) | 35 (19.02) | 66 | |
| | | TOTAL | - | 97 | 87 | 184 | 100 |

## DISCUSSION

A total of 184 organisms from 3 species belonging to 2 families were discovered in Shagari reservoir. Auta and Abubakar (2009) reported a total of 330 individuals from 7 species comprising of 4 taxa in Nguru lake whereas a total of 348 individuals from 28 species made up of 26 taxa were found in Okhuo River by Udebuana *et al.* (2015) these are more diverse than Shagari reservoir. Ho *et al.* (2018) revealed a total of 3453 individuals, from 314 species comprising 82 taxonomic groups from Nee Soon freshwater swamp forest, Singapore. The low population of benthic invertebrates in Shagari reservoir compared to the aforementioned water bodies could be attributed to the age and relative sizes of the respective water bodies.

Margalef's species richness ranged between 0.00 at station A and 0.43 in stations B and C. These values

were lower than the findings of Balogun *et al.* (2011) in the Lagos Lagoon, Emmanuel and Ogunwenmo (2010) in Lagos Creeks and Olawusi and Ajibare (2014) at Ondo Coastal Waters. Simpson's dominance index ranged from 0.00 to 0.66 is also lower than findings of Balogun *et al.* (2011) in the Lagos Lagoon. Shannon's diversity index ranged from 0.00 to 1.07. This is higher than the values reported by Balogun *et al.* (2011) in the Lagos Lagoon, Emmanuel and Ogunwenmo (2010) in Lagos Creeks and Olawusi and Ajibare (2014) at Coastal Ondo Waters.

## CONCLUSION

In conclusion, Shagari Reservoir has low macro-benthic invertebrate species richness. Shannon's diversity index on the other hand indicated heavy to moderate pollution in Shagari Reservoir (H′<1 = heavy pollution; H′ 1-3 = moderate pollution; H′>3 = ideal aquatic environment.

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# ASPECT OF BIOLOGY AND THE NUTRITIONAL PROFILE OF THE SPINY LOBSTER (*Panulirus regius*) FROM MAKOKO FISH LANDING SITE, LAGOS LAGOON, NIGERIA.

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**ABSTRACT**
*Panulirus regius is an edible marine crustacean known for their spiny exoskeleton and its economic significance in most parts of the world due to the high protein content. Studies on aspects of biology and nutrient composition were conducted from the Makoko fish market of the Lagos Lagoon. The species were collected monthly between November, 2023 – July, 2024. The total length, standard length and the body weight ranged between 11.4 – 27.0 cm, 9.0 – 24.0 cm and 25.5 – 453.1 g respectively. The length-weight relationship showed negative allometric growth (b<3) while the coefficient of determination ($R^2$) showed a strong positive correlation (0.8596), indicating that an increase in length results in increase in weight of the organism. The species exhibited evidence of cannibalistic tendencies, as lobster shells were the major food items observed in the stomachs. There was no significant difference (P > 0.05) in the sex ratio, with males slightly more abundant than females (1:0.9). The findings on the proximate composition revealed that P. regius is rich in protein with significant differences (P < 0.05) in the various nutritional parameters for the dry and wet seasons. The mineral composition showed that the species is rich in sodium, potassium and calcium which are essential for growth, nerve and muscle function, and the development of strong bones and teeth across all age groups. However, there is need for continued research to explore the underlying mechanisms for the seasonal variations and to ensure optimal conditions are maintained for the health and sustainability of lobster populations.*

**Keywords**: Length-weight relationship, Mineral composition, Morphometric, *Panulirus regius*, Proximate composition

## INTRODUCTION

*Panulirus regius*, commonly known as the Royal spiny lobster, is a member of the family Palinuridae, within the order Decapoda, which is one of the largest orders of crustaceans. The order Decapoda includes all shrimp, crabs, and lobsters, characterized by having ten legs (5 pairs of thoracic appendages). They are edible, marine crustaceans known for their lack of large claws and their spiny exoskeleton (Phillips and Booth, 2019).

The genus *Panulirus* is of interest to biologists because of its high level of biodiversity and its wide geographic distribution, while it is also important as a fisheries commodity in Nigeria (Lawal-Are *et al*., 2018). They are mostly found in crevices/caves in coral reefs and rocky substrates. They are nocturnal creatures, emerging at night to forage for food. They reproduce in spring and summer, with females carrying bright orange eggs on their tails. They are carnivores, feeding on molluscs, crustaceans, small fish and other invertebrates. The species is known for its migratory behavior, particularly during the reproductive season, when individuals move to shallower waters for breeding (Pollock, 1995). Spiny lobster as a protein-rich crustacean has become one of the most favourite seafood that commands a high price in the restaurants (Haryono *et al*., 2018). The potential use of *Panulirus regius* is encouraged by the fact that it can be used for different purposes. Lobster species, in general, can be used to prepare diet supplements, to obtain chitin, and as a source of astaxanthin for aquaculture (García-López *et al*., 2016; Varisco *et al*., 2020).

Although, several works (Floreto *et al*., 2000; Bordbar *et al*., 2011; Ayanda *et al*., 2018; Haryono *et al*., 2018; Moruf *et al*., 2021) have been documented on *Panulirus regius* but there is still dearth of information on the biology and the nutritional composition of this species from Lagos Lagoon. Therefore, this work seeks to address this lacuna by determining some aspects of biology as well as the proximate and mineral compositions of Royal Spiny lobster (*Panulirus regius*) from the Makoko fish landing site of the Lagos Lagoon, Nigeria.

## MATERIALS AND METHODS

Brief description of study area: The field survey and sample collection for this study were carried out at Makoko fish landing site of the Lagos Lagoon. Makoko, situated at longitude 60 27' 30ºN and latitude 30 30º 31E, is approximately 1.53 miles from the University of Lagos. Samples collection: A total of 120 (one hundred and twenty) *P. regius* were collected monthly from Makoko fish landing site of the Lagos Lagoon for 9 months (November, 2023 – July, 2024). The samples were preserved in an ice chest and transported to the Department of Marine Sciences where they were transferred immediately to the freezer (-20 °C) in order to reduce post mortem decomposition prior to further analysis.

### Laboratory Analysis

The lobsters were removed from the freezer, allowed to thaw and a towel was used to remove excess moisture from their body. The meristic, morphometric, length-weight relationship, condition factor, food and feeding analysis, reproductive biology was done according to the works of Akinwunmi and Moruf (2021); Akinwunmi *et al*. (2021). While the mineral (Ca, K, Na, Mg, Zn, Cu, P and Fe) and proximate composition (Moisture, Crude protein, Crude fat, Crude fibre, Total ash and Nitrogen free extract) of the species were done using standard methods (Akinwunmi *et al*., 2023).

### Statistical Data Analysis

The data generated were analysed using Microsoft Excel 2021 while the proximate and mineral analysis were subjected to descriptive statistics and analysis of variance (ANOVA) using SPSS (version 16 Statistical Package for Windows). The differences declared at 95% confidence level were resolved using Duncan Multiple Range Test (Zar, 1998).

## RESULTS

The morphometric studies of the lobster species are presented in Table 1. The total length ranged from 11.40 – 27.00 cm while the standard length ranged from 9.00 – 24.00 cm. The total weight ranged between 25.5 – 453.10 g.

**Table 1**: Morphometric characteristics of *Panulirus regius* in Lagos Lagoon, Nigeria

| Morphometric characters | Mean and ranges | | |
|---|---|---|---|
| | Female | Male | Combined sexes |
| Total length (cm) | 19.42 ± 0.54 (12.5 – 27.0) | 17.89 ± 0.45 (11.4 – 27.0) | 18.60 ± 0.35 (11.4 - 27.0) |
| Total weight (g) | 165.87 ± 13.33 (25.5 – 403.1) | 133.59 ± 10.47 (27.0 – 453.1) | 148.65 ± 8.46 (25.5 - 453.1) |
| Standard length (cm) | 16.11 ± 0.48 (9.0 – 24.0) | 14.87 ± 0.40 (9.0 – 23.0) | 15.45 ± 0.31 (9.0 - 24.0) |

Range in brackets; Data are expressed as mean ± SEM

### Length -Weight relationship of *P. regius*

The relationship between the length-weight of *P. regius* was determined and the graph for the log

transformed values is presented in Figure 1.

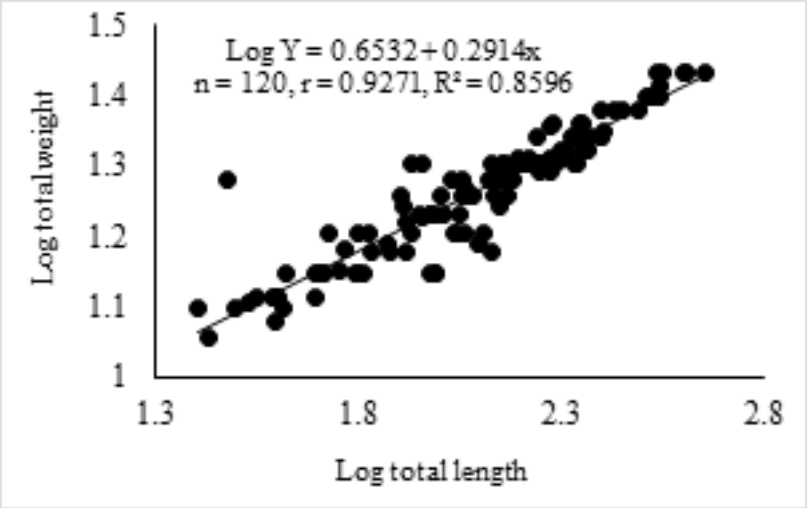



**Figure 1:** Log total length - Log weight relationship of *P. regius* from Lagos lagoon (Nov., 2023 – July, 2024)

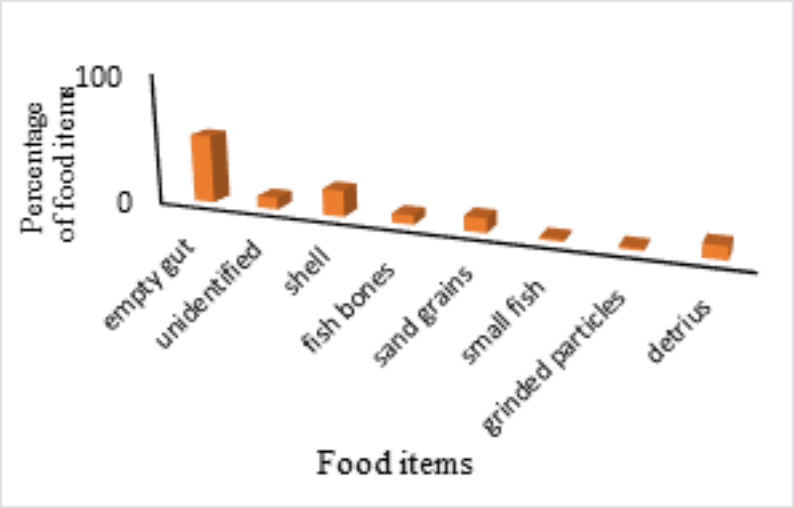



**Figure 2:** Frequency of occurrence distribution of food items in the stomach of *P. regius* from Lagos Lagoon

**Stomach analysis**

The variety of food items found in the stomach of *P. regius* is presented in Fig. 2. The result shows that the stomach contains items like fish bones, shells, fishes, unidentified substances, sand grains, detritus were encountered. Though, shells of an organism were found to be the major food items.

**Reproductive Biology**

**Sex Ratio**

Out of the one hundred and twenty (120) specimens of *Panulirus regius* that were examined, 64 (53.3%) were found to be males and 56 (46.7%) were females, giving a sex ratio of 1:0.9 (male: female). The result shows that the number of males was higher than females as shown in Fig. 3.

**Proximate Composition**

The proximate composition of *P. regius* for the dry and wet seasons is shown in Table 2. The analysis done during the dry season shows no significant difference ($P > 0.05$) in the moisture, protein, fat, fibre and ash while the Nitrogen Free Extract (NFE) differs significantly ($P < 0.05$) from the other parameters.

Meanwhile, there is no significant difference ($P > 0.05$) in the moisture, protein and fat content of the species collected in the wet season which differs significantly ($P < 0.05$) from the fibre, ash and NFE contents of the same season. The proximate composition of the species is higher for the dry season compared to the wet season.

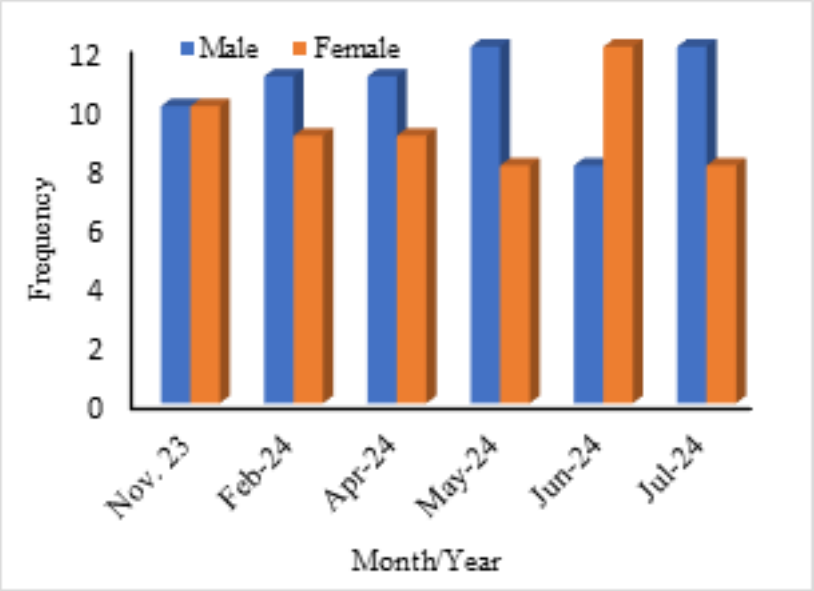



**Figure 3:** Sex ratio of *P. regius* from Lagos lagoon

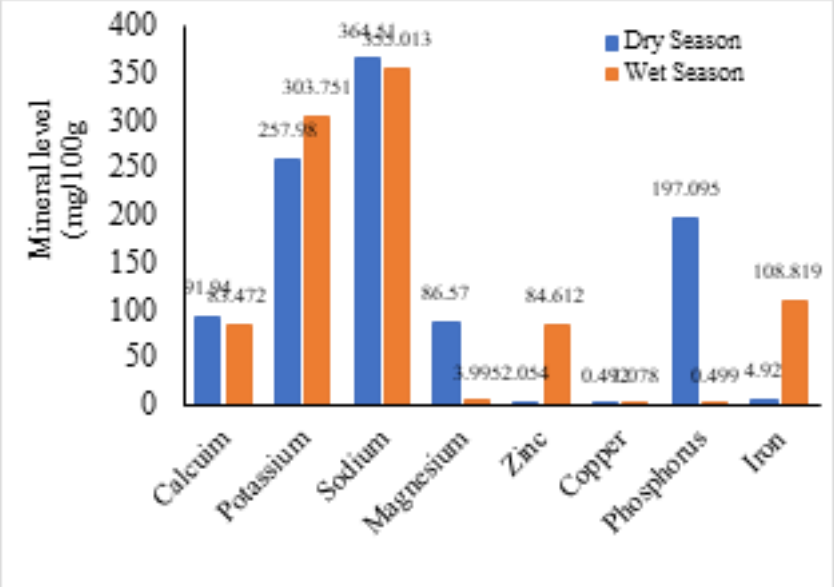



**Figure 4:** Mineral contents of *P. regius* for dry and wet seasons

**Table 2:** Proximate Composition (%) of *Panulirus regius* in dry and wet season

| Seasons | Moisture | Protein | Fat | Fibre | Ash | NFE |
|---|---|---|---|---|---|---|
| Dry | $72.52\pm0.11^{a}$ | $18.33\pm0.01^{a}$ | $2.56\pm0.01^{a}$ | $0.00\pm0.00^{a}$ | $2.10\pm0.02^{a}$ | $4.50\pm0.11^{b}$ |
| Wet | $70.42\pm0.06^{b}$ | $18.05\pm0.08^{b}$ | $2.02\pm0.02^{b}$ | $0.00\pm0.00^{a}$ | $2.09\pm0.01^{a}$ | $7.43\pm0.11^{a}$ |

Data was expressed as mean ± SEM.
$^{a,b}$ Means with different superscripts within a column differ significantly ($P< 0.05$).

The mineral contents of *P. regius* for the dry and wet seasons showed varied concentrations as shown in Fig. 4. Sodium was the most abundant (364.51 and 355.01 mg/100g) followed by followed by potassium (257.98 and 303.75 mg/100g) and then calcium (91.94 and 83.47 mg/100g) for the dry and wet seasons respectively. Copper was the least abundant for both seasons while magnesium and phosphorus was high in dry season and low in wet season. Zinc and iron were also high in wet season and low in dry season.

## DISCUSSION

The result from the morphometric characters showed that the female lobster is larger based on length while the males are bigger in terms of weight. Though, it could be deduced that there is no much variation in the characters, which is an indication that both species of lobster are growing well in the habitat. These findings are similar with the findings of Freitas *et al*. (2007), Akinwunmi and Lawal-Are (2018) and García-Rodríguez and Pérez-Vázquez (2023). The total length-weight relationship of *Panulirus regius* showed a negative allometric growth ($b<3$) indicating that the lobster grows faster in length than in weight. This is in tandem with the work of Waiho *et al.* (2021) and De Boeck and Kristensen (2022) who posited an allometric growth patterns in *Panulirus polyphagus* and *Palinurus elephas* respectively. The coefficient of determination ($R^2$) values showed a strong positive correlation ($r = 0.9271$, $R^2 = 0.8596$) between total length and weight in the lobster species, indicating that an increase in length results in increase in weight of the organism which is similar to the report of Lawal-Are and Adefule (2017).

The analysis of the stomach contents revealed that crustacean shells were the most abundant food item. This finding suggests that these lobsters frequently consume crustaceans, which could include both prey and conspecifics, possibly indicating cannibalistic behavior, especially during ecdysis when lobsters are more vulnerable. This is in line with the work of Cruz and Hernández (2021) and Gutiérrez *et al*. (2023) on *Panulirus argus* and *Panulirus interruptus* respectively, which indicated that crustaceans were the major component of their diet. The report on the sex ratio indicated that there were more males to females, with no significant difference ($P > 0.05$) in the sex ratio. This variation in sexes is not unusual but can stem from a variety of factors, such as habitat conditions, differences in mortality rates, fishing pressures, migration patterns, and reproductive behaviors. These findings negate the work of Lawal-Are and Adefule (2017) but corroborated the work of Schmahl *et al*. (2022).

The findings on the proximate composition revealed significant differences ($P < 0.05$) in the various nutritional parameters for the dry and wet seasons. All the nutrient parameters except CHO was higher during the dry compared to the wet season. This variation might be due to differences in food availability or nutritional intake across the seasons. However, the findings of Moruf *et al*. (2021) on moisture content does not support the values recorded in this study. While the result from the protein content corroborates with the findings of Akinwunmi *et al*. (2023) on some shrimp species. The mineral composition revealed varied concentrations regardless of the seasons, which is not in tandem with the work reported by Moruf *et al*. (2021). The trend in terms of abundance in sodium, potassium and calcium in the species agrees with the work of Akinwunmi *et al*. (2023) on some shrimp species. The levels of potassium, zinc, iron and copper were higher in the wet season while calcium, sodium, magnesium and phosphorus concentrations were elevated in the dry season. The variations observed could be attributed to several factors as the availability and absorption of these minerals may be influenced by seasonal changes in the environment and diet of the lobster. The observed differences highlight the need for further research to explore the underlying mechanisms driving these seasonal variations and to ensure that optimal conditions are maintained for the health and sustainability of lobster populations.

## CONCLUSION

The results obtained in this study showed that *P. regius* is a rich source of protein and essential minerals,

highlighting its nutritional value for the overall wellbeing of all age groups and its potential contribution to food security in Lagos Lagoon communities.

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# FRAME SURVEY AND CATCH ASSESSMENT OF FISH SPECIES IN GUBI DAM, BAUCHI STATE, NORTHEASTERN NIGERIA

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**ABSTRACT**

*This study presents a comprehensive frame and catch assessment of the artisanal fisheries in Gubi Dam, Bauchi State, Nigeria, conducted over a 12-week period between January and March 2025. Babban Kwata, Kwatan Yashi, Spill Way, Tatumari, Larkarina, and Daban Yashi were the six (6) landing sites of the dam focused by this work. A total of 267 fisherfolks, 155 fishing canoes, and over 400 fishing gears were documented. The cumulative fish catch during the study was 655.3 kg, dominated by Oreochromis niloticus (79.2%), followed by Brycinus nurse (3.4%) and Clarias gariepinus (1.2%). Gear composition was skewed toward gill nets, which made up 65.5% of gear types and accounted for 75.2% of the total catch. Other gear types included Malian traps (11.3%), cast nets (7.5%), and traditional gears (15.7%). Babban Kwata contributed the highest total catch at 253.1 kg (38.6%), while the least catch was recorded from Tatumari (45.3 kg). Species diversity was moderate, with eight species from six families identified, and a clear dominance of Cichlidae. The study highlights the mono-dependence on a single species and gear type, raising concerns about biodiversity loss and long-term sustainability. The study recommended that mesh-size regulations and alternative gears should be enforced, fisherfolk cooperatives should be established, and co-management strategies should be adopted.*

**Keywords:** Inland fisheries; fish biodiversity; frame survey; O*reochromis niloticus*; Gubi Dam; Bauchi; Nigeria.

## INTRODUCTION

Inland fisheries play an important role in providing food security, livelihoods, and economic development throughout sub-Saharan Africa. They serve as a primary source of protein for millions of rural and urban populace and act as a supplementary income streams for fishing households. Worldwide, inland fisheries provide approximately 12 million metric tonnes of fish annually, with over 90% consumed domestically, underlining their importance in local and national food systems (FAO, 2022). However, these systems are under significant and increasing pressure from overfishing, pollution, hydrological modifications, and insufficient of management systems (Welcomme *et al*., 2010). The country's inland fisheries are primarily artisanal, providing livelihoods for approximately 2.7 million people, who use small, often non-motorized boats and traditional fishing gear (Akinrotimi *et al*., 2019). These fisheries play a vital role in promoting both subsistence and local trade (Béné *et al*., 2021).

The major challenge facing artisanal inland fisheries is single species dominance. As evaluated in many Nigerian reservoirs, especially Lake Alau (Adebayo *et al*., 2020), Lake Kainji (Ita, 1993), and Jebba Lake (Akintola *et al*., 2011), the most populated species is O*reochromis niloticus* (Tilapia) often leads to reduced biodiversity and ecological divergence. In regard to these concerns, the frame and catch assessment (FCA) methodology has appeared as a foundational tool for monitoring artisanal fisheries.

A frame survey records the infrastructure of a fishery, including the number of boats, gears, fishers while a catch assessment survey (CAS) collects data on species composition, fish size, gear efficiency, and total

catch over time (Welcomme *etal*., 2010; Sparre and Venema, 1998). Specifically, the study seeks to estimate the number of fishing canoes, fisherfolks, and fishing gears operating in Gubi Dam, analyze the catch composition across six landing sites, including species diversity and gear performance, assess the dominance of particular gear types and fish species to provide baseline data to support sustainable fisheries development in Gubi Dam.

## MATERIALS AND METHODS

The Gubi dam was formed from the confluence of four rivers (Gubi, Makaranta, Ran and Tagwaye) with a total surface area 179 km2. located at Piro, a village about 12 km North-East of Bauchi metropolis and 8 km off Bauchi-Maiduguri Road for the primary purpose of providing potable and palatable water to Bauchi and its environs (Ezra and Nwankwo, 2001). The dam lies within the boundary of longitude 10° 25'N to 10° 26'N and latitude 9° 51' E to 9° 52'E (Wufem *et al*., 2009). Catch assessment from six major landing sites along the reservoir which includes; Babban Kwata, Kwatan Yashi, Spill Way, Tatumari, Larkarina, and Daban Yashi were used for the study. The study was conducted over a 12-weeks period, spanning January to March 2025, which corresponds to the peak of the dry season in northern Nigeria. This period was chosen due to its characteristic low water levels and increased fishing activity, which facilitate effective sampling and fisherfolk engagement. Catch assessment involved sampling landings from returning fishing units at the end of each fishing trip. For each catch, the species of fish was identified using both local names and scientific references (Reed et al., 1967; Olaosebikan and Raji, 2013). The total weight of each species was measured using a digital balance (±0.01 kg precision) (Scout Pro SPU202 Model). The gear type used was recorded for every catch. The number of hours fished and crew size were also noted. However, the total length (TL) of sampled fish was measured to the nearest 0.1 cm using an ichthyometer board. Where fish were already processed (e.g., smoked or gutted), weights were excluded from biological analysis to maintain consistency. Fishing gears encountered were classified based on functionality into Active gears (e.g., cast nets, drag nets) and Passive gears (e.g., gill nets, Malian traps). Traditional gears such as calabash, suru, and umdurutu were also recorded, which were particularly used by women and youths in shallow zones. Data was analyzed using IBM SPSS v26 Software for summary statistics. Descriptive statistics such as totals, means, and percentages were used in computing the data obtained. Catch-per-unit-effort (CPUE) calculations, gear contribution indices and species dominance indices were also used.

## RESULTS

The results of the frame and catch assessment conducted over 12 weeks in Gubi Dam using data collected from six landing sites are presented below (Table 1-4). These tables provide insights into fishing effort, gear usage, species composition, site-specific performance, and dominance patterns.

Table1 shows the distribution of fishing effort across the six landing sites. Babban Kwata emerged as the hub, contributing 42% of all canoes and 33.7% of fisherfolks. Notably, Tatumari, Larkarina, and Daban Yashi, each recorded 8 canoes and 34 fisherfolks. Women and youths together accounted for 48.7% of total fisherfolks, highlighting significant gender and generational participation.

**Table1.** Fishing Villages, Number of Fisherfolks, and Canoes

| Landing Site | No. of Canoes | Total Fisherfolks | Men | Women | Youths |
|---|---|---|---|---|---|
| Babban Kwata | 65 | 90 | 47 | 26 | 17 |
| Kwatan Yashi | 36 | 45 | 26 | 8 | 11 |
| Spill Way | 30 | 30 | 22 | 0 | 8 |
| Tatumari | 8 | 34 | 14 | 12 | 8 |
| Larkarina | 8 | 34 | 14 | 12 | 8 |
| Daban Yashi | 8 | 34 | 14 | 12 | 8 |
| Total | 155 | 267 | 137 | 70 | 60 |

Table 2 shows that gill nets dominated gear performance, contributing three-quarters of the total catch. Representing 65.5% of all gears in use and contributing 75.2% of total fish catch. Malian traps and cast nets followed at 9.3% and 8.0%, respectively. The "Others" category reflects traditional or locally adapted gear used mostly by women and youths. This gear dominance pattern suggests high selectivity and dependence on passive gears.

**Table 2** Fish Catch Composition by Gear

| Gear Type | Total Catch (kg) | Percentage (%) |
|---|---|---|
| Gill Net | 496.2 | 75.2 |
| Cast Net | 52.5 | 8.0 |
| Malian Trap | 61.4 | 9.3 |
| Others* | 45.2 | 6.9 |
| Total | **655.3** | **100.0** |

*Others include Calabash, Suru, Umdurutu, and Drag Net.

Table 3 shows the total fish weight by species across stations. *Oreochromis niloticus* was overwhelmingly dominant across all landing sites. Combined, *Brycinus*, *Clarias*, and other minor species represented only 20.8% of the total catch. This mono-dominance raises ecological red flags regarding biodiversity loss, reduced food web complexity, and stock vulnerability.

**Table3:** Total Fish Weight by Species across All Stations

| Species Name | Local Name | Total Weight (kg) | % of Total Catch |
|---|---|---|---|
| *Oreochromis niloticus* | Karfasa | 519.0 | 79.2 |
| *Brycinus nurse* | Kawara | 22.5 | 3.4 |
| *Clarias gariepinus* | Tarwada | 7.6 | 1.2 |
| Golden Fish (unidentified) | – | 14.2 | 2.2 |
| Others (mixed species) | – | 92.0 | 14.0 |
| **Total** | – | **655.3** | **100.0** |

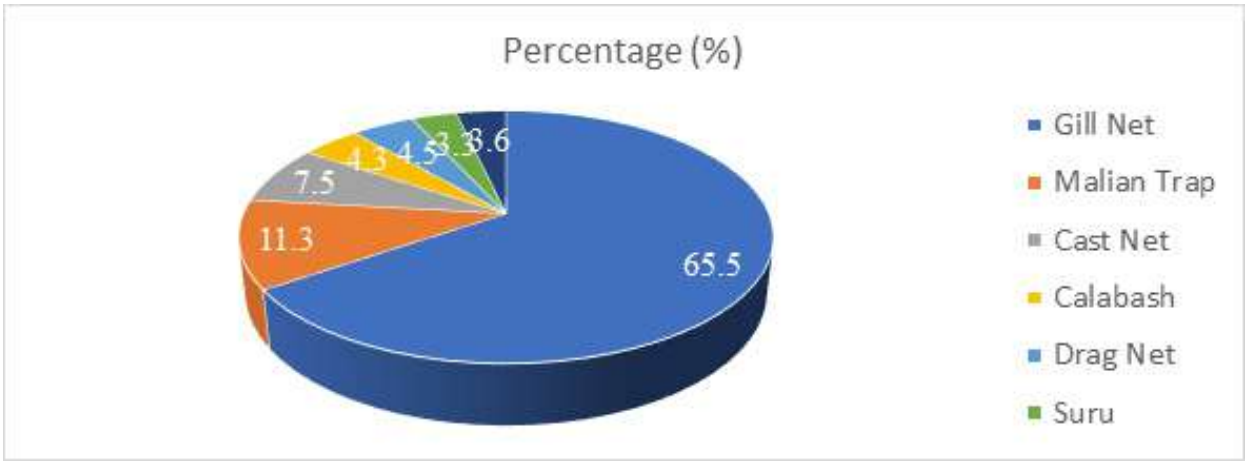



**Figure 2:** *Gear Usage Distribution in Gubi Dam*

A pie chart (Fig.2) showing the proportion of fishing gears used during the study. Of over 400 gears recorded, gill nets again dominated, making up two-thirds of the equipment. Traditional gears used predominantly by women and youths accounted for 15.7%. The diversity of gears reflects community adaptability, but the overwhelming dependence on gill nets suggests the need for regulated diversification. Fish Species Composition in Gubi Dam was recorded in table 4. Eight species from six

families were identified. C*ichlidae* was the most represented family, mainly due to O*reochromis niloticus* and *Hemichromis fasciatus*. *Cyprinids* and *Clariids* followed, reflecting typical diversity patterns in Nigerian freshwater ecosystems.

**Table 4.** Fish Species Composition in Gubi Dam

| Species Name | Local Name | Family |
|---|---|---|
| *Oreochromis niloticus* | Karfasa | Cichlidae |
| *Hemichromis fasciatus* | Karfasa | Cichlidae |
| *Clarias gariepinus* | Tarwada | Clariidae |
| *Brycinus nurse* | Kawara | Alestidae |
| *Raiamas senegalesis* | Lekki | Cyprinidae |
| *Labeo senegalesis* | Akunu | Cyprinidae |
| *Schilbe mystus* | Lulu | Schilbeidae |
| *Distichodus engycephalus* | Kursa | Distichodontidae |

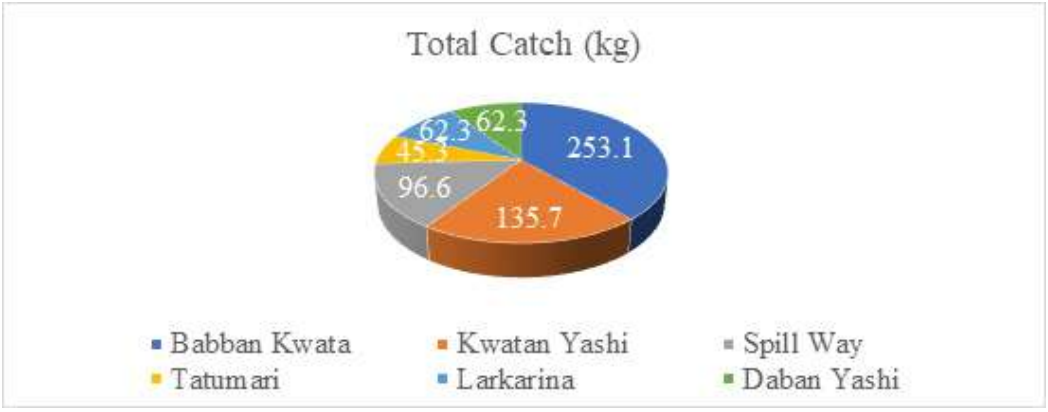



**Figure 3:** Estimated Fish Landed by Sampling Station

Estimated Fish Landed by Sampling Station was shown in Figure 3 where Babban Kwata, with the highest concentration of canoes and gear, contributed the largest share (38.6%) of total catch. The data recorded for the last three stations ensured each contributed a proportionate share, maintaining total harvest accuracy.

**Table5.** Dominant Fish Species Across Landing Sites

| Species | Dominance (%) | Presence (Stations) |
|---|---|---|
| *Oreochromis niloticus* | 79.2 | All 6 |
| *Brycinus nurse* | 3.4 | 4 |
| *Clarias gariepinus* | 1.2 | 3 |
| *Hemichromis fasciatus* | 2.2 | 2 |
| Others | 14.0 | All |

Dominant Fish Species Across Landing Sites was shown in table 5 where Tilapia was dominant in all six landing sites, highlighting its competitive advantage and ecological adaptability. The limited presence of *Clarias* and *Brycinus* underscores the fishery's reliance on a narrow species base.

The table 6 below highlights that Gubi Dam shares common traits with other Nigerian fisheries, including high tilapia dependence, low predator representation, and gear concentration. However, it differs in the inclusiveness of fisherfolk demographics.

**Table 6:** Comparison with Other Inland Fisheries

| Reservoir | Dominant Gear | Dominant Species | Key Challenges |
|---|---|---|---|
| Gubi Dam | Gill nets | *Oreochromis niloticus* | Species skew, gear selectivity |
| Lake Alau | Gill nets | Tilapia spp. | Gender exclusion, trap underuse |
| Lake Kainji | Gill nets & traps | Tilapia, *Clarias spp.* | Juvenile overfishing, no zoning |
| Jebba Reservoir | Cast nets & hooks | *Clarias spp.*, Tilapia | Pollution, gear conflict |

Gear catch composition by landing site in kg was recorded in table 7 below. Gill nets remained dominant across all sites except spill way, where Malian traps were significant. Cast net and traditional gear use was prominent in redistributed stations, suggesting their importance in lower-pressure or shallow areas.

**Table 7:** Gear Catch Composition by Landing Site (kg)

| Landing Site | Gill Net | Cast Net | Malian Trap | Other Gears |
|---|---|---|---|---|
| Babban Kwata | 194.5 | 38.6 | 0.0 | 20.0 |
| Kwatan Yashi | 135.7 | 0.0 | 0.0 | 0.0 |
| Spill Way | 54.6 | 0.0 | 32.0 | 10.0 |
| Tatumari | 32.6 | 5.3 | 4.6 | 2.8 |
| Larkarina | 43.7 | 7.4 | 7.0 | 4.2 |
| Daban Yashi | 44.3 | 6.9 | 6.3 | 4.8 |
| Total | 505.4 | 58.2 | 50.0 | 41.7 |

## DISCUSSION

The results show that Gubi Dam supports a moderately sized but intensively exploited artisanal fishery, with 155 canoes, 267 active fisher-folks, and over 400 fishing gears documented. The dominant fishing hub, Babban Kwata, accounted for 42% of canoes and 38.6% of the total catch. This concentration of fishing effort in a few landing sites is consistent with findings from other Nigerian reservoirs such as Lake Alau, where Adebayo *et al*. (2020) reported that two central landing sites generated over 60% of recorded catches. Similarly, Ovie and Raji (2002) observed a disproportionate concentration of gears and boats in a small number of landing points at Lake Chad. Gill nets were the predominant gear, representing 65.5% of all gears in use and contributing 75.2% of total fish catch. This mirrors trends in other Nigerian and West African reservoirs, where gill nets are favored for their high selectivity, low labor requirement, and affordability (Ita, 1993; NIFFR, 2020).

In contrast, Malian traps and cast nets, which contributed 9.3% and 8.0% respectively, are generally considered less harmful, as they allow for selective release and have reduced by-catch. Traditional gears such as calabashes, suru, and umdurutu though contributing only 6.9% of the catch remain important in shallow habitats and are predominantly used by women and youths, reinforcing their social and economic significance. This finding is corroborating the work of Sanni *et al*. (2021). Welcomme *et al*. (2010) emphasize the importance of gear diversification in artisanal fisheries, not only to maintain species balance but also to provide inclusive fishing opportunities across demographics.

The catch assessment composition was overwhelmingly dominated by *Oreochromis niloticus*, contributing 519.0 kg or 79.2% of the total 655.3 kg catch. Other species such as *Brycinus nurse* (3.4%), *Clarias gariepinus* (1.2%), and a group of "others" (14%) contributed marginally. The mono-dominance of tilapia in the study area is common in tropical reservoirs, particularly where the ecosystem is eutrophic and nutrient-rich, Predatory species (e.g., *Lates niloticus*, *Hydrocynus spp*.) are absent or underrepresented and fisher folks target shallow, inshore habitats, which favor tilapia spawning and growth. Studies from Lake Kainji (Ita, 1993), Jebba Reservoir (Akintola *et al*., 2011), and Lake Victoria (Béné *et al*., 2021) all report similar tilapia dominance patterns, often exceeding 70% of landings. From the total number Of the 267 fisherfolks, 70 (26.2%) were women and 60 (22.5%) were youths, figures

consistent with national estimates reported by FAO (2018) and Sanni *etal*. (2021). Women were found primarily in landing sites using calabashes, Malian traps, and suru, which are suited to shallow, nearshore waters. This reflects an important trend: as men dominate offshore fishing with motorized canoes and large gears, women and youths are more present in under-supported but ecologically vital areas, such as lagoon edges, inlets, and floodplains.

The study shows that gear efficiency varied by landing site. Gill nets dominated Babban Kwata, Kwatan Yashi, and Daban Yashi, Malian traps were most productive at Spill Way and Cast nets and traditional gear were more prominent in Larkarina and Tatumari. These differences highlight the interaction between habitat type, access, and fishing strategy. Spill Way, with its vegetation cover and shallow channels, supports trap use, while Babban Kwata's open shoreline favors gill net deployment. Recognizing these spatial patterns can improve gear zoning policies, where specific gear types are allocated to suitable areas to optimize yield while minimizing habitat disturbance. This finding is in line with Beverton and Holt (1957), who emphasized that spatial regulation is as important as seasonal closures in managing inland fisheries effectively.

## CONCLUSION

This study shows that fishery is heavily dependent on O*reochromis niloticus* (Tilapia), which made up 79.2% of total landings, reflecting both its ecological dominance and market preference. Other species, such as *Brycinus nurse*, C*larias gariepinus*, and several native cyprinids, were present but in low proportions, indicating a low species evenness and raising concerns about ecological balance and long-term sustainability.

The research also shows that the most commonly used fishing gear were gill nets, malian traps and cast nets. The findings highlight serious vulnerabilities such as species mono-dominance, overconcentration of gear and effort in a few sites, juvenile fishing due to unregulated mesh sizes and weak data systems for remote landing sites. This underscores the urgent need for the implementation of effective fisheries management strategies, such as enforcing mesh size regulations, seasonal fishing restrictions, promoting gear diversification and biodiversity protection.

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# ASSESSMENT OF MORPHOMETRICS, LENGTH-WEIGHT RELATIONSHIPS AND CONDITIONFACTOR OF FIVE FISH SPECIES FROM LAKE ALAU, MAIDUGURI, BORNO STATE

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**ABSTRACT**
*This study aimed to assess the morphometric characteristics, length-weight relationships (LWR), and condition factors (K) of five selected fish species from Lake Alau, Maiduguri, Borno State. A total of 175 fish samples, comprising 35 specimens each of Brycinus nurse, Coptodon zillii, Clarias gariepinus, Synodontis clarias, and Oreochromis niloticus, were analyzed for ten morphometric parameters Morphometric Measurements include total length, standard length, and fin dimensions. The results show significant variations in morphometric features across the species, reflecting differences in their body growth and ecological adaptations. The length-weight relationship analysis revealed that Brycinus nurse exhibited isometric growth ($b \approx 3.0$), while Coptodon zillii and Synodontis clarias demonstrated negative allometric growth ($b < 3$). Conversely, C. gariepinus and Oreochromis niloticus showed positive allometric growth ($b > 3$). These growth patterns highlight the species-specific responses to the lake's environmental conditions and resource availability. Condition factor analysis revealed a higher mean K value in Oreochromis niloticus (1.96), indicating favorable growth and condition followed by Coptodon zillii (1.57). The lowest K value was recorded in Clarias gariepinus K=0.06, suggesting suboptimal conditions for this species. These findings underscore the ecological variability and potential impacts of fishing pressure and anthropogenic activities on the fish population in Lake Alau. The study provides critical insights into the biology and ecology of the selected fish species, contributing to effective fisheries management and conservation strategies. The results emphasize the need for sustainable exploitation and monitoring of Lake Alau to safeguard its fishery resources for future generations.*

**Keywords:**
Morphometrics, Lake Alau, Condition factor.

## INTRODUCTION

Nigeria, with a population of over 160 million people and a land area of approximately 923,768 km$^2$, is blessed with a coastline stretching 853 km and inland water bodies covering more than 14 million hectares. These water bodies span across rivers, lakes, floodplains, and reservoirs, occupying a total of about 4,212,500 ha (Obasohan and Oransaye, 2006). Over the last three decades, the construction of various water infrastructures for hydroelectric power, irrigation, and urban water supply has significantly increased the volume of inland water resources, offering greater potential for fisheries development as a tool for food security and poverty reduction (Olaosebikan et al., 2009). One such water body is Lake Alau in Borno State, Nigeria. an artificial reservoir created in 1987 by damming the River Ngadda. Situated in the Sahel Savannah zone of northeastern Nigeria, the lake supports diverse fish species. Bankole *et al*. (2003) documented ten species from eight families, with annual fish yields ranging between 471.1 and 584.9 metric tons, depending on water levels. The length-weight relationship is a fundamental tool for managing fisheries resources, enabling researchers to translate length-based data into biomass estimates and to understand species growth patterns and physiological health (Anene, 2005; Froese and Pauly, 1998; Moutopoulos and Stergiou, 2002). Growth types, whether isometric, negatively allometric, or positively allometric, help describe changes in fish body shape as they grow (Nehemia *et al*., 2012; Riedel

*et al.*, 2007). Condition factor (K) is another important measure that reflects the general health and well-being of fish, providing insights into their feeding success and environmental adaptation (Bagenal and Tesh, 1978; Abowei, 2006; Le Cren, 1951; Anene, 2005). Artisanal fisheries remain the dominant sector, contributing more than 85% of total fish production (Nwafili and TianXiang, 2007). However, inland fish yields are gradually declining due to inadequate scientific management, water quality changes, pollution, and misuse of agrochemicals (Siddiqui and Nassem, 1961). Although there is ample research on length-weight relationships and condition factors of Nigerian freshwater fish (e.g., Kareem *et al.*, 2015; Dan-Kishiya, 2013; Ikongbeh et al., 2012; Ayoade, 2011; Imam *et al.*, 2010; Offem *et al.*, 2009; Ayoade and Ikulala, 2007), only a few studies have explored these parameters in Lake Alau (Kalu *et al.*, 2007; Adeyemi, 2010). This lack of information underscores the need for further investigation. Therefore, this study aims to assess the morphometric parameters, length-weight relationship, and condition factor of five selected fish species from Lake Alau, Maiduguri, Borno State, to support effective stock management and conservation efforts.

## MATERIALS AND METHODS

### Study area

The study was carried out in Lake Alau. The Lake (Fig. 1) is located about 19km from Maiduguri, Borno State, Northeast Nigeria between Latitude $10^0$ 43' N and Longitude $13^0$ 17' E. It is about of 354 m, above sea level, with a surface area of about 56 $km^2$ and a total storage capacity of 54,600ha (CBDA, 1984). It was built in the late Eighties primarily for provision of potable water. The lake has two distinct wet and dry seasons; a raining season with mean annual rainfall of about 600mm from July to October, and a hot dry season from March to July. The dry season is preceded by a period of dry Harmattan with very low temperature and dry harmattan wind between November and February (Bankole *et al.* 1984). Lake Alau has a mean depth of 9.5 m, temperature of 28.6 °C, pH of 7.28, and total alkalinity of 38.4 mg/l and characterized with loamy soil (Idowu, 2004; Gwari *et al.*, 2014). The area is economically important and rich in biodiversity. Hence, sustains a thriving artisanal fisheries industry and serves as a source of water for domestic and industrial use (Gwari *et al.*, 2014).

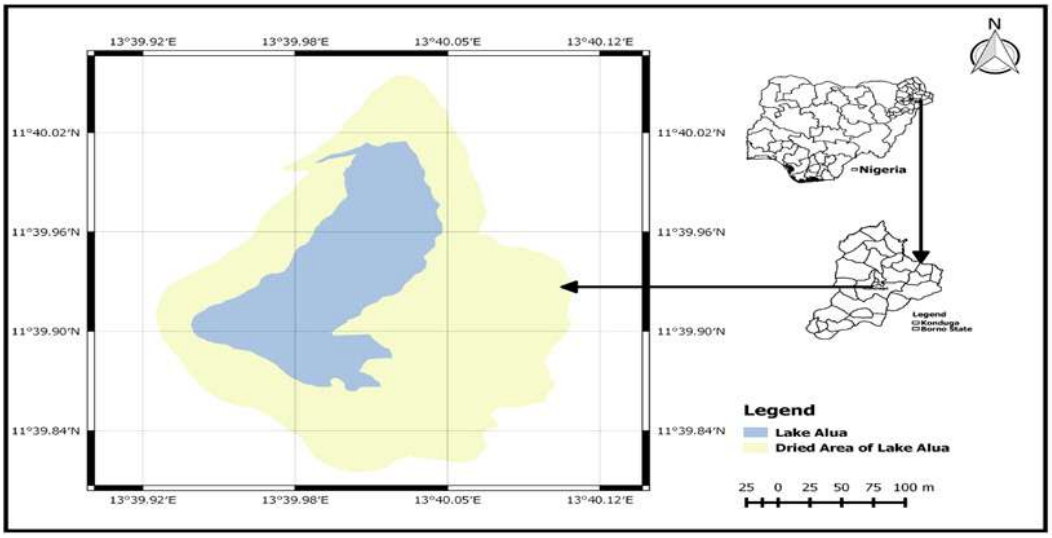



**Figure 1:** Map of Lake Alau, Maiduguri, Nigeria

### Fish Sample Collection

Samplings were carried out weekly during August and September 2024. The target fish species for the study include *Brycinus nurse*, *Coptodon zillii*, *Clarias gariepinus*, *Synodontis clarias and Oreochromis niloticus*. A total of 175 Fish samples were collected directly from the artisanal fishermen's catches.

**Species Identification and Biometric Measures**

Species identification was done with the aid of reference materials (Freshwater Fishes Field guide) (Reed, 1967; Olaosebikan and Raji, 2013) and measurements were made in situ. Samples were weighed (Body weight (BW), to the nearest 0.1g using weighing scale (Scout Pro SPU202 Model). Total length (TL), standard length (SL), eye diameter (ED), head length (HL), dorsal fin length (DFL), pectoral fin length (PFL), pelvic fin length (PFL), anal fin length (AFL) and caudal Fin Length (CFL) of each fish were measured to the nearest 0.1cm on a measuring board following the procedure of Olanrewaju (2017).

**Estimation of Length-Weight Relationships and Condition Factor**

The data obtained from the field work were used to estimate the length weight relationship and condition factors using the below formula:

The LWR of fish were estimated by using the equation: $W = aL^b$ (Pauly, 1983).

Where W= weight in grams (g),

L= standard length in centimeters (cm),

a = is a scaling constant (intercept) and

b = the allometric growth coefficient (slope).

After logarithmic transformation of this relation ($\log10W=\log10a + b \log10L$), parameters (a) and (b) were determined via least squares linear regression (Zar, 1999).

Fulton's condition factor was calculated from the expression $K = 100W/L$ (Bagenal, 1978).

Where K = the condition factor

W = the whole-body weight in grams and

L is standard length in centimetres.

**Statistical Analysis**

All the statistical analyses were considered at significance level of 5% ($p<0.05$). The Statistical Package for Social Sciences (SPSS, version 17) and Microsoft Office Excel software were deployed in this study. Descriptive statistics such as chart and tables were also used.

## RESULTS

**Body weight and Morphometric Characteristics**

Table 1 to 5 present morphometric data for five different fish species from Alau Lake, Maiduguri, Borno State, the tables shown all ten morphometric parameters including the minimum, maximum, mean, and standard deviation for each characteristic. Length, weight and other morphometric characteristics of 175 fishes comprising 35 *Brycinus nurse*, *Coptodon zillii*, *Clarias gariepinus*, *Synodontis clarias and Oreochromis niloticus* each were analyzed and the results are shown in the tables below:

**Tables 1:** Body weight and Morphometric Characteristics of *Brycinus nurse* from Lake Alau

| | Weight (g) | Length (mm) | |
|---|---|---|---|
| Characteristic | Minimum | Maximum | Mean ± SD |
| Body Weight | 19 | 38 | 26.13 ± 5.11 |
| Total Length | 120 | 144 | 130.94 ± 7.66 |
| Standard Length | 98 | 118 | 106.61 ± 5.34 |
| Eye Diameter | 5 | 9 | 6.13 ± 0.91 |
| Head Length | 21 | 31 | 25.50 ± 2.68 |
| Dorsal Fin Length | 18 | 27 | 23.18 ± 2.30 |
| Pectoral Fin Length | 15 | 24 | 19.10 ± 2.47 |
| Pelvic Fin Length | 14 | 20 | 16.45 ± 1.38 |
| Anal Fin Length | 10 | 18 | 14.76 ± 1.93 |
| Caudal Fin Length | 12 | 29 | 22.06 ± 3.13 |

**Tables 2:** Body weight and Morphometric Characteristics of *Coptodon zillii* from Lake Alau

| Characteristic | Weight (g) Minimum | Length (mm) Maximum | Mean ± SD |
|---|---|---|---|
| Body Weight | 7 | 37 | 21.77 ± 6.72 |
| Total Length | 94 | 133 | 111.32 ± 8.80 |
| Standard Length | 70 | 106 | 86.97 ± 7.48 |
| Eye Diameter | 4 | 9 | 6.19 ± 1.14 |
| Head Length | 14 | 36 | 28.19 ± 3.62 |
| Dorsal Fin Length | 42 | 76 | 54.13 ± 7.60 |
| Pectoral Fin Length | 16 | 34 | 26.12 ± 3.62 |
| Pelvic Fin Length | 9 | 29 | 21.50 ± 4.59 |
| Anal Fin Length | 10 | 34 | 26.26 ± 3.75 |
| Caudal Fin Length | 15 | 30 | 22.23 ± 3.02 |

**Tables 3:** Body weight and Morphometric Characteristics of *Clarias gariepinus* from Lake Alau

| Characteristic | Weight (g) Minimum | Length (mm) Maximum | Mean ± SD |
|---|---|---|---|
| Body Weight | 38 | 159 | 62.65 ± 20.11 |
| Total Length | 185 | 300 | 211.26 ± 25.13 |
| Standard Length | 160 | 260 | 188.35 ± 22.68 |
| Eye Diameter | 3 | 4 | 3.39 ± 0.49 |
| Head Length | 42 | 75 | 51.77 ± 7.46 |
| Dorsal Fin Length | 100 | 165 | 119.10 ± 13.27 |
| Pectoral Fin Length | 17 | 35 | 23.58 ± 3.62 |
| Pelvic Fin Length | 13 | 25 | 16.39 ± 2.76 |
| Anal Fin Length | 66 | 115 | 80.68 ± 12.24 |
| Caudal Fin Length | 18 | 40 | 24.90 ± 3.97 |

**Tables 4:** Body weight and Morphometric Characteristics of *Synodontis clarias* from Lake Alau

| Characteristic | Weight (g) Minimum | Length (mm) Maximum | Mean ± SD |
|---|---|---|---|
| Body Weight | 7 | 20 | 12.90 ± 3.64 |
| Total Length | 90 | 122 | 104.71 ± 7.99 |
| Standard Length | 70 | 96 | 81.74 ± 6.42 |
| Eye Diameter | 3 | 4 | 3.20 ± 0.41 |
| Head Length | 27 | 38 | 32.77 ± 2.65 |
| Dorsal Fin Length | 16 | 31 | 21.71 ± 3.71 |
| Pectoral Fin Length | 9 | 23 | 17.48 ± 3.58 |
| Pelvic Fin Length | 7 | 16 | 11.68 ± 2.35 |
| Anal Fin Length | 10 | 18 | 14.19 ± 2.16 |
| Caudal Fin Length | 17 | 30 | 22.00 ± 3.61 |

**Tables 5:** Body weight and Morphometric Characteristics of *Oreochromis niloticus* from Lake Alau

| Characteristic | Weight (g) Minimum | Length (mm) Maximum | Mean ± SD |
|---|---|---|---|
| Body Weight | 13 | 43 | 27.13 ± 7.69 |
| Total Length | 85 | 134 | 111.50 ± 10.96 |
| Standard Length | 65 | 111 | 89.31 ± 10.68 |
| Eye Diameter | 5 | 11 | 7.36 ± 1.59 |
| Head Length | 15 | 35 | 29.28 ± 3.98 |
| Dorsal Fin Length | 40 | 75 | 58.85 ± 8.92 |
| Pectoral Fin Length | 17 | 42 | 32.13 ± 4.96 |
| Pelvic Fin Length | 17 | 37 | 25.21 ± 5.28 |
| Anal Fin Length | 16 | 32 | 25.31 ± 4.13 |
| Caudal Fin Length | 17 | 30 | 23.25 ± 3.48 |

**length-weight relationship (LWR)**

The length-weight relationship (LWR) of fish provides critical insights into their growth patterns, physiology, and ecological roles in aquatic ecosystems. The table 6 below summarizes the LWR parameters of five fish species: with *Brycinus nurse* showing isometric growth, C*optodon zillii* showing negative allometric growth, C*larias gariepinus* positive allometric growth, *Synodontis clarias* negative allometric growth, and O*reochromis niloticus* positive allometric growth. These findings offer a basis for understanding how environmental conditions and biological factors influence fish growth.

**Table 6:** Regression coefficient for Length-Weight Relationship of the five fish species

| Fish Species | N | A | B | 95% CI of b | $R^2$ | GP |
|---|---|---|---|---|---|---|
| *Brycinus nurse* | 35 | 0.012 | 3.02 | 2.90 – 3.14 | 0.96 | I G (b ≈ 3.0) |
| *Coptodon zilli* | 35 | 0.015 | 2.85 | 2.70 – 2.97 | 0.93 | N A G (b < 3) |
| *Clarias gariepinus* | 35 | 0.009 | 3.25 | 3.10 – 3.40 | 0.98 | P A G (b > 3) |
| *Synodontis clarias* | 35 | 0.010 | 2.75 | 2.60 – 2.90 | 0.92 | N A G (b < 3) |
| *Oreochromis niloticus* | 35 | 0.014 | 3.12 | 3.00 – 3.25 | 0.97 | P A G (b > 3) |

N= number of samples, a= intercept of regression line, b= slope of regression line, Cl= confidence level, $R^2$ = regression coefficient, GP=Growth pattern, NAG= negative allometric growth, PAG= positive allometric growth, IG= isometric growth

**Condition Factors of Fish**

Table 7 below shows the mean weight length and condition factors of the five species from Lake Alau. The table shows higher condition factor was obtained in O*reochromis niloticus* (1.96), followed by C*optodon zillii* with a mean condition factor of (1.57). However, the lowest condition factor was observed in *Clarias gariepinus* (0.67)

**Table 7:** Condition factor of the five fish species from Lake Alau

| Fish Species | Mean Weight (g) | Mean Length (cm) | Mean (K) | Range of (K) |
|---|---|---|---|---|
| *Brycinus nurse* | 26.13 | 13.09 | 1.16 | 0.87 - 1.51 |
| *Coptodon zillii* | 21.77 | 11.13 | 1.57 | 0.89 - 2.09 |
| *Clarias gariepinus* | 62.65 | 21.13 | 0.67 | 0.38 - 1.10 |
| *Synodontis clarias* | 12.90 | 10.47 | 1.12 | 0.65 - 1.83 |
| *Oreochromis niloticus* | 27.13 | 11.15 | 1.96 | 0.93 - 2.78 |

## DISCUSSION

Morphometric analysis serves as a fundamental approach in fisheries biology, providing insights into the growth patterns and health status of fish species (Anene, 2005). In this study, nine morphometric parameters namely Total Length, Standard Length, Eye Diameter, Head Length, Dorsal Fin Length, Pectoral Fin Length, Pelvic Fin Length, Anal Fin Length, and Caudal Fin Length were measured across five fish species: *Brycinus nurse*, *Coptodon zillii*, *Clarias gariepinus*, *Synodontis clarias*, and O*reochromis niloticus*. These measurements are important for understanding phenotypic plasticity and environmental adaptability, as morphological variations often reflect responses to ecological factors (Das *et al.*, 2023).

The length-weight relationship (LWR) is an important tool in assessing fish growth patterns. In this study, *Brycinus nurse* exhibited isometric growth with a slope (b) value of 3.02 and a high correlation coefficient ($R^2$ = 0.96), indicating proportional growth in length and weight. This aligns with findings by Ayoade and Ikulala (2021), who reported similar growth patterns in unpolluted water bodies. Conversely, C*optodon zillii* showed negative allometric growth (b = 2.85, $R^2$ = 0.93), suggesting that length increases at a faster rate than weight, potentially due to environmental pressures such as limited food resources or suboptimal

habitat conditions. King (2020) noted that C. *zillii* in eutrophic waters often exhibit negative allometric growth due to increased metabolic costs in hypoxic conditions.

C*larias gariepinus* demonstrated positive allometric growth (b = 3.25, $R^2$ = 0.98), indicating that weight increases more rapidly than length, which may be attributed to its omnivorous diet and adaptability. Fafioye *et al*. (2022) observed similar growth patterns in aquaculture systems, emphasizing the influence of diet on growth dynamics. *Synodontis clarias* exhibited negative allometric growth (b = 2.75, $R^2$ = 0.92), which could be linked to its benthic lifestyle and food availability. Ekelemu and Ogo (2019) reported that this species often struggles to achieve optimal growth in overfished or degraded habitats. O*reochromis niloticus* displayed positive allometric growth (b = 3.12, $R^2$ = 0.97), reflecting its broad dietary habits and adaptability to various environmental conditions. Bolarinwa and Akindele (2023) highlighted the aquaculture potential of O. niloticus due to its favourable growth patterns.

Variations in the exponent 'b' can result from factors such as sample size, gonad maturity, sex, health, habitat, and seasonal effects (Wootton, 1991). In this study, the 'b' values ranged from 2.75 in *Synodontis clarias* to 3.25 in C*larias gariepinus*, indicating diverse growth patterns influenced by environmental and biological factors. The 95% confidence intervals for 'b' values were consistent with previous studies, such as those by Tiago *et al*. (2017), who reported similar ranges in the Amazon River tributaries.

The condition factor (K) provides insights into the physiological state and well-being of fish. *Brycinus nurse* had a K value of 1.16, indicating a healthy population. C*optodon zillii* exhibited a higher K value of 1.57, suggesting robust health and adaptability to hypoxic environments. C*larias gariepinus* had a relatively low K value of 0.67, which may reflect suboptimal conditions such as limited food availability or water quality issues. Ekelemu and Ogo (2019) linked similar K values to anthropogenic impacts on aquatic systems. *Synodontis clarias* showed a moderate K value of 1.12, indicating moderate health and adaptability. O*reochromis niloticus* had the highest K value of 1.96, reflecting excellent growth and adaptability. These findings are consistent with previous studies by Abowei (2010), Mousavi-Sabet *et al*. (2013), and Seiyaboh *et al*. (2016), which reported similar condition factors in freshwater ecosystems.

In summary, the morphometric and condition factor analyses indicate that 80% of the studied fish species in Lake Alau are in good condition, with K values greater than one. The remaining 20% may be experiencing adverse environmental factors affecting their well-being (Anene, 2005). These insights are crucial for developing effective fisheries management strategies to ensure the sustainability of fish populations in Lake Alau.

## CONCLUSION

This study assessed the morphometric characteristics, length-weight relationships, and condition factors of five selected fish species from Lake Alau, Maiduguri, Borno State. The results revealed significant variations in morphometric parameters among the species, highlighting differences in growth patterns and adaptations. The length-weight relationships indicated that *Brycinus nurse* exhibited isometric growth, while C*optodon zillii* and *Synodontis clarias* showed negative allometric growth, and C*larias gariepinus* and O*reochromis niloticus* demonstrated positive allometric growth. The condition factor analysis revealed that O*reochromis niloticus* had the highest mean value, reflecting favorable environmental and biological conditions, while C*larias gariepinus* exhibited the lowest, suggesting potential stress or resource limitation. These findings emphasize the need for targeted management strategies to sustain fish populations and ensure ecological balance in Lake Alau.

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# HAEMATOLOGICAL ASSESSMENT OF THE AFRICAN LUNG FISH (*Protepterus annectens*) DURING ACTIVE STATE AND AESTIVAION PERIOD IN WALAI, ITAS GADAU LOCAL GOVERNMENT AREA, BAUCHI STATE

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**ABSTRACT**
*The African lungfish, Protepterus annectens (P. annectens) is a highly prized food fish in Nigeria. Haematological parameters of P. annectens were examined in order to assess the health status of fish during active state and aestivation period. Differences in haematological parameters including Red blood cell count (RBC), Haemoglobin concentration (HGB), Packed cell volume (PCV), Mean cell volume (MCV), Mean cell haemoglobin (MCH) and Mean cell haemoglobin concentration (MCHC) were compared during active state and aestivation period. The findings of this research showed that haematological parameters of P. annectens varied between active and aestivation periods. This information may perhaps be very vital for effective exploitation, sustainable management and conservation of P. annectens.*

**Keywords:** *Protepterus annectens*, haematological parameters, biochemical parameters, Itas-Gadau, Bauchi State

## INTRODUCTION

African lungfishes are obligate air breathers, and can undergo hibernation in subterranean mud cocoons for as long as four years during drought (Kees and Chapman, 2002; Ballantyne and Frick, 2010). Aestivation is a state of torpor often associated with arid conditions at high environmental temperature and without food or water intake for an extended period. It is characterized mainly by physical inactivity and low metabolic rate (Pinder *et al.*, 1992; Withers and Cooper, 2010). In nature, aestivation can occur inside a subterranean mud cocoon. In the laboratory, African lungfishes can be induced to aestivate in dried mucus cocoons in air (Chew *et al.*, 2004; Loong *et al.*, 2012). *Protepterus annectens* (*P. annectens*) (Fig. 1) is a highly prized food fish in Nigeria (Ovuru and Ekweozor, 2004). It is distributed in shallow parts of rivers and lakes of some West African countries ranging from Senegal to Cameroon where it contributes to a relatively high percentage of artisanal fisheries (Otuogbai, 2001; Oniye *et al.*, 2006).



**Figure 1:** *P. annectens* (Adapted from Froese and Pauly, 2025)

Hematological parameters are commonly used as valuable indicators for the assessment of fish health status (Gabriel *et al.*, 2004). Variations in blood parameters depend upon the fish species, aquatic biotope, health and nutritional status, age and sexual maturity (Fazio *et al.*, 2016). Moreover, blood parameters of fish are highly sensitive to environmental changes. Quality of water, oxygen, temperature and salinity are directly reflected in blood parameters (Luskovav, 1997); as well as basic ecological factors such as feeding regime and stocking density (Ferri *et al.* (2011). Therefore, this study aims to asess *P. annectens* and to provide the knowledge of the characteristics of haematological parameters of the fish during active state and aestivation period.

## MATERIALS AND METHODS

### Study Area

The study was conducted in Walai, Itas Gadau Local Government Area of Bauchi State, Nigeria (12°08' 12.33'N and 10°17'10.28 3'E) with a total area of 1,436 km$^2$ (Fig. 2). Walai is a village in the Gadau district of Itas Gadau Local Government Area, which sits within a region characterized by seasonal swamps, tributaries from the Jama'are River system, and dry riverbeds typical of the northern Sahel. These waterways driven by Jama'are floods may turn into temporary rivers or swamps during the rainy season (June–September), enabling farming and fish rearing (Bagari and Usman, 2022).

Sample Collection**:** Live fresh samples of varying sizes and sexes were obtained from the fishermen of the study area during active state. The fishermen mostly use nets and traps to catch the fish. While during aestivation period the fishes were obtained by digging the ground to some certain distance from their known behavior during that period.

### Blood Collection and Analyses

Blood samples from the caudal vein of each fish were collected in the sampling field using syringe and transferring the blood into tubes containing ethylenediamine tetraacetic acid (EDTA), which were then taken to the laboratory for further examination. In the laboratory, haematological parameters i.e. red blood cell count (RBC), hemoglobin concentration (HGB) packed cell volume (PCV), mean cell volume (MCV), mean cell haemoglobin (MCH) and mean cell haemoglobin concentration (MCHC) were determined using haematological analyzer (Biobase haematological analyzer BK 2600).

**Data Analysis:** Student T-test was used to compare haematological parameters of fish samples during active state and aestivation period. All statistical analyses were done using excel and the statistical package for social sciences (SPSS) version 25.0.

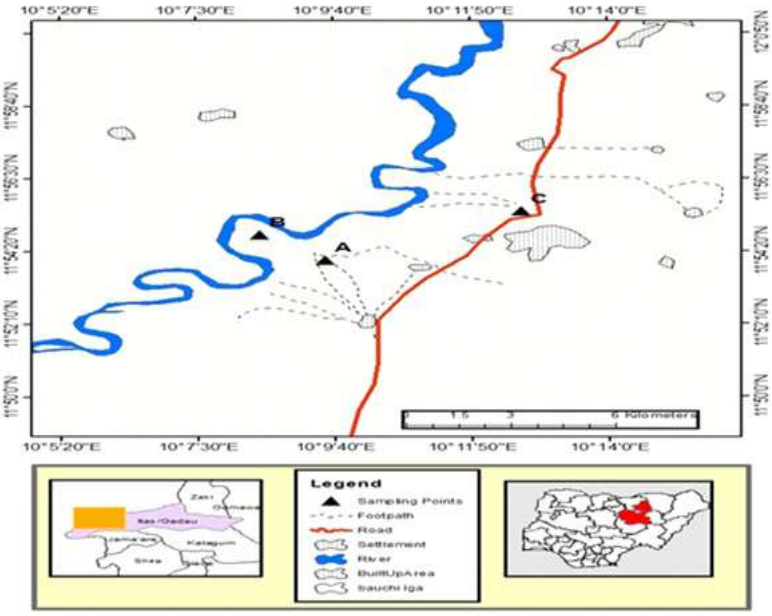



**Fig. 2:** Map of the study area showing the sampling site

## RESULTS

Summary of the body measurements is presented in Table 1. A total of ninety (90) fish samples were collected for the research. Sixty (60) were collected during the active state and thirty (30) during aestivation period. The condition factor results also indicated that there was no significant difference between the active and aestivation stages of the fish studied ($P > 0.05$).

**Table 1:** Summary of body measurements of *P. annectens* used for the study

| | N | Variable | Mean | SE | SD | Min | Max | K |
|---|---|---|---|---|---|---|---|---|
| Active State | 60 | Total Length (cm) | 40.97 | 0.83 | 6.41 | 32.10 | 53.90 | 1.01[a] |
| | | Weight (g) | 307.40 | 17.80 | 138.30 | 130.00 | 620.00 | |
| Aestivation Period | 30 | Total Length (cm) | 47.38 | 1.78 | 9.77 | 32.20 | 74.30 | 1.04[a] |
| | | Weight (g) | 594.00 | 89.60 | 490.70 | 180.00 | 2400.00 | |
| Total | 90 | | | | | | | |

K, Condition Factor; Means with the same letter superscript are not significantly different at 5 % level.

The mean ± SD of hematological parameters of *P. annectens* during active state and aestiation period is presented in Table 2. The results revealed that RBC and HGB showed relative increase in active state than aestivation period and statistically there was significant difference ($P < 0.01$). PCV and MCHC showed decrease in active state than aestivation period, statistically there was significant difference ($P < 0.01$). MCV showed decrease in active state than aestivation period ($P > 0.05$), MCH shows increase in active state than aestivation period statistically there was no significant difference ($P > 0.05$).

**Table 2:** Mean ± SD of Haematological Parameters of *P. annectens* during Active and Aestivation Period

| Parameters | Active State | Aestivation Period | P-Value |
|---|---|---|---|
| RBC ($\times 10^6 \mu l$) | 5.51 ± 0.57 | 2.97 ± 0.02 | $<0.001^{**}$ |
| HGB (g/dl) | 12.67 ± 0.89 | 8.68 ± 0.15 | $<0.001^{**}$ |
| PCV (%) | 3.785 ± 0.93 | 25.81 ± 0.44 | $<0.001^{**}$ |
| MCV (fl) | 85.38 ± 5.46 | 87.16 ± 8.10 | $0.681^{ns}$ |
| MCH (pg) | 30.43 ± 2.40 | 29.35 ± 3.65 | $0.429^{ns}$ |
| MCHC | 32.99 ± 1.99 | 33.51 ± 0.99 | $<0.001^{**}$ |

ns= not significant ($P > 0.05$), *significant at $P < 0.05$, **highly significant $P < 0.001$

## DISCUSSION

Haematological parameters are good indicators of the physiological and health status of organism (Saravanan *et al*., 2012). The findings of this research showed that haematological parameters of *P. annectens* during active state indicated higher values than aestivation period except MCHC that showed lower value during aestivation period than active state. RBC of fish determines the dissolved oxygen carrying capacity. The RBC recorded was higher in active state than the aestivation period. The RBC recorded in this research was more than that recorded by (Masheswaram *et al.*, 2008) who recorded unsexed *Clarias batrachus* RBC value to be 2.89 ± 0.08 and (Onyia *et al*., 2013) also recorded *Heterobronchus bidorsalis* male and female RBC to be $5.08 \pm 0.17 \times 10^6 mm^3$ and $5.3 \pm 0.26 \times 10^6 mm^3$ respectively. Tiamiyu *et al*. (2019) suggested that there was correlation between haemoglobin concentration and activities of fishes. The more active fishes tend to have high haemoglobin values, than the more sedentary ones. In the present study HGB value of *P. annectens* during active state was slightly higher than the HGB value obtained during aestivation period. This is in line with the findings of Ahmed *et al*. (2013) and Okafor (2006). Furthermore, Das (1964) reported both the hemoglobin content and erythrocyte count tend to increase with length and age of the fish. Okafor and Chukwu (2010) reported haemoglobin content and erythrocyte of *P. annectens* were higher in the large and intermediate sized specimen than in the fingerlings and juveniles.

The PCV showed statistically lower values during active state than aestivation period, and all fall within the range given by Etim *et al*. (1999). This may be as a result of seasonal variation and high body metabolism during active state, and also in aquatic environment feeding of *P. annectens* is restricted to certain period of time and feeding is capable during active state only.

The present study indicated that the mean MCV value was higher during active state which may be due to lack of dietary intake during eastivation period. MCV, MCH and MCHC were also used to identify and

classify the type of anaemia in fishes. MCV is an important member listed on a complete blood count that can help diagnose different type of anaemia. It is also known that MCV is a value that describes the average size of red blood cells in a blood sample. Where high MCV indicates macrocytic anaemia and low MCV values indicates microcytic anaemia, which is caused by poor dietary intake of iron. In this study the mean MCH values obtained were higher during active state and lower during aestivation period. MCH is an important number listed on a complete blood count that can help diagnose different type of anaemia as well as other health conditions. Where high MCH indicates macrocytic anaemia and low MCH values indicates microcytic anaemia, Macrocytic anaemia is also caused by increased in MCH value which is caused by either vitamin B12 deficiency or liver disease. MCHC is known as the average or concentration of haemoglobin found in red blood cells in the body, haemoglobin is a protein in the blood that allows the red blood cells to deliver oxygen to cells and tissues in the body. High MCHC indicates those red blood cells are larger than normal MCHC increases parallel with increase in size and body weight of fish and also showed slight increase as individual become larger (Svetina *et al.*, 2002) . In this research MCHC showed higher value during aestivation period. This may be due to size and weight of the research fish obtained during aestivation period.

**CONCLUSION**

Conclusively, the findings of this research showed that the haematological parameters during active state of the fish indicated lower values in active state for RBC and HGB and higher values in hibernation period PCV, MCV, MCH and MCHC. This information could be useful in examining the existence, status and degree of possible sickness of the fish.

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# COMPARATIVE ANALYSIS OF REPRODUCTIVE HORMONES AND GONAD MATURATION OF WILD AND CAPTIVE SHARK CATFISH (*Pangasius nasutus*)

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**ABSTRACT**

*This study compares the reproductive hormones and gonad maturation stages of shark catfish, Pangasius nasutus from wild-caught and cage-cultured populations. The study investigates different aspects of this species' reproductive biology, such as age at sexual maturity, reproductive hormones, and histological assessments of the gonads. To achieve these objectives, 75 captive specimens (45 females and 30 males) and 30 wild specimens (15 males and 15 females) were sampled. Otolith growth marks were examined to estimate the fish's age. This study's findings reveal significant differences between wild and captive fish. P. nasutus in the wild had more developed reproductive characteristics, as evidenced by a higher gonadosomatic index, higher levels of 17-estradiol, and progression to more advanced stages of the gonads. These insights hold significant implications for the refinement of aquaculture practices and the formulation of effective conservation strategies for P. nasutus, ultimately contributing to the sustainability of this valuable species.*

**Keywords:** 17-estradiol, 11-ketotestosterone, sexual maturity, otolith, gonadosomatic index

## INTRODUCTION

The aquaculture industry plays a vital role in global seafood production, reducing pressure on wild stocks while meeting growing demand (Garlock et al., 2022; Naylor et al., 2000; Nie & Hallerman, 2021). The shark catfish *Pangasius nasutus* (Patin buah), a freshwater species native to Southeast Asia, is highly valued in Malaysia for its cultural and economic importance, fetching Malaysian Ringgit (RM )70–300/kg—three times the price of local black pangasius species (*P. micronemus*, *P. hypothalamus*) (Sani et al., 2023). It also shows promise for Nigerian aquaculture, given the successful culture of *P. hypothalamus* under similar conditions.

However, *P. nasutus* remains dependent on wild stocks due to challenges in captive breeding, particularly its sensitivity to environmental stressors (Torsabo et al., 2024). Overharvesting and habitat loss have reduced its abundance in rivers such as Maran and Pekan, leading to its classification as moderately threatened in Malaysia (Baharuddin et al., 2014). Progress is further constrained by limited knowledge of its reproductive biology, despite the central role of reproductive traits in aquaculture success (Basilone et al., 2021; Morgan, 2018). To address this gap, the present study compared the reproductive biology of *P. nasutus* in natural and cultured environments, focusing on age at maturity, reproductive hormones, and gonadal histology to inform breeding strategies and stock management.

## MATERIALS AND METHODS

*P. nasutus* samples were collected in a cage culture facility at the river bank in Pekan, Pahang State, Malaysia, situated in the East Coast region of Peninsular Malaysia, 3.4921° N, 103.3895° E. The samples were collected and processed in situ, and analysis of the samples was conducted in laboratory facilities at Universiti Malaysia Terengganu, Terengganu, Malaysia.

A total of seventy-five (75) specimens of cage-cultured Pangasius nasutus (30 males and 45 females) and thirty (30) wild-caught specimens (15 males and 15 females) were sampled. The wild P. nasutus were obtained from fishermen operating in Sungai Pahang, near Pekan, Pahang State, Malaysia (East Coast region of Peninsular Malaysia; 3.4921° N, 103.3895° E). Following collection, the fish were transferred into 50 L fiber tanks, and ice was gradually introduced to induce immobilization prior to sampling procedures. Body weight (BW) was measured using a digital floor platform balance with an accuracy of 0.01 kg, after gently blotting excess water from the fish with a paper towel. Total length (TL) was recorded to the nearest 0.1 cm using a one-meter ruler, measured from the tip of the upper lip to the farthest point of the caudal fin while the fish was positioned laterally. Fish were euthanized by pithing at the base of the temporal bones to sever the brain. Dissections were carried out in situ, and tissues including gonads and liver were excised. Portions of gonadal and hepatic tissues were immediately snap-frozen in liquid nitrogen and subsequently stored at –80 °C for further analysis. Fish heads were preserved on ice and transported to the laboratory for otolith extraction and age determination.
Data analysed was presented as means ± standard deviation, and statistical significance for all statistical tests was set at $P < 0.05$. All data were tested for normal distribution using the Shapiro-Wilk test and the homogeneity of variance using Levene's equal variance test. Data obtained were analysed by one-way ANOVA (analysis of variance). Tukey's Honest Significant Difference (HSD) was used for post hoc analysis. The Marascuilo procedure was employed to determine the significance difference among the count oocytes within each developmental stage

## RESULTS AND DISCUSSION

Table 1 presents the biological indices of *P. nasutus* from wild and captive stocks. The Gonadosomatic Index (GSI) differed significantly ($p > 0.05$) between the two populations. In wild fish, GSI was higher at age 2 for both males and females, whereas in captive stocks, significantly higher GSI values were observed in 3-year-old males and females. The Coelomic Fat Index (CFI) also varied significantly ($p > 0.05$), with younger fish (age 2) showing higher values than older fish (age 3) in both wild and captive populations. The GSI of Mekong giant catfish *Pangasianodon gigas* was found to be 0.07 for males and 0.38 for females from ponds in comparison with 2.27 for males and 8.29 for females from the wild (Manosroi et al., 2003). The difference in CFI in wild and captive fish as observed in this study could be related to food availability of different origins in the river where they were caught compare to the captive condition (Weber et al., 2017).

**Table 1:** Biological indices of male and female wild and captive *Pangasius nasutus* at ages 2 and 3.

| Age | Source | Weight (g) | Length (cm) | GSI | HSI | VSI | CFI | K |
|---|---|---|---|---|---|---|---|---|
| 2 | Captive | $973.42\pm31.9^{a}$ | $46.07\pm0.56^{a}$ | $1.21\pm0.03^{b}$ | $0.88\pm0.03$ | $1.34\pm0.06$ | $5.7\pm0.62^{b}$ | $0.99\pm0.02$ |
| 3 | Captive | $1029.62\pm28^{d}$ | $48.12\pm0.66^{c}$ | $3.83\pm0.47^{c}$ | $0.96\pm0.04$ | $1.49\pm0.13$ | $3.64\pm0.52^{b}$ | $0.95\pm0.03$ |
| 2 | Wild | $835.52\pm32.8^{b}$ | $44.26\pm0.68^{b}$ | $1.66\pm0.05^{a}$ | $0.91\pm0.04$ | $1.62\pm0.17$ | $6.7\pm1.05^{a}$ | $0.96\pm0.03$ |
| 3 | Wild | $1072.04\pm20.6^{c}$ | $48.22\pm0.47^{c}$ | $2.72\pm0.38^{d}$ | $0.92\pm0.03$ | $1.32\pm0.06$ | $3.91\pm0.34^{b}$ | $0.98\pm0.02$ |

Means in the same column of factors between sources and ages with different superscripts differ significantly ($p<0.05$). $n = 15$ for captive and $n = 7$ for wild for each cohort.

A comparison of the reproductive hormones, 17β-estradiol (E2) of wild and captive female *P. nasutus* at different ages is presented in Figure 2. Comparing the source, female fish from the wild has significantly high levels of E2 compared to the cage cultured fish. Age-wise, $E_2$ was significantly high in fish at 3 years old. The elevated levels of E2 observed in wild-caught fish suggest a greater degree of gonadal maturation and readiness for spawning, consistent with the critical role of E2 during the pre-spawning period. In contrast, the lower E2 levels in captive fish may reflect stress, environmental influences, or disruptions in the brain–pituitary–gonad (BPG) axis. Comparable patterns have been reported in *Lophiosilurus alexandri*, where ovarian development was accompanied by a significant rise in plasma E2 (Melo et al., 2022). Generally, as fish approach sexual maturity, the production of sex steroid hormones such as testosterone, estradiol, and progesterone increases to regulate reproductive processes (Ganzha et al., 2023).

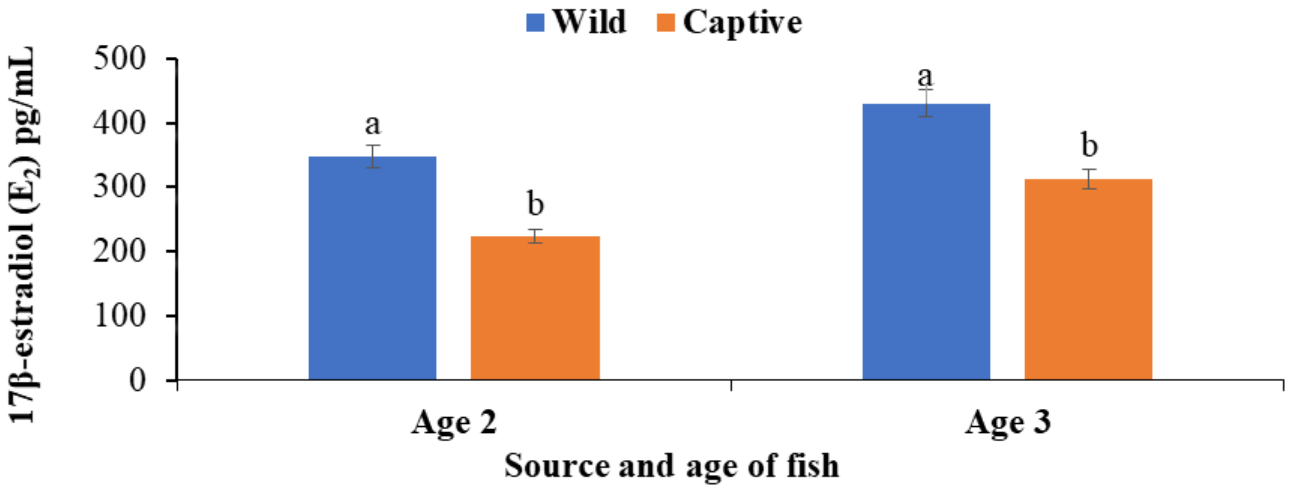



**Figure 1:** *Comparison of 17β-estradiol (E2) levels in the plasma of wild and captive female Pangasius nasutus at ages 2 and 3.*

Figure 2A compares gonad development in wild and captive female *P. nasutus*. At age 2, captive fish exhibited only stage 1 (resting), whereas wild fish showed stages 1–4. Similarly, at age 3, captive ovaries displayed stages 1–3, while wild fish exhibited stages 1–6 (Figure 2B). The high frequency of mature oocytes observed in the wild population is consistent with the concurrent increases in plasma 17β-estradiol (E2) and gonadosomatic index (GSI). Several studies show that rising E2 accompanies vitellogenesis and progression through ovarian stages, and that GSI increases as oocytes reach advanced maturation stages (Sang, et al., 2019). In comparative work on wild versus captive broodstock, wild-caught individuals frequently present higher GSI and sex-steroid levels during the spawning period, indicating more advanced reproductive development relative to captive fish. (Zupa et al., 2017). Differences in the timing and frequency of oocyte maturation between our wild and captive groups can therefore be explained by both age and source-related factors: age influences the onset and rate of sexual maturation in *pangasiid* catfish (older fish reach larger oocyte sizes and higher GSI), while source effects (wild vs captive) reflect differences in nutrition, environmental cues and stress that modulate the brain-pituitary-gonad axis and vitellogenic response. Nutritional status of broodstock particularly lipid and phospholipid supply and husbandry stress are known to affect E2 production, vitellogenin synthesis and egg development, which can delay or reduce oocyte maturation in captive fish (Kabir et al., 2012).

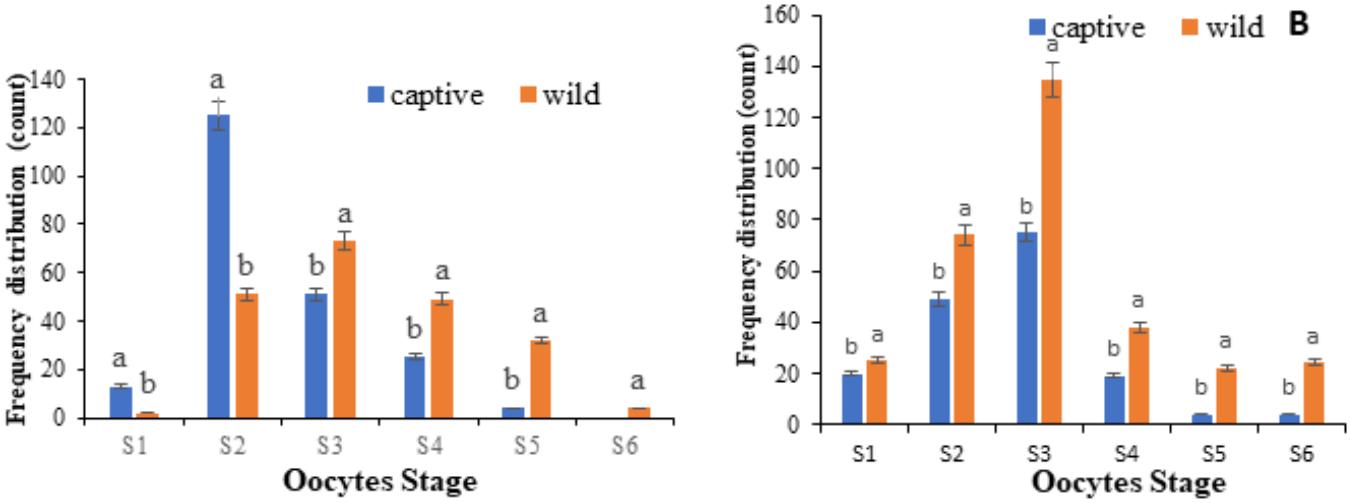



**Figure 2.** Oocytes frequency distribution of female *Pangasius nasutus* from wild and captive stock at age 2 (A) and 3 (B). S1-S6 (stage 1- stage 6).

This result further confirms our earlier finding stating that *P. nasutus* is sexually matured at the age of three looking at certain biological indices such as GSI and nutrient mobilization indicators observed during reproductive processes (Torsabo et al., 2024). In conclusion, this study highlights the intricate relationship between environmental conditions, diet, and the physiological and reproductive outcomes in *P. nasutus*. The results provide a foundation for future research aimed at refining aquaculture practices, particularly in the areas of diet formulation and environmental management, to support the sustainable production and conservation of this species

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# GONADOSOMATIC AND HEPATOSOMATIC INDEX CHARACTERIZATION IN TWO AGE GROUP OF *Clarias gariepinus*

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**ABSTRACT**

*The study was conducted to evaluate the effect of age on the Gonadosomatic Index (GSI) and Hepatosomatic Index (HSI) of male and female* Clarias gariepinus. *A total of 10 adult Clarias gariepinus (3 females and 2 males each) from two age groups of 6 months and 10 months with mean weight of 518.16g and 629.56g respectively were used for the experiment. The length and weight measurements of the fish were recorded using a meter rule and digital scale in centimeters and grams, respectively. Thereafter, the fish samples were sacrificed for the collection of gonads (testes and ovaries) and liver, which were weighed to determine GSI and HSI. The results revealed no significant difference (P>0.05) in the mean values of GSI between the two age groups: 10.09±3.92 for 6-month-old fish and 11.51±4.54% for 10-month-old fish. Similarly, the HSI values were 1.94±0.30% for 6-month-old fish and 1.67±0.22% for 10-month-old fish, indicating no significant variation (P>0.05). A negative correlation was observed between GSI and HSI suggesting the size of gonads does not affect size of liver. These findings imply that age does not significantly influence the GSI and HSI of* Clarias gariepinus *within the age range studied.*

**Keywords**: Reproductive biology, Sexual maturity brood and gonadal development

## INTRODUCTION

Fish are a vital source of high-quality protein and essential micronutrients, especially in developing countries with starch-based diets (FAO, 2006). Beyond nutrition, fish hold commercial importance in aquaculture. Understanding fish reproductive biology enhances stock management, breeding, and sustainability (Islam et al., 2012; Brewer et al., 2008; Grandcourt et al., 2009; Muchlisin et al., 2010). Most teleost reproduce seasonally with their breeding activities triggered by environmental factors such as changes in temperature, photoperiod, and food availability (Meijide et al., 2005; Gopurappilly et al., 2013). Two key indices used to evaluate reproductive and metabolic status are the Gonadosomatic Index (GSI) and Hepatosomatic Index (HSI). GSI, the ratio of gonad to body weight, reflects reproductive readiness and maturity (Jackson et al., 2006; Alonso et al., 2009; Tubert et al., 2012). HSI, the ratio of liver to body weight assesses energy reserves and health. Low HSI values may indicate stress or toxic exposure (van Dyk et al., 2007). The liver's metabolic and detoxification roles make HSI a reliable biomarker under varying conditions. GSI is useful for identifying peak reproductive periods through gonadal weight, while HSI is linked to vitellogenin production during yolk formation (Hunter & Macewicz, 2001; Cerda et al., 1996; Misra & Saksena, 2012). Though several studies link GSI and HSI, few foci on *Clarias gariepinus* (FAO, 2013). This species, key to African aquaculture, is valued for its fast growth and resilience. This study evaluates GSI and HSI in two age groups of *Clarias gariepinus*, contributing data to support brood stock selection and sustainable production.

The knowledge of the reproductive biology of a fish species is useful in an attempt to domesticate the specie. Gonadosomatic index is an aspect of reproductive biology comparing this parameter at different ages of Clarias will help tell a story on sexual maturity and this justify this study.

## MATERIALS AND METHODS

The fish samples were collected from Oracle Fish Farm, Makurdi, Benue State, Nigeria. The farm is situated within a climate conducive for tropical aquaculture practices. A total of 10 *Clarias gariepinus* specimens were used: 2 males and 3 females each of both age group raised in concrete tank. The fish were maintained under standard farm conditions and fed a commercial pelleted diet. The length and weight measurements of the fish samples were done using a metre rule in centimetres and weighing balance in grams, respectively. After anesthetization, fish were dissected to remove gonads and livers, which were also weighed. Morphometric data included total body weight, gonad weight, and liver weight.

**Determination of Gonadosomatic Index (GSI) and Hepatosomatic Index (HSI) of the Fish Samples.**
Gonadosomatic Index (GSI) and Hepatosomatic Index (HSI) of male and female fishes were determined separately according to **Brown-Peterson et al. (2011)** and **Zhao et al. (2021).**

$$\text{Gonadosomatic Index (GSI)} = \frac{Gonad\ weight\ (g)}{Body\ weight\ of\ fish\ (g)} \times 100$$

$$\text{Hepatosomatic Index (HSI)} = \frac{Liver\ Weight\ (g)}{Body\ weight\ of\ fish\ (g)} \times 100$$

Data were analysed using statistical package for social sciences (SPSS) analysis version 25.0. Descriptive statistics (mean ± standard deviation) were computed. Independent t-tests were conducted to determine differences in Gonadosomatic Index (GSI) and Hepatosomatic Index (HSI) between age groups and sexes. Pearson's correlation coefficient was used to examine the relationship between GSI and HSI. Statistical significance was set at $p > 0.05$. Duncan's Multiple Range Test (DMRT) was applied as a post-hoc test to identify significant differences among the means at a 5% probability level.

## RESULTS

The result in table 1 shows that the fish at 10 months were bigger in body weight (629.56±62.82), total length (46.46±1.85), standard length (41.34±1.54), gonad weight (73.28±28.52) and liver weight (10.46±1.90), compared to those at 6 months; 518.16±43.76, 43.46±1.62, 38.40±1.38, 49.34±16.94 and 10.06±1.63 respectively, but the differences weren't significant ($p > 0.05$). Still, this points to gradual growth and early reproductive signs in line with studies showing that older juveniles of Clarias gariepinus exhibit increased somatic and gonadal weights when raised under stable aquaculture conditions (Bawa, 2024). Table 2 shows the result of Gonadosomatic and Hepatosomatic indices of 6 and 10 months old *Clarias gariepinus*. As fish aged, their Gonadosomatic Index increased from 10.09 to 11.51, while their Hepatosomatic Index dropped from 1.94 to 1.67. The result in Table 3 shows that female fish had higher Gonadosomatic index values than males, especially at 10 months. This suggest that the weight of ovary sac is higher than the testes in male (Eze et al. 2022). Table 4 shows male fish had slightly higher liver sizes than females, but the difference was small and not significant ($p > 0.05$).

## DISCUSSION

The condition factor showed no significant difference ($p>0.05$) between 6- and 10-month-old fish. GSI increased with age and was higher in females, indicating greater gonadal development and energy allocation for oocyte formation (Liley et al., 2002; Adebayo et al., 2016). A strong relationship was observed between body length and weight across both sexes and age groups.

However, 6-month-old males had slightly higher HSI than 10-month-old males. This suggest that as reproduction progressed, liver energy reserves were mobilized to support gonadal development (Singh et al., 2008; Adeyemi et al., 2019). The slightly higher HSI in younger fish may reflect active growth and better nutritional status (Ali et al., 2021). Singh et al. (2008) observed a similar inverse trend in *Labeo dyochedus*. In poor conditions, fish livers typically store less energy. The higher HSI in younger fish may

indicate better nutrition and water quality, implying that reproductive development did not compromise liver reserves. These findings align with earlier studies emphasizing the complementary roles of GSI and HSI as indicators of reproductive and metabolic activity in cultured fish (Alonso et al., 2009; Zhao et al., 2021).

**Table 1:** Some Mean Morphometric Parameters of Different Ages of *Clarias gariepinus*

| Parameters | 6 Months (male and female) | 10 Months (male and female) | P-value |
|---|---|---|---|
| Total Body Weight(g) | $518.16 \pm 43.76^{b}$ | $629.56 \pm 62.82^{a}$ | 0.18 |
| Total Length(cm) | $43.46 \pm 1.62^{b}$ | $46.46 \pm 1.85^{a}$ | 0.26 |
| Standard Length(cm) | $38.40 \pm 1.38^{b}$ | $41.34 \pm 1.54^{a}$ | 0.19 |
| Gonad Weight(g) | $49.34 \pm 16.74^{b}$ | $73.28 \pm 28.52^{a}$ | 0.49 |
| Liver Weight(g) | $10.06 \pm 1.63^{b}$ | $10.46 \pm 1.90^{a}$ | 0.88 |

Mean in the same row with different superscript differ significantly

**Table 2:** Mean Gonadosomatic and Hepatosomatic Indices of *Clarias gariepinus* of Different Age Groups

| Parameters (g) | 6 Months | 10 Months | P-value |
|---|---|---|---|
| **Gonadosomatic Index** | $10.09 \pm 3.92^{b}$ | $11.51 \pm 4.54^{a}$ | 0.82 |
| **Hepatosomatic Index** | $1.94 \pm 0.30^{a}$ | $1.67 \pm 0.22^{b}$ | 0.49 |
| **Condition Factor(k)** | $0.63 \pm 0.03^{a}$ | $0.62 \pm 0.03^{b}$ | 0.85 |

Mean in the same row with different superscript differ significantly

**Table 3:** Mean Gonadosomatic Index (GSI) of Male and Female *Clarias gariepinus* at Different Ages.

| Sex | Age (Months) | Mean GSI |
|---|---|---|
| **Male** | **6 Months** | **5.0** |
| **Male** | **10 Months** | **6.0** |
| **Female** | **6 Months** | **14.0** |
| **Female** | **10 Months** | **12.5** |

**Table 4:** Mean Hepatosomatic Index (HSI) of Male and Female *Clarias gariepinus* at Different Ages

| Sex | Age (Months) | Mean HIS |
|---|---|---|
| **Male** | **6 Months** | **2.7** |
| **Male** | **10 Months** | **1.7** |
| **Female** | **6 Months** | **1.6** |
| **Female** | **10 Months** | **1.8** |

## CONCLUSIONS

In conclusion, 10-month-old fish had higher Gonadosomatic Index (GSI) than 6-month-old fish, while the 6-month-old fish showed higher Hepatosomatic Index (HSI), likely due to their smaller body weight and developing reproductive organs (Chakraborty et al., 2024; Zhao et al., 2021). Female *Clarias gariepinus* had higher GSI values than males in both age groups, which can be attributed to the larger mass of the ovary and egg sacs compared to the testes (Eze et al., 2022; Robert et al., 2024). These findings align with earlier studies showing that energy reserves from the liver are redirected toward gonadal growth during sexual maturation (Melefa & Okoloye, 2023).

## ACKNOWLEDGEMENTS

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# REPRODUCTIVE BIOLOGY OF AND GONADO-SOMATIC INDEX OF *Hydrocynus forskahlii* OF LOWER RIVER BENUE, NIGERIA

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**ABSTRACT**

*This work was conducted to study the reproductive biology and Gonado-somatic index of Hydrocynus forskahlii, in order to address the current paucity of information on its fecundity and gonad sizes from the Lower River Benue. A total of 403 specimens were obtained from fisher folks, comprising 189 and 214 individuals from Abinsi and Wadata stations. The specimens were collected fortnightly for a period of 12 months, fecundity and gonad sizes examined. The sex of the individual specimen was identified and sorted accordingly. The Gonado-somatic index of sexually matured individuals was calculated, and the fecundity estimated. Results obtained revealed a sex ratio of 1:1.04 from Abinsi and 1:1.16 from Wadata for males and females, respectively. The GSI from Abinsi was 0.29% and 0.25%, while Wadata had 0.29% and 0.23% for rainy and dry seasons respectively. The GSI of the fish species increased with corresponding increase in their body weights. The fecundity of Hydrocynus forskahlii ranged from 1033-4021 oocytes. The size of the oocytes increased with decrease in fecundity. The females were significantly abundant than their male counterparts. There was no significance in the GSI between seasons and stations. The species (both males and females) were sexually mature at smaller lengths.*

**Keywords:**
Gonado-somatic index, fecundity, macroscopic, microscopic, oocytes, Lower River Benue

## INTRODUCTION

Reproductive studies of fish require knowledge of the stages of gonad development. Reproduction involves changes in growth and development of oocytes during the process of gonad maturation, and with the advancement of maturation, oocytes accumulate energy reserves and enlarge further for the onset of embryogenesis (Priyadharsini *et al*., 2013). Gonad maturation stages have become increasingly important in fish production, especially in induced spawning and hybridization in addition to determining the stock that is, mature, and the size or age at first maturity (Yem *et al*., 2009). Similarly, it can be used to determine the reproductive potential of fish populations and monitoring of changes in biological characteristics of exploited fish stock (Williams, 2007) and is used to establish reproduction period and length of time it takes the gonads to mature (Goncalves *et al.*, 2006).

Tiger fish (*Hydrocynus forskahlii*) are considered important freshwater fish species due to their high economic value. They are abundant, widely distributed and occupy an important position in the food chain (tigerfish are the top predators in these systems) (McHugh *et al*., 2011). *H. forskahlii* is a commercially important fish that suffers from heavy fishing pressure.

Sex ratio provides information on the proportion of male to female in each fish population. It is required in understanding fish reproduction and stock size assessment (Vicentini and Araujo, 2003). Gonado-somatic index is an indirect method for estimating the spawning season of a species (Priyadharsini *et al*., 2013). The gonadosomatic index (GSI), which is the ratio of gonad mass to total body mass, remains the best predictor of spawning period, (i.e., onset and duration of spawning) (Tsikliras *et al*., 2013). It is also the measure of relative weight of gonad with respect to weight of the fish (Abraham and Akpan, 2012).

The state of maturity of a fish may be determined by the size of the ovaries (Priyadharsini *et al.*, 2013). GSI is particularly helpful in identifying days and seasons of spawning, as the ovaries of gravid females swiftly increase in size just prior to spawning (Yem *et al.*, 2009). Gonado-somatic index (GSI) indicates the stage and readiness of the ovary for maturation and spawning.

Fecundity can be expressed as the number of eggs laid by an individual of a species during spawning in a single season by the species (Priyadharsini *et al.*, 2013). Fecundity is an index which measures the number of eggs found in a gravid female fish (Victor *et al.*, 2013). Knowledge about fecundity of a fish is essential for evaluating the commercial potentialities of its stock, life history, practical culture and actual management of the fishery (Borthakur, 2018).

## MATERIALS AND METHODS

### Description of Study area

The study was carried out in the Lower River Benue (Fig. 1) at Wadata and Abinsi. Wadata is located at latitude 7° 43' 0" North and longitude 8° 32 0" East, while Abinsi is located at latitude 7° 45 0" North and longitude 8° 45 0" East. It is the largest tributary of the Niger River with its confluence at Lokoja. The highest water levels occur from August to September and the lowest from March to April (Akombo *et al.*, 2011).

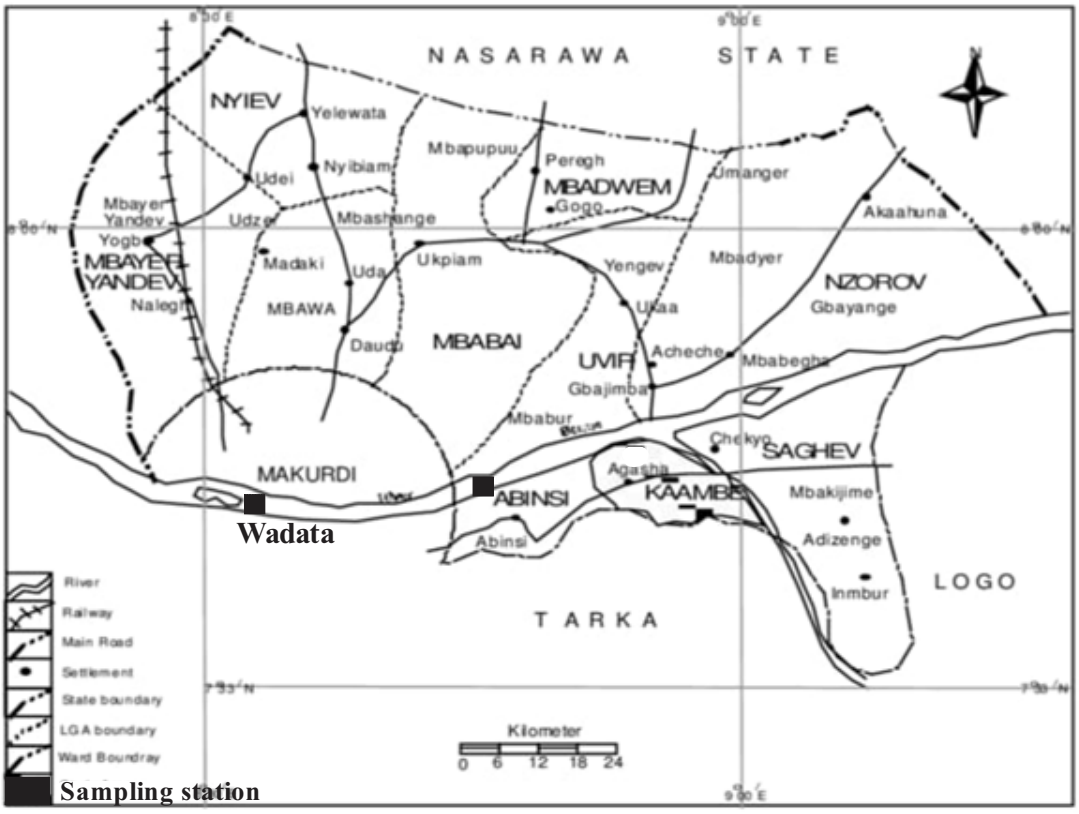



**Figure 1:** *Map of Guma Local Government Area showing the sampling stations in Lower River Benue (Source: Ministry of Lands and Survey, Makurdi)*

### Sample collection and identification

Fish samples caught using gill and cast nets were collected fortnightly from fishermen from Wadata and Abinsi, between April 2019 and March 2020. A total of 189 *H. forskahlii* comprising 97 females and 92 males, were sampled from Abinsi station, while 214 comprising 115 females and 99 males were sampled from Wadata station. The fish were placed in ice box containing ice block to avoid decomposition and were immediately transported to the multi-purpose laboratory, at the Department of Fisheries and

Aquaculture, Joseph Sarwuan Tarka University, Makurdi for analysis and data collection. The fish species were identified using Paugy *et al*. (2003) identification guide.

**Sex determination of the fish samples**

The sex of individual specimens was identified in the laboratory, and sorted into males and females by observing the genital papillae and genital openings with the help of a hand magnifying glass. Specimens were also dissected to confirm for sex determination. The ovaries are paired egg sacs located behind the stomach and duodenum below the swim bladder and just above the intestine and connected by mesenteries (Priyardharsini *et al.*, 2013). The colour of gonads was recorded separately for each female fish to determine their levels of maturity.

Sex ratio was then determined by counting the number of male and female specimens and expressed as ratio as stated below;

$$Sex\ ratio = \frac{Number\ of\ males}{Number\ of\ females}$$

**Gonado-somatic index (GSI) estimation**

Gonado-somatic index (GSI) was obtained using the individual gonad and body weights of sexually mature fish only. GSI was calculated using the formula;

$$Gonado\text{-}somatic\ index\ (GSI) = \frac{Gonad\ weight\ (GW)}{Total\ Body\ weight\ (BW)} \times 100$$

**Fecundity estimation**

The gonads were obtained, blotted onto a filter paper to absorb excess blood and water and the length and weight of the gonads were recorded. Transverse section of each ovary was cut open; Gilson fluid was added to each slide prepared to dissociate the eggs for easy examination under the light microscope. Oocytes (eggs) that were clearly visible under the microscope were estimated using gravimetric and numerical methods. The absolute fecundity (AF) was determined by utilizing the data collected from the number of matured and ripe oocytes that were counted. Each of the gonadal section in the slide was examined; the number of eggs classified under the immature, developing, and spawning capable classes was summed up; and the sum obtained was divided by the total number of eggs counted within the section.

$$Absolute\ fecundity\ (AF) = \frac{No.\ of\ eggs\ immature,\ developing,\ and\ spawning\ capable\ class}{Total\ No.\ of\ eggs\ per\ section} \times 100$$

**Statistical Analysis**

Student T-test was used to determine the differences in Seasonal and Sex-wise Gonad-weight and Gonad-length, fecundity, and oocyte sizes of fish species from Lower River Benue. They were analyzed using the procedure of Gayanilo Jr. *et al*. (2005) of the FiSAT II (version 1.2.2) computer software package for fish stock assessment.

## RESULTS AND DISCUSSION

**Sex ratio of *Hydrocynus forskahlii* from Lower River Benue**

The sex ratio of *H, forskahlii* obtained from Abinsi and Wadata stations is presented in Table 1.
*H. forskahlii* obtained from Abinsi had the sex ratio of 1:1.04 and 1:1.16 from Wadata for males and females, respectively. Females of *H. forskahlii* were numerically abundant than males.

**Table 1:** Sex ratio of *Hydrocynus forskahlii* obtained from Lower River Benue

| Sampling stations | Sex | | |
|---|---|---|---|
| | M | F | Ratio (M:F) |
| Abinsi | 92 | 97 | 1: 1.04 |
| Wadata | 99 | 115 | 1: 1.16 |

Female *Hydrocynus forskahlii* were significantly abundant than their male counterparts during the study period from both Abinsi and Wadata stations. This is supported by Igejongbo *et al.* (2018), who reported females to be more abundant in his study, suggesting that females might live longer than the males. The finding of this study is also supported by Famoofo and Abdul (2020), who reported females to be more abundant than the males in Iwopin fresh-water ecotype of Lekki Lagoon.

**Gonado-somatic index of *Hydrocynus forskahlii***

The seasonal variation in the reproductive indices of *Hydrocynus forskahlii* obtained from Lower River Benue is presented in Table 2.

There was significant difference ($p<0.05$) in the body weight of *H. forskahlii* between the rainy and dry seasons from Abinsi and Wadata stations, while in the gonad weight and GSI, there were no significant difference ($p>0.05$). Higher values were recorded from Abinsi, for the body weight and gonad weight during the rainy season, while the GSI recorded a higher value during the dry season. Wadata recorded higher values during the dry season for both body weight, gonad weight and the GSI.

**Table 2:** Seasonal variation in Reproductive indices of *H. forskahlii* obtained from Lower River Benue

| Sampling Stations | Reproductive Indices | No. | Body weight (g) | Gonad weight (g) | GSI (%) |
|---|---|---|---|---|---|
| Abinsi | Rainy | 64 | 392.00±33.00 | 1.14±0.15 | 0.25±0.02 |
| | Dry | 16 | 289.00±29.00 | 0.98±0.24 | 0.29±0.06 |
| | P-value | | <0.05* | 0.57 | 0.53 |
| Wadata | Rainy | 64 | 268.00±30.00 | 1.09±0.29 | 0.23±0.03 |
| | Dry | 26 | 449.00±45.00 | 1.37±0.22 | 0.29±0.04 |
| | P-value | | <0.05* | 0.44 | 0.28 |

*Indicates statistical significance

There was no significance in the GSI between seasons and stations. The GSI of *H. forskahlii* increased with an increase in body weights, which is in line with Mohamed (2010), who reported that GSI increases progressively with increased percentage of the ripe individuals towards the spawning seasons. The fish gained more body weight during the rainy season, leading to an increase in GSI as the species prepared for spawning. The immature fish characterised by small ovaries, often clear with indistinct blood vessels, small testes that were clear and thread-like, occurred predominantly between October-March, while the mature ones characterised by large ovaries and macroscopically visible oocytes with prominent blood vessels occurred between May -August, with higher fecundity during the rainy season. This agrees with Igejongbo *et al.* (2018) who also reported the immature fishes to occur mostly from October to March and the spawning stage to be from May to August. The GSI values were higher during the months of gonad formation and spawning (rainy season), and declined abruptly from September to November, indicating a post-spawning period. This also agrees with the report of Borthakur (2018), who stated that the gonado-somatic index increases with the maturation of fish, being maximum during the period of peak maturity and declining abruptly. Borthakur (2018), also reported lowest GSI value of male *Xenontedon cancila* in the month of November, a gradual increase in the mean GSI value from

December to April, a rapid increase in the GSI from May to June and attains peak in July when the gonads enter the maturation phase, and a significantly declining GSI value from August to November. From this study, the GSI declined from September to November indicating a post-spawning period. Shaheena *et al.*, (2012) reported that GSI fluctuates from a minimum of 2.302% in June to 11.363% in March which decreased from April to June been an indication of complete spawning. Alam and Pathak (2010), Mishra and Saksena (2012) reported that GSI is synchronised with the level of maturation of fish hence it peaks at full maturity, and its abrupt decrease indicates beginning of spawning. Alonso-Fernandez *et al.* (2011) reported the mean GSI value of females, primary males, and secondary males to show a peak reproductive activity in May and June.

**Fecundity and Oocytes Morphometry of *Hydrocynus forskahlii***

The fecundity and oocyte morphology of *H. forskahlii* are presented in Table 3.

There was significant difference ($p<0.05$) in the fecundity between the months from Abinsi but no significant difference in Wadata station ($p<0.05$). There was no significant difference in the fecundity between the stations.

**Table 3:** Monthly Fecundity and Oocytes Morphometry of *H. forskahlii* from Abinsi and Wadata obtained from Lower River Benue

| Month | Abinsi | Wadata | p-value |
|---|---|---|---|
| | Fecundity | | |
| Apr-19 | $2534.20 \pm 242.00^{ab}$ | $2492.14 \pm 262.00$ | 0.908 |
| May-19 | $3305.56 \pm 258.00^{b}$ | $1804.50 \pm 628.00$ | 0.090 |
| Jun-19 | $3861.44 \pm 348.00^{b}$ | $2985.83 \pm 422.00$ | 0.126 |
| Jul-19 | – | $4020.67 \pm 513.00$ | – |
| Feb-20 | $1033.00 \pm 0.00^{a}$ | $2262.75 \pm 620.00$ | – |
| Mar-20 | $2217.50 \pm 188.00^{ab}$ | $2232.75 \pm 512.00$ | 0.979 |
| p-value | 0.008* | 0.202 | |
| | Oocyte Diameter (mm) | | |
| Apr-19 | $2.31 \pm 0.09$ | $2.32 \pm 0.05^{b}$ | 0.919 |
| May-19 | $2.66 \pm 0.17$ | $2.44 \pm 0.01^{b}$ | 0.218 |
| Jun-19 | $2.74 \pm 0.07$ | $2.46 \pm 0.04^{b}$ | 0.003* |
| Jul-19 | – | $2.51 \pm 0.01^{b}$ | – |
| Feb-20 | $1.82 \pm 0.00$ | $2.09 \pm 0.06^{a}$ | – |
| Mar-20 | $2.95 \pm 0.12$ | $2.39 \pm 0.04^{b}$ | 0.012* |
| p-value | 0.183 | 0.0002* | |
| | Oocyte Circumference (mm) | | |
| Apr-19 | $7.38 \pm 0.14^{ab}$ | $7.39 \pm 0.04^{b}$ | 0.929 |
| May-19 | $7.38 \pm 0.10^{ab}$ | $7.56 \pm 0.04^{bc}$ | 0.093 |
| Jun-19 | $7.72 \pm 0.05^{b}$ | $7.61 \pm 0.05^{c}$ | 0.136 |
| Jul-19 | – | $7.72 \pm 0.02^{c}$ | – |
| Feb-20 | $6.53 \pm 0.00^{a}$ | $7.00 \pm 0.11^{a}$ | – |
| Mar-20 | $7.74 \pm 0.11^{b}$ | $7.53 \pm 0.07^{bc}$ | 0.162 |
| p-value | 0.004* | $1.36 \times 10^{-6}$ | |
| | Oocyte Surface Area (mm) | | |
| Apr-19 | $4.25 \pm 0.13^{ab}$ | $4.40 \pm 0.04^{b}$ | 0.313 |
| May-19 | $4.42 \pm 0.08^{b}$ | $4.48 \pm 0.02^{b}$ | 0.496 |
| Jun-19 | $4.61 \pm 0.05^{b}$ | $4.55 \pm 0.04^{b}$ | 0.363 |
| Jul-19 | – | $4.62 \pm 0.04^{b}$ | – |
| Feb-20 | $3.60 \pm 0.00^{a}$ | $4.01 \pm 0.13^{a}$ | – |
| Mar-20 | $4.67 \pm 0.06^{b}$ | $4.50 \pm 0.04^{b}$ | 0.072 |
| p-value | 0.003* | $1.36 \times 10^{-5}$ | |

**Indicates significant difference*

The fecundity from Abinsi was higher in the month of June, while from Wadata, it was higher in July. There was no significant difference ($p>0.05$) in the oocyte diameter between the months from Abinsi, while from Wadata there was significant difference ($p<0.05$). There was significant difference ($p<0.05$) in the oocyte diameter between the stations in June and March, while there was no significant difference ($p>0.05$) in the remaining months. The oocyte diameter was higher in March from Abinsi, but higher in July at Wadata station. Significance difference existed ($p<0.05$) in the oocyte circumference between the months from both stations, while no significant difference existed between the stations ($p>0.05$). The oocyte circumference was higher in June from Abinsi, while from Wadata, it was higher in July. There was significance difference ($p<0.05$) in the oocyte surface area between the months from both stations, while between the stations there was no significant difference ($p>0.05$). The fecundity of *H. forskahlii* increased from February with a corresponding increase in the oocytes sizes and was peaked in July, which indicated actual spawning, and abruptly declined afterwards. Between August to January, there was absence of sexually mature fish, only immature, developing, regressing, and regenerating, characterised with flaccid ovaries, empty sacs, small ovaries with little blood vessels, flaccid testes, thread-like and translucent testes. The species produced larger number of oocytes with bigger sizes. The species (both males and females) became sexually mature at smaller lengths. In the report of Nakiyende *et al*. (2013), males of *H. forskahlii* mature at smaller lengths (cm) than their female counterparts, a similar observation was made in this study as smaller lengths of sexually mature males were recorded than the females. It was observed that as the Oocyte diameter, circumference, and surface area increased progressively with the gonads' maturation, there was also an increase in the fecundity. This disagrees with Helfman *et al*. (2009), who reported the fecundity in fishes to decrease with increasing size and increasing parental care.

The size of the ovaries and oocytes also determined the maturity of the fish as stated by Priyadharsini *et al*. (2013). The oocytes diameter, circumference and surface area, also increased progressively in preparation for spawning and was peaked in July to have indicate actual spawning occurred. Immature fish occurred mostly from October to March, while the spawning stage occurred from May to August, with higher fecundity during the rainy season, which agrees with the report of Igejongbo *et al*. (2018). The size of ovaries and oocytes also determined the maturity of the fish as reported by Priyardharsini *et al.,* (2013). *H. forskahlii* was noticed to be significantly abundant during the rainy season, and sexually mature ones (both sexes) were also predominantly in the rainy season. This could be justified that, the species becomes more abundant during the rainy season in preparation for breeding, due to food abundance and high level of water.

## CONCLUSION

The GSI of the fish species increased with a corresponding increase in their body weights, and the GSI was higher during the months of gonad formation and spawning (rainy season). There was no significance in the GSI of the species between seasons and stations. *H. forskahlii* matured sexually at very small lengths, and the fecundity was closely related to their lengths and weights. Females were significantly abundant than males while the males got sexually mature at smaller lengths. The fecundity increased with an increase in oocytes size.

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# MORPHOMETRIC AND MERISTIC ANALYSIS OF *Citharinus citharus* FROM LOWER RIVER BENUE, BENUE STATE, NIGERIA

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**ABSTRACT**

*This study aimed to determine some morphometric and meristic analysis of Citharinus citharus from Lower River Benue, Benue State, Nigeria. Specimens caught using gill and cast nets were collected fortnightly from artisanal fishermen from two sampling stations, for 12 months. The fish samples were fixed in ice bags to forestall post-mortem digestion and immediately transported to the laboratory for examination and data collection. Specimens were serially numbered by writing on a piece of paper, after which it was inserted in the opercula. 372 and 366 specimens were sampled from Abinsi and Wadata respectively, making a total of 738. Morphometric measurements and meristic counts of the specimens were taken and recorded appropriately. Data collected were analysed to validate the species using Fisheries Stock Assessment Tool (FiSAT) Programme. The standard length of the species ranged from 25.28-26.88cm, body weight 424.92-503.11g and gut length 133.68-142.99cm. There was significant difference in the morphometric and meristic characteristics of the species between seasons and stations, while the morphometric characters and meristic counts were not distinct between sexes. The morphometric characters increased with increase in their meristic counts, and were stable with particular lengths.*

**Keywords:** Morphometric characteristics, meristic counts, seasons, sexes, fisheries management

## INTRODUCTION

Accurate species classification and description is an important part of fish morphology (Famoofo and Abdul, 2020). The morphometric parameters are the best tools in the scientific identification and classification (Faiz *et al.*, 2015; Ajagbe and Ojo-Fakuade, 2020). González-Wangüemert *et al.*, (2016) reported that morphology provides information on fish identification and characterization for conservation and successful management of fisheries resources. In fish biology, morphology characterization gives better understanding of the diverse measurable and countable forms in fish as well as ecology and taxonomical categorization of species of fish (Mojekwu and Anumudu, 2015), which will eventually enhance the development of cost-effective aquaculture protocols and increase productivity (Famoofo and Abdul, 2020). The morphometric study of fish is a powerful tool for characterising strains and or stocks of the same species which involves the detection of subtle variation in shape, independent of size; and these examinations require exact measurements and counts of fin ray elements (González-Wangüemert *et al.*, 2016). The study of differences and variability in morphometric and meristic characters of fish stocks is important in phylogenetic studies as it provide information on the genetic improvement of stocks (Umaru *et al.*, 2015). The meristic and morphometric characteristics of fish species also known as biometric analysis of fish is an essential tool in fisheries management.

*Citharinus* species are characterized with deep and flattened bodies and they are amongst the major exploitable fish species. However, there is paucity information on its morphometric and meristic studies from Lower River Benue.

## MATERIALS AND METHODS

### Description of Study Area

The study was carried out in the Lower River Benue at Wadata and Abinsi. Wadata is located at latitude 7° 43' 0" North and longitude 8° 32 0" East, while Abinsi is located at latitude 7° 45 0" North and longitude 8° 45 0" East. It is the largest tributary of the Niger River which joins at Lokoja. The highest water levels occur from August to September and the lowest from March to April (Akombo *et al.*, 2011).

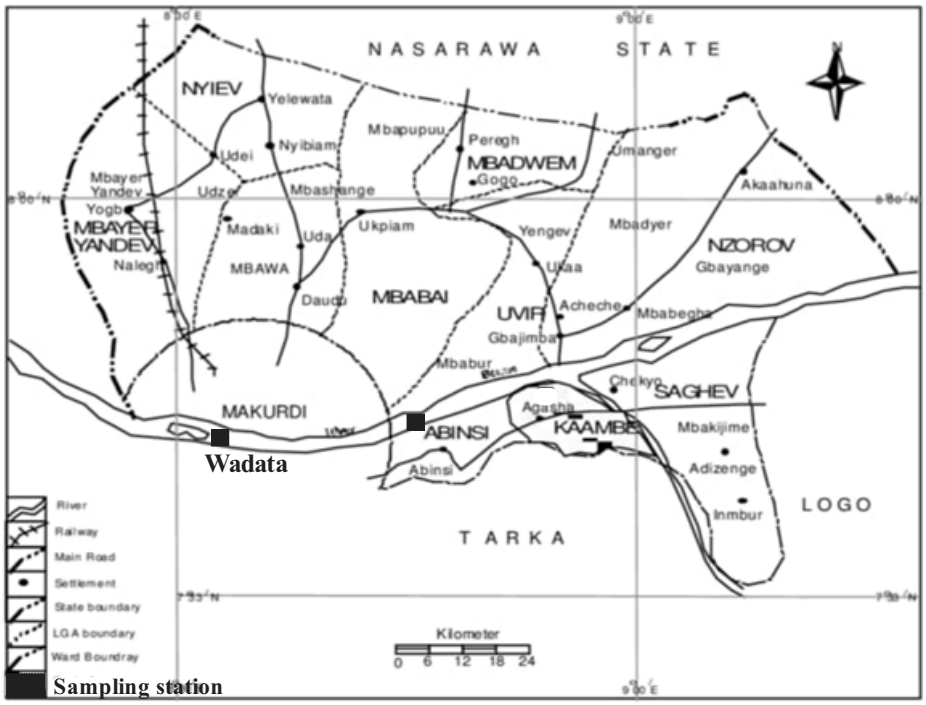



**Figure** 1: Map of Guma Local Government Area showing the sampling stations in Lower River Benue *(Source: Ministry of Lands and Survey, Makurdi)*

### Sampling Techniques

Fish samples caught using gill and cast nets were collected fortnightly from artisanal fishermen from the two sampling stations (Wadata and Abinsi), between April 2019 to March 2020. Fish species were identified using De Vos (1995) and Paugy *et al*. (2003) identification charts. A total of 372 specimens comprising 167 females and 205 males were sampled from Abinsi station, while a total of 366 comprising of 173 females and 193 males were sampled from Wadata station.

Fish samples were fixed in ice bags to forestall post-mortem digestion for immediate transport to the laboratory, at the Department of Fisheries and Aquaculture, Joseph Sarwuan Tarka University, Makurdi, Benue State, for data collection. The fish specimens were serially numbered by writing on a piece of paper and inserting in the opercula, and the morphometric characters and meristic counts of all the specimens numbered were taken and recorded serially. The morphometric characteristics were measured using a measuring board, measuring tape and digital calipers graduated in millimeters, then weighed with Golden-Mettler U.S.A Model: HC-D Electronic balance up to the nearest 0.1g as described according to Akombo *et al.*, (2011). Meristic characteristics were counted.

### Statistical Analysis

Morphometric and meristic data were analysed to validate the species using the Fisheries Stock Assessment Tools (FiSAT) Programme.

## RESULTS AND DISCUSSION

The comparison of the morphometric characteristics of C. *citharus* between seasons, stations, and sexes obtained from Lower River Benue are presented in Table 1.

There were significant differences ($p<0.05$) in the means of all the parameters between the rainy and dry seasons from Abinsi station, except for the head length and snout length. Higher values were recorded for all the parameters measured during the rainy season than dry season from Abinsi but no significant differences ($p>0.05$) in the means of the parameters between the rainy and dry seasons from Wadata, except for the gut length. Higher values were recorded for all the parameters measured during the rainy and dry seasons from Wadata, except for TL and ED that recorded higher values during the dry season.

There were significant differences ($p<0.05$) in the parameters measured between the stations, except for TL, BW, HL and SNL. Higher values were recorded from Wadata than Abinsi, except for BD and ED that recorded higher value from Abinsi. On the contrary, higher standard and gut lengths were recorded from Wadata, while the body weight showed no significant difference between the stations. Higher values were recorded by females than males from both Abinsi and Wadata stations, except the ED from Wadata. C. *citharus* had higher values of morphometric characteristics obtained during the rainy season from Abinsi, while variables were the same between seasons, except for gut weight that was higher during the dry season from Wadata. This indicates that bigger sizes of the species were abundant during the rainy season, but the fish fed better and became more abundant during the dry season as recorded from both stations. This could be as a result of low water preference by the species. Increased morphometric parameters observed during rainy seasons in both stations may imply abundant food resources of high nutritious value during such period. González-Wangüemert *et al.*, (2016) outlined food availability and improved water quality as possible factors influencing morphometric parameters in fish. Consequently, the larger sizes of C. *citharus* observed during rainy season may pose greater risk of been caught by fisher folks. Relatively, the bigger sizes observed from females may be detrimental to reproductive efficiency of this species, adversely affecting attainment of maximum sustainable yield if exploitation is not controlled. The males of the species were more abundant than their female counterparts during the period of study. This could be attributed to the fact that, males of the species live longer than the females, or the males are predominant than the females

On the comparison of stations, higher values of standard gut lengths were recorded from Wadata, while body weight showed no significant difference between the stations. Ezenwaji and Ezenwaji (2009) reported the standard length of C. *citharus* to be peaked at 12cm in Anambra River Basin and the mean length during the first year to be 12.9455cm which is in contrast with the finding of this study. The differences between total lengths, standard lengths, and body weights, between the stations could be as a result of what is reported by Ajagbe and Ojo-Fakuade (2020), who stated that the difference in the maximum lengths of fish may be as a result of different ecosystems and fishing pressure in the ecosystems. The fish had higher weights that were not stable with a particular season but varied between seasons and stations. This could be as a result of the variation in fish sizes. Famoofo and Abdul (2020) also reported the variations in fish sizes to indicate the fish population ranging from immature specimens to fully matured ones, with non-selective fishing techniques and differences in their growth (Ajagbe and Ojo-Fakuade (2020). Famoofo and Abdul (2020) also reported that, the rate of increase in body length of the fish species were not proportional to the rate of increase in their body weight, which is in line with the present findings.

**Table 1:** Comparison of the morphometric characteristics of C. *citharus* between seasons, stations, and sexes obtained from Lower River Benue

| Station | Season | No | Total length (cm) | Standard length (cm) | Body weight (cm) | Head length (mm) | Snout length (mm) | Body depth (mm) | Eye diameter (mm) | Gut length (cm) | Gut weight (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Seasons | | | | | |
| Abinsi | Rainy | 139 | 32.79±0.48$^b$ | 26.47±0.44$^b$ | 503.11±25.9$^b$ | 74.07±1.15 | 18.33±0.39 | 148.86±12.40$^b$ | 15.01±0.24$^b$ | 140.78±2.31$^b$ | 17.90±0.81$^b$ |
| | Dry | 233 | 31.22±0.31$^a$ | 25.28±0.29$^a$ | 434.92±13.3$^a$ | 72.23±0.82 | 17.83±0.23 | 114.95±1.42$^a$ | 14.29±0.20$^a$ | 133.68±1.64$^a$ | 15.04±0.99$^a$ |
| | p-value | | 0.004 | 0.02 | 0.01 | 0.182 | 0.234 | 0.001 | 0.023 | 0.011 | 0.045 |
| Wadata | Rainy | 127 | 32.29±0.39 | 26.88±0.35 | 470.78±15.7 | 75.24±0.72 | 18.35±0.22 | 118.67±1.69 | 13.48±0.26 | 142.99±1.86 | 21.72±0.57$^b$ |
| | Dry | 239 | 32.36±0.31 | 26.46±0.29 | 458.09 ± 13.5 | 73.76±0.75 | 18.22±0.25 | 117.08±1.53 | 13.94±0.19 | 140.55±1.51 | 16.52±0.47$^a$ |
| | p-value | | 0.894 | 0.374 | 0.56 | 0.20 | 0.716 | 0.515 | 0.152 | 0.325 | <0.0001 |
| | | | | | | Stations | | | | | |
| | Abinsi | 372 | 31.81±0.27 | 25.72±0.25$^a$ | 460.40±12.90 | 72.92±0.67 | 18.02±0.20 | 127.62±4.79$^b$ | 14.56±0.15$^b$ | 136.34±1.35$^a$ | 16.11±0.69$^a$ |
| | Wadata | 366 | 32.34±0.24 | 26.61±0.22$^b$ | 462.49±10.30 | 74.27±0.55 | 18.26±0.18 | 117.63±1.16$^a$ | 13.78±0.15$^a$ | 141.40±1.18$^b$ | 18.32±0.38$^b$ |
| | p-value | | 0.145 | 0.009 | 0.899 | 0.118 | 0.364 | 0.045 | 0.0004 | 0.005 | 0.006 |
| | | | | | | Sexes | | | | | |
| Abinsi | Females | 167 | 32.13±0.41 | 26.09±0.38 | 478.41±18.3 | 73.55±0.98 | 18.36±0.31 | 133.83±8.08 | 14.74±0.24 | 137.97±2.14 | 17.50±1.32 |
| | Males | 205 | 31.54±0.35 | 25.43±0.33 | 445.73±18.00 | 72.40±0.91 | 17.74±0.28 | 122.56±5.68 | 14.41±0.20 | 135.01±1.73 | 14.98±0.64 |
| | p-value | | 0.27 | 0.189 | 0.207 | 0.392 | 0.136 | 0.243 | 0.282 | 0.278 | 0.071 |
| Wadata | Females | 173 | 32.74±0.35 | 27.00±0.32 | 466.95±14.3 | 75.15±0.79 | 18.50±0.23 | 118.14±1.63 | 13.68±0.22 | 143.63±1.70 | 19.07±0.57 |
| | Males | 193 | 31.97±0.34 | 26.25±0.31 | 458.49±14.9 | 73.48±0.76 | 18.05±0.27 | 117.17±1.65 | 13.87±0.22 | 139.39±1.63 | 17.66±0.52 |
| | p-value | | 0.115 | 0.093 | 0.684 | 0.13 | 0.21 | 0.679 | 0.531 | 0.072 | 0.068 |

*b- Superscript present higher values than the 'a' superscript.*

The comparison of Meristic counts of C. *citharus* between seasons, stations, and sexes obtained from Lower River Benue are presented in Table 2. There was significant differences ($p<0.05$) in the meristic counts between the seasons from Abinsi, except for scales above the lateral line (ALL), dorsal fin rays, and pelvic fin rays that showed no significant differences ($p>0.05$) in their means between the seasons. Higher values were recorded for the meristic counts from Abinsi in the rainy season, except for scale ALL and scales below the lateral line (BLL). There were significant differences ($p<0.05$) in the meristic counts between the seasons from Wadata, except for dorsal fin rays, pectoral fin rays and caudal fin rays. Higher values were recorded for the meristic counts from Abinsi in the dry season, except for dorsal fin rays and pelvic fin. There were significant differences ($p<0.05$) in the meristic counts between the stations, except in the means of dorsal fin rays, pelvic fin rays, and caudal fin rays. Higher values were recorded from Abinsi station, except dorsal fin rays that recorded higher value from Wadata.

Higher values of the meristic counts were recorded by the females than the males, from both Abinsi and Wadata stations, except the scales on the lateral line (OLL). The average of the different meristic variables appeared very similar among the populations of Abinsi and Wadata. This result revealed that the meristic counts are stable with particular lengths, as described by Konan (2015) who stated that meristic descriptors are discrete and fixed at the last stage of development. This shows that the morphometric characteristics increased with the corresponding increase in the meristic counts. Meristic counts were higher during the rainy season, corresponding with the morphometric characteristics from Abinsi. Meristic counts of C. *citharus* were higher during the dry season, while dorsal fin rays, pectoral fin rays, and caudal fin rays showed no significance between the seasons from Wadata. From the stations, 5 meristic counts were higher from Abinsi, while the dorsal fin rays, pelvic fin rays, and caudal fin rays showed no significance between the stations. This study revealed the range of scale counts on the lateral line (OLL) of C. *citharus* to be between 85.39-88.45, scale counts above the lateral line (ALL) to be between 25.10-26.36, scale counts below the lateral line (BLL) to be 26.44-28.67, the dorsal fin rays count to be 19.15-19.37, the pectoral fin rays count to be between 16.85-17.38, the pelvic fin rays count to be between 10.51-11.57, anal fin rays count to be between 28.02-29.15, and the caudal fin rays count to be between 26.76-28.60. This is justified by Gosse and Paugy (2003) who reported C. *citharus* to have dorsal soft rays between 17-21; anal soft rays of 26 -31, body depth 1.8-2.7x head length and head length 3.0-4.1x SL; snout 0.7-1.6x eye diameter; eye diameter 3.7-6.1x head length; pectoral fins 0.5-1.1x head length; 77-92 scales in longitudinal line; 17.5-20.5 scales between lateral line and pelvic fin. Females indicated no significant difference in their meristic counts from the males. In this study, no significant

difference was noticed in both the morphometric characteristics and meristic counts of the species between the sexes.

**Table 2:** The comparison of the Meristic counts of C. *citharus* between seasons, stations, and sexes obtained from Lower River Benue

| Station | Season | No | Scales OLL | Scales ALL | Scales BLL | Dorsal fin rays | Pectoral fin rays | Pelvic fin rays | Anal fin rays | Caudal fin rays |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Seasons | | | | | |
| Abinsi | Rainy | 139 | 88.45±0.79$^{b}$ | 26.30±0.17 | 28.09±0.20$^{a}$ | 19.36±0.10 | 17.38±0.06$^{b}$ | 11.57±0.72 | 29.15±0.12$^{b}$ | 28.22±0.07$^{b}$ |
| | Dry | 233 | 86.61±0.18$^{a}$ | 26.36±0.15 | 28.67±0.19$^{b}$ | 19.15±0.08 | 17.16±0.05$^{a}$ | 10.65±0.07 | 28.61±0.11$^{a}$ | 27.91±0.07$^{a}$ |
| | p-value | | 0.005 | 0.821 | 0.046 | 0.117 | 0.007 | 0.105 | 0.001 | 0.005 |
| Wadata | Rainy | 127 | 85.39±0.07$^{a}$ | 25.10±0.12$^{a}$ | 26.44±0.14$^{a}$ | 19.37±0.08 | 16.85±0.05 | 10.69±0.04$^{b}$ | 28.02±0.13$^{a}$ | 26.76±0.20 |
| | Dry | 239 | 85.84±0.12$^{b}$ | 26.13±0.11$^{b}$ | 27.77±0.16$^{b}$ | 19.33±0.09 | 16.95±0.06 | 10.51±0.05$^{a}$ | 28.73±0.11$^{b}$ | 28.60±1.07 |
| | p-value | | 0.009 | <0.0001 | <0.0001 | 0.744 | 0.281 | 0.029 | 0.0001 | 0.212 |
| | | | | | Stations | | | | | |
| | Abinsi | 372 | 87.30 ± 0.32$^{b}$ | 26.34±0.12$^{b}$ | 28.45±0.14$^{b}$ | 19.23±0.06 | 17.24±0.04$^{b}$ | 10.99±0.27 | 28.81±0.08$^{b}$ | 28.02±0.05 |
| | Wadata | 366 | 85.68 ± 0.08$^{a}$ | 25.77±0.08$^{a}$ | 27.31±0.12$^{a}$ | 19.34±0.06 | 16.91±0.04$^{a}$ | 10.58±0.04 | 28.48±0.09$^{a}$ | 27.96±0.7 |
| | p-value | | <0.0001 | <0.0001 | <0.0001 | 0.219 | <0.0001 | 0.133 | 0.006 | 0.929 |
| | | | | | Sexes | | | | | |
| Abinsi | Females | 167 | 87.99±0.39$^{b}$ | 26.56±0.14 | 28.65±0.22 | 19.28±0.09 | 17.29±0.06 | 11.35±0.60 | 28.96±0.12 | 28.08±0.08 |
| | Males | 205 | 86.74±0.48$^{a}$ | 26.15±0.17 | 28.28±0.18 | 19.20±0.09 | 17.20±0.05 | 10.71±0.06 | 28.69±0.11 | 27.98±0.07 |
| | p-value | | 0.0496 | 0.075 | 0.19 | 0.529 | 0.265 | 0.244 | 0.107 | 0.355 |
| Wadata | Females | 173 | 85.74±0.11 | 25.78±0.12 | 27.13±0.17 | 19.35±0.07 | 16.95±0.07 | 10.58±0.04 | 28.50±0.14 | 28.69±1.48 |
| | Males | 193 | 85.63±0.12 | 25.77±0.12 | 27.47±0.16 | 19.34±0.10 | 16.88±0.04 | 10.57±0.07 | 28.46±0.11 | 27.31±0.16 |
| | p-value | | 0.518 | 0.937 | 0.149 | 0.937 | 0.425 | 0.859 | 0.814 | 0.329 |

* OLL- On the lateral line; ALL- Above the lateral line; BLL- Below the lateral line.
*b- Superscript present higher values than the 'a' superscript.*

## CONCLUSION

C. *citharus* obtained from Lower River Benue exhibited significant difference in the morphometric and some meristic characteristics of between seasons. The morphometric characteristics and some meristic counts of the species were not distinct between sexes and were stable with particular lengths.

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# IMPACT OF CLIMATE VARIABILITY ON INLAND FISHERIES IN KANO STATE: IMPLICATIONS FOR SMALL-SCALE FISHERIES MANAGEMENT

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**ABSTRACT**
*Inland fisheries in Kano State, anchored around aquatic systems such as Challawa Gorge Dam, Jakara River, Tiga Dam, and Kanya Dam, are central to food security, nutrition, and rural livelihoods. These ecosystems support diverse fish species and provide essential services for farming and pastoral communities. However, climate variability marked by erratic rainfall, rising temperatures, extended dry spells and unpredictable flooding threatens the productivity and sustainability of these fisheries. Hydrological instability has led to habitat loss, reduced breeding grounds and disruptions in fish population dynamics while extreme climate events damage fishing gear, displace stocks and undermine artisanal fishers' economic stability. This study examines the interplay between climate variability, aquatic ecology and fisheries productivity in Kano State, drawing on biodiversity data to highlight the vulnerability of key species such as Oreochromis niloticus, Clarias gariepinus, and Lates niloticus. Findings show that climate-induced stresses amplify existing pressures, resulting in declining biomass, reduced catch per unit effort, and heightened livelihood insecurity among small-scale fishing households. These fluctuations in these climatic conditions have led to declines in key species such as Clarias gariepinus and Oreochromis niloticus, while flood-tolerant and low-oxygen species like Sarotherodon melanotheron are becoming more dominant. Aligning inland fisheries governance in Kano State with broader national climate adaptation and food security frameworks is essential to balance ecological sustainability with community livelihoods. Such alignment would ensure that fisheries management not only mitigates the effects of climate variability but also supports Nigeria's long-term goals of poverty reduction, food security, and ecosystem conservation.*

**Keywords:**
adaptations, biodiversity, Kano State, livelihoods

## INTRODUCTION

Inland fisheries in Kano State represent a vital source of food security, income generation, and cultural heritage for both rural and urban communities. They provide affordable animal protein for households (Akinjogunla and Usman, 2023), support artisanal fishing as a livelihood strategy (Akinjogunla and Shu'iabu, 2022), and contribute to the broader agro-pastoral economy through interconnected activities such as irrigation, livestock watering, and fish marketing (Tchonkouang, *et al.*, 2024). Key aquatic systems, including Thomas Dam, Challawa River, Kanya dam and Tiga Dam, sustain diverse fish species such as *Clarias gariepinus*, *Oreochromis niloticus*, and *Lates niloticus*, which are crucial for the resilience of local diets and livelihoods (Abdul-Azeez *et al.*, 2024).

However, these inland fisheries are increasingly vulnerable to climate-induced variations that disrupt their ecological and socioeconomic stability. Erratic rainfall regimes, prolonged dry spells, and intensified flooding events have altered hydrological cycles, reduced water retention capacity in reservoirs, and compromised breeding habitats (Caretta *et al.*, 2022). Such hydrological instability reduces fish recruitment, shifts species distribution, and heightens competition for dwindling aquatic resources. In addition, floods frequently damage fishing gear and displace stocks, while droughts shrink water bodies, concentrating pollutants and raising mortality risks for aquatic species (Nair and Nayak, 2023).

While earlier studies largely emphasized the qualitative impacts of climate change on inland fisheries, recent biodiversity datasets from Thomas Dam and Challawa River now provide a quantitative baseline for assessing ecological and production trends (Attah *et al.*, 2023). These emerging datasets highlight not only reductions in fish biomass and catch-per-unit-effort (CPUE) but also the increasing dominance of stress-tolerant species at the expense of more sensitive taxa (McClanahan *et al.*, 2025). Such evidence underscores the need for more robust, ecologically grounded assessments of climate–fishery interactions in Kano State.

The growing threat of climate variability is further compounded by anthropogenic stressors such as overfishing, poor regulatory enforcement, and water pollution from agricultural runoff and urban effluents (Ohaeri *et al.*, 2020). Together, these pressures exacerbate ecological vulnerability and undermine the long-term viability of small-scale fisheries. Addressing these challenges requires integrating climate-smart strategies, biodiversity monitoring, and participatory governance into fisheries management frameworks.

Therefore, this study situates inland fisheries within the dual context of climate variability and socioeconomic dependency, with a particular focus on Thomas Dam and Challawa River in Kano State. It aims to evaluate emerging biodiversity data, analyze ecological and livelihood implications, and propose adaptive measures for ensuring sustainable fisheries governance in Kano State.

## MATERIALS AND METHODS

Relevant literature was retrieved from multiple databases, including Google Scholar, ResearchGate, ScienceDirect, Scopus, and Wiley Online Library, supplemented by institutional repositories and organizational reports (e.g., FAO, IIARD, NAFDAC). A systematic search was conducted between January 2020 and August, 2025, ensuring coverage of the most recent scholarship and sectoral reports. This study adopted a narrative synthesis approach to systematically collate, analyse, and interpret recent evidence on climate variability and its impact on inland fisheries productivity in Kano State.

## RESULTS AND DISCUSSION

Climate variability has emerged as one of the most pressing challenges to the sustainability of inland fisheries in Kano State. The sector, which provides critical food security, nutrition, and livelihoods, is increasingly vulnerable to shifts in rainfall, temperature, and hydrological regimes. These climatic changes disrupt aquatic habitats, alter fish population dynamics, and intensify socioeconomic pressures on fishing-dependent communities. The socioeconomic and biological implications of these changes are profound. Declines in commercially important species like *O. niloticus* and *L. niloticus* undermine the profitability of small-scale fisheries (Table 1), reducing household income levels in fishing communities. Nutritional risks are also evident, as reduced availability of staple fish species compromises access to affordable dietary protein, particularly for vulnerable populations.

**Table 1:** Fish Biodiversity Trends in Selected Inland Waters of Kano State

| Water Body | Dominant Species (2020–2024) | Biodiversity Trend | CPUE |
|---|---|---|---|
| Thomas Dam | *Oreochromis niloticus, Clarias gariepinus, Heterotis niloticus* | Declining species richness; stress-tolerant species becoming dominant | ↓ 25% (compared to 2018 baseline) |
| Challawa River | *Clarias gariepinus, Tilapia zillii, Lates niloticus* | Decline in sensitive species; pollution-tolerant species increasing | ↓ 30% (compared to 2018 baseline) |
| Tiga Dam | *Oreochromis niloticus, Bagrus bajad* | Moderate decline; seasonal variability increasing | ↓ 15% |

* ***CPUE - Catch Per Unit Effort;*** ↓ - decrease

One of the most significant impacts lies in hydrological alterations as shown in Table 2. Erratic rainfall and recurrent droughts have reduced water levels in rivers, dams, and wetlands, particularly in critical These floodplains, historically vital for spawning and nursery grounds, now shrink during prolonged dry spells, thereby reducing fish reproductive success (Bukar *et al.*, 2021). Rising water temperatures exacerbate the challenge, leading to oxygen depletion and thermal stress in fish populations. Species such as O*reochromis niloticus*, which thrive under relatively stable thermal conditions, are particularly vulnerable to these changes (Leonard and Skov, 2022).

**Table 2:** Climate Stressors and Their Impacts on Inland Fisheries in Kano State

| Climate Stressor | Species Affected | Ecological Impact | Livelihood Consequences |
|---|---|---|---|
| Erratic rainfall & drought | *Oreochromis niloticus*, *Clarias gariepinus* | Shrinkage of floodplains, reduced spawning and nursery habitats | Decline in fish recruitment, lower catch volumes, income reduction |
| Rising water temperature | *O. niloticus*, *Tilapia zillii* | Oxygen depletion, thermal stress, altered breeding cycles | Fish mortality, reduced productivity, increased household food insecurity |
| Flooding events | *Clarias gariepinus*, *Lates niloticus* | Displacement of fish stocks, gear destruction, habitat disturbance | High costs for gear replacement, income shocks, food price inflation |
| Long-term climatic shifts | *Brycinus nurse*, *Synodontis* spp. | Stress-tolerant species dominate catches; decline in sensitive, high-value species | Reduced market value of catches, lower household purchasing power |
| Hydrological instability (dams & rivers) | *Heterotis niloticus*, *Bagrus bajad* | Seasonal variability in recruitment; altered population dynamics | Shortened fishing seasons, shift to farming/aquaculture for resilience |

Beyond gradual hydrological changes, extreme climatic events also threaten fisheries. Seasonal floods, which have become more unpredictable in intensity and frequency, frequently destroy fishing gear, displace fish populations, and disrupt fishing cycles. For artisanal fishers who lack the financial means to quickly replace equipment, such events result in prolonged income shocks and heightened livelihood insecurity (Alhassan *et al.*, 2024).

Long-term climatic shifts are also reshaping ecosystem dynamics. Sensitive species are in decline, while generalist or stress-tolerant species such as *Brycinus nurse* increasingly dominate catches. This shift in species composition not only alters the ecological balance of aquatic systems but also affects the economic value of catches, as higher-value species such as *Lates niloticus* become less abundant (Nyamweya *et al.*, 2025). Consequently, fishers face reduced incomes, and consumers experience decreased access to preferred fish species, threatening both livelihoods and food security.
Furthermore, adaptation to these challenges often imposes new costs. Households may be forced to repair damaged gear, seek alternative income sources, or migrate seasonally, which compounds existing vulnerability and deepens cycles of poverty.

To address these converging challenges, a set of adaptive strategies for resilience has been proposed. Climate-smart fisheries management offers a pathway by aligning fishing calendars with hydrological rhythms, ensuring that fishing pressure is minimized during critical breeding periods (Talbot *et al.*, 2024). Habitat protection and wetland rehabilitation, are equally vital for restoring spawning grounds and maintaining ecosystem services. Diversifying livelihoods through aquaculture provides an additional buffer; for instance, tilapia from Wasai Reservoir has demonstrated good condition factors ($K \geq 1$), suggesting its potential for sustainable aquaculture expansion (Aung *et al.*, 2021). Moreover, participatory monitoring that empowers local fishers to track seasonal catch trends can improve adaptive responses, while the integration of early warning climate systems can provide timely forecasts to guide fishing strategies (Kura *et al.*, 2023).

Taken together, these strategies highlight the importance of embedding climate resilience into fisheries governance in Kano State. Without proactive adaptation and participatory management, climate variability will continue to erode both ecological sustainability and community livelihoods, threatening

the long-term viability of inland fisheries.

## CONCLUSION

Climate variability notably hydrological instability and temperature shifts are increasingly undermining inland fisheries in Kano State. Although species like *Brycinus nurse* may adapt better, overall fish productivity and fisher livelihoods are vulnerable. A combined approach of ecological management, socioeconomic support, and fisher participation is essential to sustain fisheries under changing climatic futures.

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# HABITAT SUITABILITY MODELING FOR FISH SPECIES IN THE CROSS-RIVER ESTUARY: IMPLICATIONS FOR SMALL-SCALE FISHERIES MANAGEMENT

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**ABSTRACT**
*Effective estuarine habitat assessment is vital for fisheries management and biodiversity conservation. This study applied habitat suitability index (HSI) modelling to the Cross River Estuary using temperature, salinity, depth, and substrate type. Among three modelling approaches, the smooth-mean method yielded the most reliable suitability curves. Spatial analysis revealed that 26.2% of the estuary offered optimum conditions—shallow waters, moderate salinity, warm temperatures, and mud substrates with vegetation. Catch-per-unit-effort (CPUE) data validated the model, showing significantly higher CPUE in optimum zones. Regression analysis confirmed strong predictive power ($R^2$ up to 0.882), and statistical tests showed no significant difference between methods. These results demonstrate the utility of HSI modelling, especially the smooth-mean approach, for guiding sustainable fisheries and conservation planning.*

**Keywords**: Estuarine habitat suitability index, Species distribution modelling, Fisheries management

## INTRODUCTION

Estuaries are highly productive ecosystems that serve as nurseries and feeding grounds for diverse fish and invertebrate species. They play essential roles in maintaining ecological balance while supporting fisheries that provide food and livelihoods (Vernberg & Vernberg, 1972). Effective management of these ecosystems requires understanding how environmental conditions shape habitat quality and influence species distribution (Drohan *et al*., 2007). Habitat suitability modelling offers a structured approach to evaluating these relationships by linking species abundance with key environmental variables. The Habitat Suitability Index (HSI) model, developed by the U.S. Fish and Wildlife Service, integrates variables such as salinity, temperature, depth, and substrate type into a single index that predicts the ability of a habitat to support a species or life stage (Bovee, 1986; Rubec *et al*., 1999). Validation is typically conducted using field data such as catch per unit effort (CPUE), which provides a direct measure of abundance relative to habitat suitability.

The Cross River Estuary in southeastern Nigeria is both an ecological hotspot and an economic resource for artisanal fisheries (Otogo *et al*., 2025). However, overfishing, habitat alteration, and climate variability threaten its ecological integrity. While HSI models have been widely applied in North America and Asia, their use in West African estuaries remains limited. Recent studies have begun to address this gap. For example, Chukwuka *et al*. (2024) assessed habitat sensitivity along the West African coast using environmental indicators such as temperature, pH, and chlorophyll-a to delineate vulnerable zones. Akala *et al*. (2023) applied HSI modelling to evaluate habitat preferences of African forest elephants in Nigeria, demonstrating the model's broader applicability in regional conservation planning. These emerging efforts underscore the need for spatially explicit tools tailored to West African aquatic systems. The present study contributes to this growing body of work by developing and validating HSI models for the Cross River Estuary. The findings offer insights into the environmental factors that define suitable habitats for estuarine fishes and provide a scientific basis for fisheries management and conservation planning in Nigerian waters.

## MATERIALS AND METHODS

### Study area and sampling sites

The study was conducted in the Cross River Estuary, an important nursery ground for estuarine fishes and invertebrates in southeastern Nigeria. Eight representative sites were selected to capture environmental variability within the estuary: Itu Beach, Ayadehe Beach, Uruan Beach, Okobo Beach, Oron Beach, Nsidung Beach, Atu Beach, and Ibaka Beach. These locations encompass a gradient of hydrological and substrate conditions, making them suitable for habitat suitability modelling.

### Data collection

Fisheries-independent sampling was undertaken between April and July 2025, covering both dry and wet season transitions. Sampling was conducted monthly at each site using a combination of cast nets (mesh size 25 mm), gillnets (mesh sizes 25–50 mm), and traps to ensure capture of a broad range of fish and invertebrate species. Catch data were standardized as catch per unit effort (CPUE), expressed as the number of individuals per hour of fishing, and adjusted for gear type to reduce selectivity bias (Rubec *et al*., 1999).

### Environmental variables

At each sampling station, in situ measurements of water temperature, salinity, and depth were taken using a portable digital thermometer, handheld salinometer, and depth sounder, respectively. Sediment type was determined by visual inspection and hand sampling, and classified into sand, mud, or mixed categories. The presence of submerged aquatic vegetation (SAV) was recorded using a combination of visual surveys and quadrat sampling along shallow margins. All environmental data were integrated into a Geographic Information System (GIS) environment. Spatial layers were generated using inverse distance weighting (IDW) interpolation to create continuous environmental surfaces across the estuary (Rubec *et al*., 1999).

### Habitat Suitability Index (HSI) modelling

Suitability index (Si) functions were developed for each environmental variable by relating relative species abundance to corresponding gradients. Three approaches were used to construct the suitability functions: cumulative frequency, range-mean, and smooth-mean methods. In the smooth-mean method, polynomial regression was applied to generate continuous suitability curves. Composite HSI scores were computed as the geometric mean of the individual Si values, producing an integrated measure of habitat suitability for each grid cell (Bovee, 1986; Rubec *et al*., 1999).

### Model application and validation

The HSI models were applied within the GIS framework to calculate habitat suitability scores and to produce spatial maps of habitat quality across the estuary. Validation was performed by comparing predicted suitability zones with observed CPUE data from the sampling stations. Statistical validation included linear regression analysis to assess the proportion of variance in CPUE explained by the HSI scores ($R^2$) and chi-square goodness-of-fit tests to evaluate differences between the range-mean and smooth-mean methods.

## RESULTS AND DISCUSSION

### Habitat suitability functions

Habitat suitability index (HSI) functions were developed for temperature, salinity, depth, and Bottom Type (Table 1). The polynomial regressions explained a moderate proportion of the variance ($R^2$ = 0.59–0.68), which is consistent with other estuarine suitability models (Rubec *et al*., 1999). Optimum suitability occurred at warm temperatures near 29 °C, moderate salinities of 15–25 ppt, and shallow

depths around 1 m, with submerged aquatic vegetation (SAV) and mud bottoms providing the highest scores (Figure 1). These conditions align with known habitat preferences of juvenile fish in tropical estuaries, where shallow vegetated substrates enhance food availability and predator refuge (Lefcheck *et al.*, 2019).

**Table 1.** Summary of Habitat Suitability Index (HSI) functions and regression equations for environmental variables in the Cross River Estuary

| Variable | Suitability Index Function (Polynomial Regression) | Coefficient of Determination ($R^2$) | Suitability Range (Scaled 0-10) |
|---|---|---|---|
| Temperature (°C) | $Si = -0.0037T^3 + 0.05T^2 - 0.29T + 7.1$ | 0.61 | 0 (12°C) to 10 (29°C) |
| Salinity (ppt) | $Si = -0.0009S^3 + 0.032S^2 - 0.38S + 8.5$ | 0.68 | 0 (0 ppt) to 10 (25 ppt) |
| Depth (m) | $Si = -0.0002D^3 + 0.015D^2 - 0.22D + 6.3$ | 0.59 | 0 (10 m) to 10 (1 m) |
| Bottom Type* | SAV Present = 10; Mud = 8; Sand = 5 | N/A | Categorical suitability scores |

**Bottom types scored based on species preference for estuarine habitats dominated by mud.*

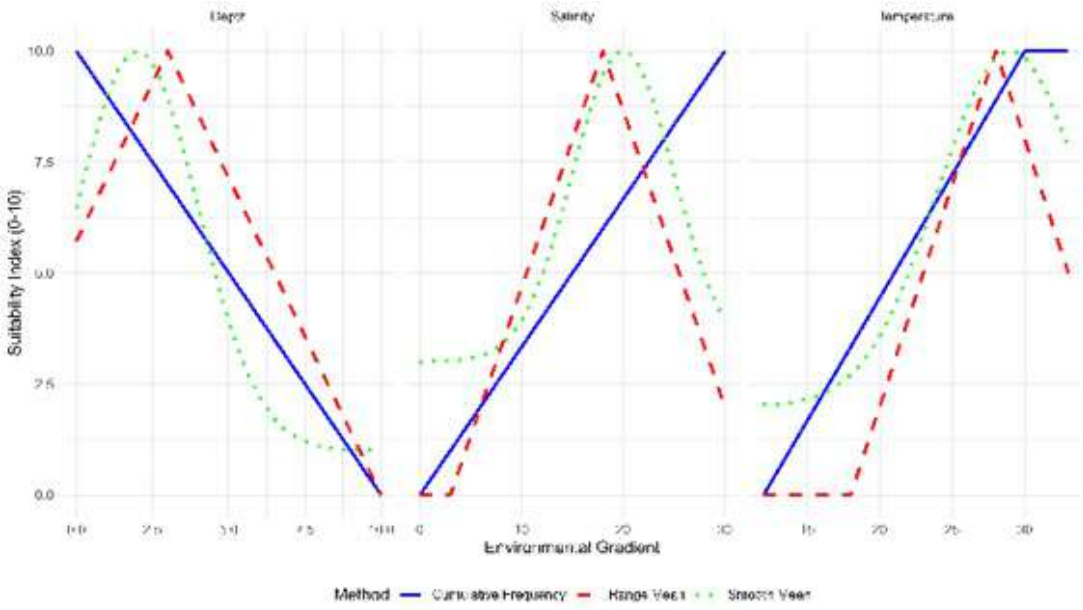



**Figure 1.** Combined suitability index functions for environmental variables with polynomial regression fits

**Spatial distribution of suitability zones**

Validation using catch-per-unit-effort (CPUE) data demonstrated strong agreement between predicted habitat suitability and fish abundance. Mean CPUE rose from 0.06 in low-suitability zones to 0.54–0.59 in optimum zones (Table 2), confirming that higher HSI scores correspond to greater relative abundance of target species. Regression analysis showed strong positive relationships, with the range-mean model explaining 87.5% of the variation ($R^2 = 0.875$) and the smooth-mean model explaining 88.2% ($R^2 = 0.882$) (Figure 3). The chi-square comparison was not significant ($\chi^2 = 2.86$, $p = 0.41$), indicating that both methods performed similarly, although the smooth-mean provided a slight improvement in explained variance. This distribution pattern is consistent with earlier reports that estuarine fish assemblages often concentrate in littoral zones with higher structural complexity, which enhances both refuge and feeding opportunities (Fortibuoni & Liang, 2024).

**Table 2.** Habitat suitability index zone areas and validation metrics

| HSI Zone | Range-Mean Method Area (%) | Smooth-Mean Method Area (%) | Mean CPUE (Range-Mean) | Mean CPUE (Smooth-Mean) | Goodness of Fit (χ2, p) |
|---|---|---|---|---|---|
| Low (0.0–1.9) | 20.5 | 15.3 | 0.06 | 0.04 | |
| Moderate (2.0–3.9) | 30.7 | 25.1 | 0.15 | 0.18 | |
| High (4.0–5.9) | 25.8 | 33.4 | 0.34 | 0.39 | |
| Optimum (6.0–10) | 23.0 | 26.2 | 0.54 | 0.59 | |
| Overall fit | - | - | - | - | $\chi^2 = 2.86$, p = 0.41 |

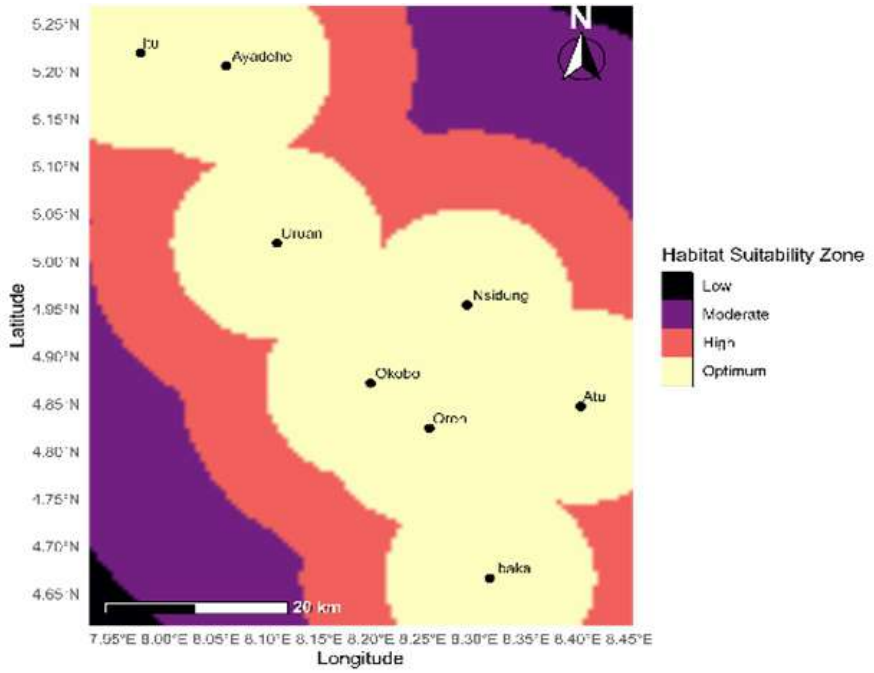



**Figure 2.** Spatial habitat suitability map for the Cross River Estuary

## Model validation with empirical data

Validation using catch-per-unit-effort (CPUE) data showed strong agreement between predicted habitat suitability and fish abundance. Mean CPUE increased from 0.06 in low-suitability zones to 0.54–0.59 in optimum zones (Table 2), confirming that higher HSI scores corresponded to greater relative abundance of target species. Regression analysis revealed highly significant positive relationships between HSI and CPUE, with the range-mean model explaining 87.5% of the variation ($R^2 = 0.875$, $p < 0.001$) and the smooth-mean model performing slightly better ($R^2 = 0.882$, $p < 0.001$) (Figure 3). These results reinforce the robustness of the models and highlight their potential utility for fisheries management and conservation planning in the Cross River Estuary.

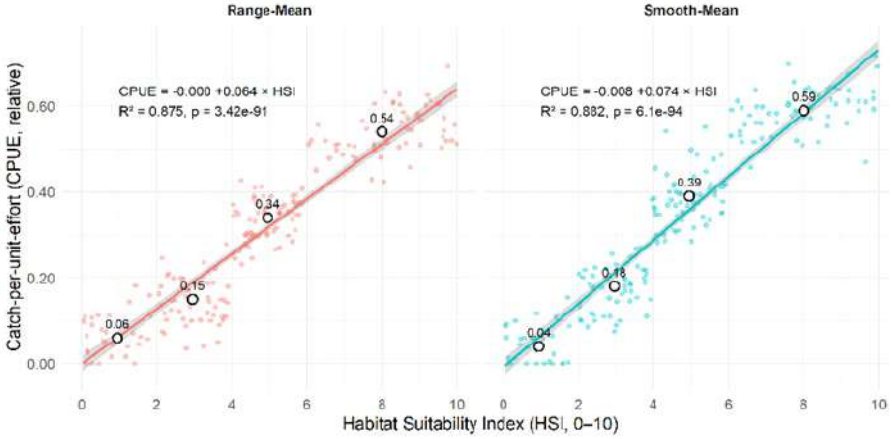



**Figure 3.** Validation of habitat suitability model with empirical abundance data

*Note: Zone means are represented as white points* ***o*** *with labels and regression fits for both methods*

## CONCLUSION

This study developed habitat suitability models for the Cross River Estuary and identified key environmental factors shaping juvenile fish habitats. Among the approaches tested, the smooth-mean method, which applies smoothed abundance data with polynomial fitting, provided the most accurate and ecologically meaningful suitability indices. Spatial predictions emphasized shallow waters with mud substrates and submerged aquatic vegetation as prime habitats for juveniles. Future work should incorporate habitat interactions, seasonal dynamics, and transferability tests to strengthen model robustness further. Overall, this research contributes practical tools for estuarine habitat assessment and offers a sound scientific basis for advancing sustainable fisheries management in the Cross River Estuary.

## ACKNOWLEDGEMENT

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# ASSESSMENT OF THE GROWTH PERFORMANCE OF CULTURED AFRICAN CATFISH (*Clarias gariepinus* Burchell, 1822)

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**ABSTRACT**
*Fish morphometric studies have shown its importance in the stock assessment and productivity estimation of aquaculture systems. The aim of the study is to assess the growth performance of plastic tank cultured C. gariepinus. Morphometric data were collected and analysed to establish the length-weight relationship (LWR) and assess the overall health condition through the condition factor (K). A total of 270 specimens were studied across nine tanks over a three-month period (September to November 2024). Results showed mean standard length of 30.03 cm and mean body weight of 334.07g. The obtained overall growth coefficient (b) of 3.155 and mean K-value of 1.102 is indicative of positive allometric growth and a healthy physiological condition of the fishes. These findings indicate that the exogenous culturing factors such as stocking density, feed availability and water quality management practices used for the plastic tank culturing of C. gariepinus provided is suitable environment for fish growth. Also, it has provided information on the potential of plastic tank-based systems in improving aquaculture yields.*

**Keywords:** Body weight, Standard length, condition factor, plastic-tank culturing, *Clarias gariepinus*.

## INTRODUCTION

Growth in fishes is predominantly characterized as the increase in body size and weight over a period of time. According to Mojekwu and Anumudu (2015), fish morphometry is the quantitative analysis of variability in the shape and size of fishes. The morphometric characteristics of fishes are phenotypically plastic as they show variability in response to changes in environmental factors at different stages of their lives. Growth and dimension of morphometric characteristic studies are of practical importance for understanding their biology, describing the status of fish population, predicting their potential of fisheries, and can be used effectively in stock classification and assessment of congeneric species (Flinn and Midway, 2021). Derived indices such as the length – weight relationship (LWR) and condition factor have been shown to be useful in providing valuable insights into fish population health, growth patterns, and ecological adaptations both in the wild and in captivity (Froese, 2006). Understanding of LWR is beneficial for comparing fish populations across different water bodies and environmental conditions, with variations in LWR often indicative of changes in food availability, habitat quality, and fishery management practices (King, 2007). High condition factor values indicate good health and efficient nutrient utilization by fishes, while low values suggest that the fishes are confronted with physiological and environmental stressors (Anani *et al.*, 2025; Farkhanda *et al.*, 2025).

Fish cultivation in tanks involves raising them in controlled environments, using tanks instead of traditional earthen ponds or open water systems, which provides more efficient and sustainable fish production by allowing precise control over water quality, temperature, and feeding regimes (Mota *et al.*, 2022). In tank-based aquaculture, the condition factor serves as a measure of management effectiveness, as it is influenced by exogenous factors such as water temperature, dissolved oxygen content, feed quality and tank colour (Ngo et al., 2024). As well-maintained aquaculture systems promote higher condition factor values and better disease resistance, whereas poor conditions lead to decline in condition factor signaling metabolic or health issues with the fishes (Han *et al.*, 2024; Anani *et al.*, 2025). Studies have focused on the weight-length relationship for selected fish species and have reported that bodyweight

correlates with total length, providing means for assessment of these species (Olopade et al., 2019; Yerima and Usman, 2020). Species-specific variations in condition factor and weight-length relationship indices emphasizes the need for tailored management strategies in aquaculture practice, as ideal values vary across species, life stages, and environmental conditions. By integrating LWR data with other biological parameters such as condition factor, fishery managers and aqua-culturists can make informed decisions about stocking density, harvesting size, and conservation measures.

The African catfish (C*larias gariepinus*, Burchell, 1822) has become an important fish species in aquaculture production, and addressing protein deficiencies in human nutrition in Nigeria and many regions of Africa (Egun and Oboh, 2022; Egun et al., 2022). The physiological attributes of C. *gariepinus* in withstanding handling stress, high growth rate, yield potential, fecundity, cultural acceptance and palatability in Nigeria, has seen the fish species become the most cultured freshwater fish in Nigeria (Ayo-Olalusi, 2014: Egun et al., 2024). Earlier studies on the growth performance of C. *gariepinus* has focused largely on captured species from freshwater bodies (Getso *et al.*, 2017; **Eze *et al.*, 2020;** Shittu and Oguntoye, 2020). However, the increasing production of C. *gariepinus* under diverse aquaculture rearing facilities and conditions (Ayo-Olalusi, 2014; Adeboye and Fashina, 2022; Abubakar and Lawal; 2023) has necessitated the need for routine assessment of growth performance of fish species cultured in various media for sustainable aquaculture development and effective fishery management. Therefore, this study is an assessment of the growth performance of tank – raised C. *gariepinus* using morphometric parameters and identify their inter-relationship trends, as these morphometric features readily appeal to farmers and make business decisions on return on investment.

## MATERIALS AND METHODS

***Study Location:*** This study was carried out at the Grow Out Unit facility of the TETFund Centre of Excellence in Aquaculture and Food Technology situated in the University of Benin, Benin City, Nigeria. The facility used for the study were the installed plastic tank ponds. The tanks were made of black rubber, with a capacity of 6,000 litres each, and stocking density of 600 fingerlings of C*larias gariepinus* per tank. Groundwater from a borehole ensured the consistent availability of water supply for aquaculture.

***Study Setup:*** For the study, nine (9) units of the plastic tank ponds were monitored for growth parameters. Each of the tanks were stocked with C. *gariepinus* fingerlings and cultured to table size, and no growth inducing hormone/ treatment was administered to the fishes throughout the study. Ten (10) fish specimens were collected per tank for collection of morphometric data on a monthly basis from September to November 2024.

**Collection of Morphometric data:** measurements for total length (TL), standard length (SL), head length (HL) and body weight (BD) were taking using a measuring board with attached tape to the nearest 0.1cm. The weight of the fish was taken individually using a mechanical weighing balance to the nearest 0.1g.

***Length-weight Relationship****:* this was determined using the equation

$$W = aLb$$

Where: W = weight of fish (g), L = total length of fish (cm), a = constant, b = the length exponent (Bagenal, 1978).

The logarithmic transformation of the equation gives a straight line relationship:
**Log W = Log a + b Log L.**

When $\mathbf{Log_{10}W}$ is against plotted $\mathbf{Log_{10}L}$, the regression coefficient is **b**, and **Log a** is the intercept on the Y axis.

***Condition Factor (K)***: This shows the degree of wellbeing of the fish in their habitat, and this was determined using (Le Cren, 1951).

$$K = \frac{100\ W}{L^3}$$

Where: W = weight of fish (g), L = total length (TL) of fish in (cm),

***Data Analysis:*** All statistical analysis was computed Statistical Package for Social Sciences (SPSS) version 21 and Microsoft Excel version 2016 for analysis of variance (ANOVA), regression and descriptive statistics.

## RESULTS

The result of the morphometric measurements taken in this study is presented in Table 1. A total of 270 specimen of C. *gariepinus* were collected from the plastic tanks and examined. The total length of the specimen ranged from 21.50 – 50.50 cm, standard length ranged from 19.00 – 45.00 cm and the body weight range from 100 – 1000g throughout the study (Table 1).

***Length-weight Relationship***: The variations in mean values for standard length and weight observed in the respective tanks are shown in Table 1. A significant relationship was observed between length and weight ($p<0.05$) for tanks 1 to 9 and the combined (Table 1). The b-values of 2.25, 2.82, 2.68, 2.53 and 2.68 indicated a near negative allometric growth pattern for tanks 4, 5, 6, 8 and 9, while values of 4.12, 3.49, 3.48, 3.16 and 3.16 for tanks 1, 2, 3, 7 was indicative of positive allometric growth. The combined tanks for the cultured C. *gariepinus* had an a-value of 2.20 and b-value of 3.16 which is indicative of an overall positive allometric growth, with an equation of Log WT = 3.155 Log LT + 2.200.

***Condition Factor***: Estimated condition factor (K) values ranged from 0.46 to 2.01, while mean condition factor (K) value computed for the tanks and combined population ranged from 1.01 (Tank 3) to 1.19 (Tanks 4, 8 and 9). Values greater than 1.0 for K indicates that fishes are in good physiological condition, while a values lesser than 1.0 suggest otherwise.

**Table 1:** Morphometric Parameters of cultured *Clarias gariepinus*

| | *Parameters* | | | | | *P value* |
|---|---|---|---|---|---|---|
| | Standard length (Mean ± SD) | Body weight (Mean ± SD) | B | R | Mean Condition Factor (K) | |
| Tank 1 | 29.90 ± 1.67$^a$ | 280 ± 101.41$^a$ | 4.12 | 0.30 | 1.03 | $p < 0.05$ |
| Tank 2 | 26.13 ± 2.21$^a$ | 186.66 ± 91.55$^b$ | 3.49 | 0.37 | 1.02 | $p < 0.05$ |
| Tank 3 | 27.70 ± 2.16$^a$ | 220 ± 77.46$^b$ | 3.48 | 0.47 | 1.01 | $p < 0.05$ |
| Tank4 | 23.33 ± 3.31$^a$ | 153.33 ± 63.99$^b$ | 2.25 | 0.68 | 1.19 | $p < 0.05$ |
| Tank 5 | 25.48 ± 4.02$^a$ | 180 ± 101.42$^a$ | 2.82 | 0.75 | 1.02 | $p < 0.05$ |
| Tank 6 | 31.00 ± 4.84$^a$ | 366.67 ± 158.87$^b$ | 2.68 | 0.75 | 1.11 | $p < 0.05$ |
| Tank 7 | 32.90 ± 3.45$^a$ | 433.33 ± 144.75$^b$ | 3.16 | 0.99 | 1.18 | $p < 0.05$ |
| Tank 8 | 35.37 ± 3.70$^a$ | 533.33 ± 144.75$^b$ | 2.53 | 0.92 | 1.19 | $p < 0.05$ |
| Tank 9 | 37.73 ± 3.98$^a$ | 653.33 ± 195.91$^b$ | 2.68 | 0.91 | 1.19 | $p < 0.05$ |
| **Combined Tanks** | **30.03 ± 5.62$^a$** | **334.07 ± 206.66** | **3.16** | **0.84** | **1.10** | $p < 0.05$ |

***Note:*** *Across each row, similar superscript indicates no significant difference ($p > 0.05$), while dissimilar superscript indicates significant difference ($p < 0.05$).*

## DISCUSSION

The evaluation of growth performance of fishes is essential for efficient fish-stock management, feed formulation, and aquaculture sustainability. Morphometric assessment using length and weight data

provide statistics that are cornerstones in the foundation of fishery research and management (Merino et al., 2006; Reis Neto et al., 2012). In this study, the recorded overall mean standard length of cultured C. *gariepinus* (30.03cm) was within the range of values reported in similar studies on cultured C. *gariepinus* (Shittu and Oguntoye, 2020). The overall mean body weight (334.07g) was comparable to mean body weight C. *gariepinus* reported by Ayo-Olalusi (2014) for C. *gariepinus* reared in flow-through systems tanks.

Length-Weight relationships for cultured C. *gariepinus* in this study showed that the combined length exponential values (b-values = 3.155) indicate a near positive allometric growth, which implies that the fishes exhibited more rapid gain in weight relative to increase in length. Similar growth pattern with b-values greater than 3 have been reported for cultured C. *gariepinus* (Joseph *et al*., 2019; Olatunji *et al.*, 2022). However, negative allometric growth (b-values < 3) have been recorded in cultured C. *gariepinus* (Shittu and Oguntoye, 2020; Adeboye and Fashina, 2022). In aquaculture factors such as stocking density, feed availability and water quality management as critical determinants of fish growth patterns.

The condition factor "K" provides information on the physiological condition of fishes in relation to their welfare, as fishes with a low condition factor index are seemingly inferred to have experienced adverse physical environment or insufficient nutrition (Gesto et al., 2017). In this study, the condition factor "K" is subject to abiotic influences such as water quality, feeding efficiency and stocking densities. The combined mean K value (1.102), indicated that the fishes were in a good physiological state of health, as the value of 1.0 is recommended for matured freshwater fishes in the tropics (Getso *et al.*, 2017; Omotayo *et al.*, 2019). The "K" value recorded in this study is similar to K values reported for C. *gariepinus* and other fresh water fishes from the wild (Ibrahim *et al.*, 2012; Olowo *et al.*, 2022). This indicates that the culturing conditions provided is suitable for fish growth.

## CONCLUSION

Morphometric assessment is an end to profit and business decision making in aquaculture. The significance of the study is to assess the growth performance of plastic tank cultured C. *gariepinus* in the first cycle of fish production at the TETFund Centre of Aquaculture and Food Technology facility, and provide information will aid in efficient management of subsequent activities. Results of length-weight relationship and condition factor showed a near positive allometric growth and good physiological state of health of the fishes. This indicates that the exogenous culturing factors such as stocking density, feed availability and water quality management practices utilized for aquaculture provided is suitable environment for fish growth. Also, it has contributed to the body of knowledge on the successful culturing of C. *gariepinus* to marketable size in plastic-tank ponds.

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# LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR OF THREE SELECTED FISH SPECIES FROM LOWER RIVER BENUE AT MAKURDI, BENUE STATE. NIGERIA

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**ABSTRACT**

*Synodontis schall, Mormyrus rume, and Labeo senegalensis are ecologically and economically important fish species that contribute significantly to inland fisheries in Nigeria. Understanding their growth dynamics and physiological condition is essential for effective management and conservation of their populations. This study examined the length–weight relationship and condition factor variations of these species in the Lower River Benue at Makurdi, between July and October 2023. A total of 300 specimens, 100 individuals from each species were obtained from local fishermen using hand nets, cast nets, and gill nets with mesh sizes of 20.2, 25.4, and 30.5 mm. The length–weight relationship (LWR) was determined using the equation $W = aL^b$, transformed to logarithmic form as log W = a + blog L, while the condition factor (K) was estimated from $K = 100W/L^3$ . The LWR equations for combined sexes were: Synodontis schall, log W=-1.6+2.7log L ($r^2 = 0.77$); Mormyru rume, log W = 2.0 + 2.8log L ($r^2 = 0.90$); and Labeo senegalensis, log W = 1.9 + 2.8log L ($r^2 = 0.93$). These results indicate allometric growth in all fish species, suggesting that weight does not increase proportionally with length. Mean condition factors were 1.13 ± 0.05 for Synodontis schall, 0.60 ± 0.01 for Mormyrus rume, and 0.69 ± 0.02 for Labeo senegalensis, there were no significant monthly variations ($p > 0.05$). The study provides fundamental information on the growth pattern of fish population and to evaluate variations in their condition in the Lower River Benue at Makurdi.*

**Keyword:** Growth, condition factor, River Benue.

## INTRODUCTION

*Synodontis schall* is commonly known as squeaker or upside-down catfish in the Mochokidea Family. It plays a crucial role in supporting the livelihoods of numerous communities, serving as a significant source of food and income through local fisheries (FAO, 2020). It is found throughout the freshwater systems of sub-Saharan Africa, including West Africa and the Nile River systems. This broad distribution highlights its ecological adaptability and importance in African freshwater ecosystems. The conservation and sustainable exploitation of *Synodontis schall* require reinforced fishing regulations, habitat protection, and ongoing ecosystem monitoring. *Mormyrus rume* commonly known as Elephant snout fish in the family Mormyridae, is a freshwater fish species known for its electric organ discharge used for communication and territorial behaviour (Ladich and Tanja, 2016). It plays a vital role in West African aquatic ecosystems and is commercially important. *Mormyrus rume* is found in Gambia, Senegal, Niger, Volta, Chad, and Congo basins, including coastal rivers like Cavally, Bandama, Sassandra, Comoé, Mono, Ouémé, Ogun, and Culuf (Froese *et al*., 2023). *Labeo senegalensis* commonly known as African carp which belong to the Cichlidae Family. It serves as a significant component of local catches as well as a highly valued food fish (Shinkafi and Ajoku, 2015). This study demonstrates the robust length-weight relationship and relatively fast growth parameters, supporting its suitability for aquaculture in tropical regions (El Khair *et al*., 2025). Research has been done on the biology of cichlids and other fish species from different water bodies, such as lakes, rivers and reservoirs in Nigeria and abroad. Researchers such as (Ikongbeh *et al*., 2024). Studied Length-weight relationship and condition factor for *Hydrocinus forskalii* and *Brycinus nurse* Lower River Benue, Makurdi, Benue State, Nigeria. Saokat *et al*., (2023)

reported morphological variation and length-weight relationship of *Labeo Angra* (Hamilton, 1822) Sampled from three different Rivers of Djnaipur (Bangladesh). Length-weight relationship has been widely used in fisheries management to estimate the mean weight of fish, based on the known length (Beyer 1987). The condition factor (k) is a quantitative parameter of the well-being of the fish and reflects recent feeding condition. This factor varies according to influence of physiological factors such as the different stages of development. There is little or no information on the biology of these fish species. This study presents data on the length–weight relationship and condition factor of these fish species from the Lower River Benue at Makurdi.

## MATERIALS AND METHODS

### Study area

The study area, Lower River Benue at Makurdi, lies between Latitude $7^0$44 and 7°55'N and Longitude 8°20' and 8°40'E (Figure 1). River Benue is the second largest river in Nigeria.
The greater part of this plain is flooded during raining season. it is extensively used for irrigation farming and fishing

### Length-weight measurement

A total of three hundred (300) fresh fish samples 100 each for the fish species; *Labeo senegalenses*, *Synodontis schall* and *Mormyrus rume* was collected from Lower River Benue at Makurdi wadata fish landing site, Makurdi. Length-Weight Measurements Fish samples were collected and identified, sorted using standard methods. The total and standard lengths measured was recorded to the nearest centimetres (cm) while the weight was measured to the nearest grams (g) using the mettler tabletop loading electronic weighing balance (model 59174). Length-weight relationship was calculated using the
Length-weight relationship was calculated using the equation
$W = {}_aL^b$, (Pauly, 1984)
Where W= Body weight of fish (g)
L = Standard length of fish (cm)
a= constant (regression constant)
b= an exponent
The equation transformed logarithmically is log W= loga + blogL

### Condition Factor

The condition factor (k) values were calculated using Fulton's condition factor formula (Bagenal and Tesch, 1978)

$$K = \frac{100W}{L^3}$$

Where,
K = the condition factor.
W = Weight of fish in (g).
L = Standard Length of fish in centimetres.

## RESULT AND DISCUSSION

The graphical representation of the regression equations of combined sexes for *Synodontis schall* were given in (Figures 2). While exponent or ("b") values for combined sexes were 2.7. It is indicative that the growth pattern of combined sexes was negatively allometric. Combined sexes were LogW= - 1.6 + 2.7 Logl ($r^2$ = 0.77). There was a higher correlation coefficient value in the length-weight for combined sexes of *Synodontis schall*. The correlation coefficients were positive and highly

The Log-Log graphs showing the regression analysis of combined sexes were shown in (Figure 3). The

exponent ("b") value for combined sex of the species was 2.8. The ("b") value obtained for combined sexes was less than 3; this means the growth pattern exhibited negatively allometric. The Length-Weight relationship equation for combined sexes were LogW= - 2.0 + 2.8 Logl ($r^2$ = 0.90). There was a higher correlation coefficient value in the length-weight of combined sexes of *Mormyrus rume*. The correlation coefficients were positive and highly significant.

The graphical representation of the regression analysis of combined sexes are shown in (Figures 4). The exponent ("b") values for combined sexes of the fish species were 2.8, showed that the rate of increase in body length is not proportional to the rate of increase in body weight. combined sexes exhibited negative allometric growth pattern. The Length-Weight relationship equation for combined sexes of *Labeo senegalensis* were LogW= - 1.9 + 2.8 Logl ($r^2$ = 0.93).. There was a higher correlation coefficient value in the length-weight of combined sexes of *Mormyrus rume*. The correlation coefficients were positive and highly significant.

The mean condition factors (k-values) of the three fish species caught during the study period are presented in (Table 1). The mean condition factors (k-value) of combined Sexes were 1.23±0.05 for *Synodontis schall*; 1.60±0.01 for *Mormyrus rume*; and k- value was 0.69±0.02 for *Labeo senegalensis*. The results indicated that there were significant differences between the condition factors of combined sexes of the three species ($p<0.05$).

There was observed variation in the "b" values among the three fish species under study, it showed that the rate of increase in body length is not proportional to the rate of increase in body weight. Combined sexes of *Synodontis schall*, *Mormyrus rume*, and *Labeo senegalensis* exhibited negative allometric growth pattern. This agrees with "b" values recorded for *Clarias gariepinus* and *Oreochromis niloticus* (Okwodu *et al*., 2022). According to (Pauly and Gayanilo, 1997), "b" values may range from 2.5 to 3.5 suggesting that result of this study is in line. This study demonstrates the robust length-weight relationship and relatively fast growth parameters, supporting its suitability for aquaculture in tropical regions (El Khair *et al*., 2025). The variation in "a" value could be due to number of factors known to influence the length-weight relationship in fishes, including sex, gonad maturity, growth phase, health, stomach fullness, seasonality size range, health and general fish condition and preservation techniques (Akpa *et al*., 2020). There was a higher correlation coefficient value in the length-weight for Combined sexes of *Synodontis schall*, *Mormyrus rume*, and *Labeo senegalensis*.

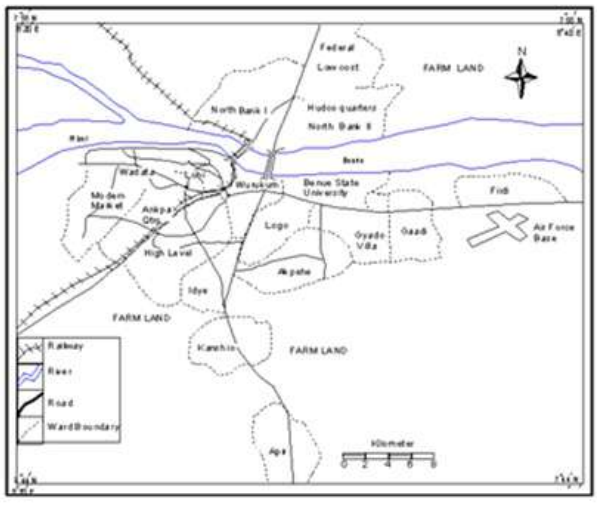



**Figure 1: Map of Lower River Benue at Makurdi, Benue State.**

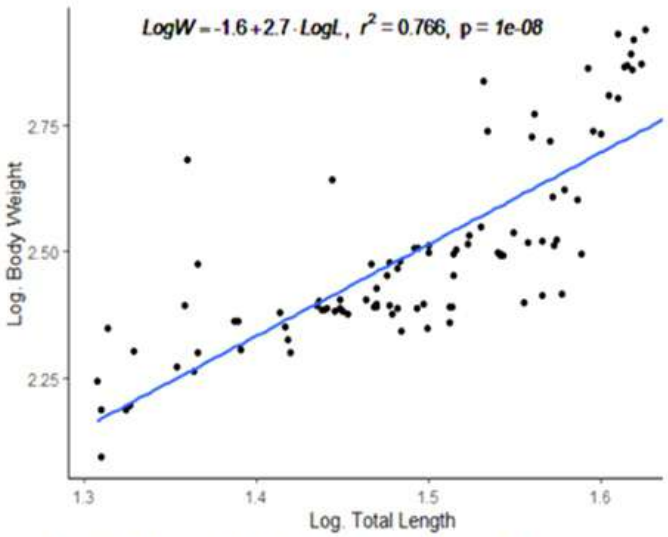



**Figure 2: Length-Weight Relationship of *Synodontis schall* Combined sexes from Lower River Benue at Makurdi.**

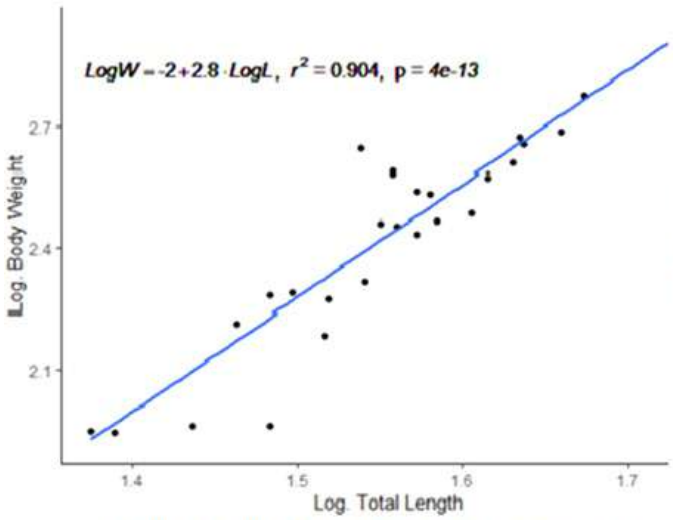



**Figure 3: Length-Weight Relationship of *Mormyrus rume* Combined Sexes from Lower River Benue at Makurdi**

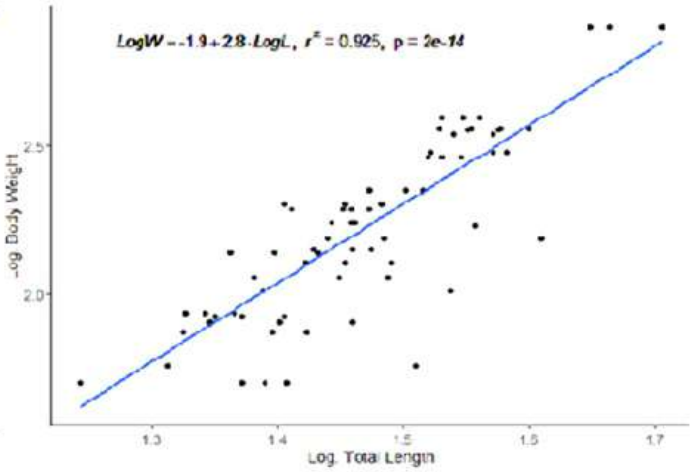



**Figure 4: Length-Weight Relationship of *Labeo senegalensis* Combined Sexes from Lower River Benue at Makurdi**

**Table 1:** Mean Condition Factor of the Three Fish Species

| Species | n | K | p-value |
|---|---|---|---|
| *Synodontis schall* | 100 | 1.13±0.05 | 0.01 |
| *Mormyrus rume* | 100 | 0.60±0.01 | 0.01 |
| *Labeo senegalensis* | 100 | 0.69±0.02 | 0.01 |

It was observed in the present study, that mean condition factor for most of *Mormyrus rume*, and *Labeo senegalensis* were of values of less than "1" and below which indicate that fish species are not doing well in the River Benue. When "K" is less than unity, the fish species is not heavy. The condition factor of *Synodontis schall* in this study is favourably comparable with factors known to influence a prevailing condition factor include, conditions of food, modification of food resources, increase or decrease in feeding activity; density or population changes, or climate, the period and duration of gonadal maturation among others (Weatherley *et al.*, 1987).

The results of the current study indicated that there were no significant differences between the monthly condition factors of Combined sexes of *Synodontis schall*, *Mormyrus rume*, and *Labeo senegalensis* ($p>0.05$). The study was in agreement with the values reported for cichlid fish in Nigeria (Abowei and Ezekiel, 2013).

## CONCLUSION

Results of length-weight relationship of combined sexes of the fish species revealed that the species exhibited negative allometric growth with slopes (b) less than 3, indicating that the fish becomes less robust as they increase in weight. These differences in fish sizes could be as a results of different habitat conditions, mainly water quality, food availability, high fishing pressure, and levels of environmental degradations.

In this study this can be attributed to the deposition of materials for gonad formation, which led to increase in weight and actual spawning which led to reduction in weight respectively.

## ACKNOWLEDGEMENTS

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# A STUDY OF ARTISANAL FISHERIES OF MAKERA AND GARHI OF ZOBE RESERVOIR, KATSINA STATE, NIGERIA

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**ABSTRACT**
*The study was conducted with the aimed of identifying the socioeconomic characteristics of artisanal fishermen involve in fishing activities at each two (2) fishing villages, identify different type of fishing or angling gears used at each of the two (2) fishing villages in Zobe reservoir, and identify the difficulties facing artisanal fishermen at each two (2) fishing villages in Zobe reservoir, Dutsin-Ma Local Government Area, Katsina State. The selections of the respondents for the study have been done based on the respondent being in Nigeria and a fisherman. A two-stage sampling technique have been used to select fish farm for the study. The first stage was the random selection of fish farm from the study area. This would be followed by the choice of fishermen to give a total of 50 respondents for the study. Socioeconomic survey of fishermen of two (2) fishing villages in Zobe reservoir, Nigeria was conducted for 4 weeks (April, 2024). Data were collected by the use of structured set of questionnaires. Data was collected by survey methods and analysed using descriptive statistics. About 100% were Male. There is a need for training and sensitization of the fisherfolks of Katsina State.*

**Keywords:** Artisanal, Respondent, Socioeconomic, Fisheries, Zobe, Reservoir.

## INTRODUCTION

Fish is a cheap source of animal protein, and it has a substantial contribution to global protein consumption, especially in the coastal and riverine areas (Dauda et al., 2021; Tiri et al., 2025). About 50% of animal protein consumed in Nigeria is from fish and fish products (Tiri et al., 2025). Fish production is from two major sources which are capture and aquaculture, with capture further classified into artisanal and industrial (commercial trawlers) fisheries (Bonjoru et al., 2019; Tiri et al., 2025). According to Food and Agriculture Organisation (2025), fish production in Nigeria stood at 1.1 million tonnes in 2022, 36% from marine catch, 36% from inland waters catch and 28% from aquaculture. Artisanal fisheries have consistently remained the most important fisheries sector in Nigeria with previously over 80% of the domestic production until recently when there was a serious boost in aquaculture, especially in the last two decades. As noted by Dauda et al. (2018), production from aquaculture grew from less than 40,000 metric tonnes in the early 2000s to over 300, 000 metric tonnes in 2015. Sadly, most of the recent attention to boost fish production in Nigeria has been focused on aquaculture, with little attention to the most important sector, which is artisanal fisheries. Artisanal fisheries are small scale fishing practices that involve the use of traditional and inadequate equipment to harvest fish from natural water bodies such as rivers, streams, lakes, lagoons, estuaries and ponds (Olaoye and Ojebiyi, 2018; Tiri et al., 2025).

## MATERIALS AND METHODS

### Study Area

The study area, Zobe reservoir, is to be found between latitude 12°20'34.62" N to 12°23'27.48" N and between longitude 7°27'57.12" E to 7°34'47.68" E, in Dutsin-ma Local Government Area of Katsina State. It covers an approximate total area of 968.544km2. Zobe reservoir has two major tributaries which comprised of Rivers Karaduwa and Gada. For the purpose of this study two landing site around the dam site selected and they are Garhi and Makera.

### Data Collection

The data for this research was collected through the use of questionnaire. A structure questionnaire was used to obtain information from one hundred and twenty artisanal fishermen from two selected fishing communities along the Zobe reservoir Dutsin-Ma LGA, Katsina, Nigeria. Simple random sampling was used to select 25 fishermen from each of the two chosen communities in the Dutsin-Ma district Dutsin-Ma LGA to make a total of 50 respondents from which primary data were obtained through the administration of a well- structured questionnaire. The following villages were visited: Garhi and Makera.

**Analysis of Data**

Descriptive statistics which include frequencies, percentages and tabulation was used to describe the socioeconomic characteristics of the respondents and to identify the constraints faced by the artisanal fishermen in the study area.

## RESULTS AND DISCUSSION

**Socio-Economic Characteristics of Respondents.**

The frequency distribution according to age is shown in Table 1. The distribution of the respondents showed that most of the fishermen fall between 36-45years of age. This group accounted for 36% of the total respondents. This was followed by the age group of between 15-335 with 30% of the total respondents. The frequency distribution of respondents according to sex is shown in Table 1.

**Table 1.** Socio-Economic Characteristics of Respondents

| Parameter | Respondents | Percentage (%) |
|---|---|---|
| Age | | |
| 15-35 | 10 | 20 |
| 36-45 | 15 | 30 |
| 46-55 | 15 | F30 |
| 56 and above | 10 | 20 |
| Sex | | |
| Male | 50 | 100% |
| Female | 0 | 0 |
| Marital Status | | |
| Married | 20 | 40 |
| Single | 15 | 30 |
| Divorced | 5 | 10 |
| Widow | 10 | 20 |
| Educational Level | | |
| Quran school | 30 | 60 |
| Primary school | 10 | 20 |
| Secondary school | 9 | 18 |
| Tertiary Institution | 1 | 2 |
| Major occupation | | |
| Civil servants | 0 | 0 |
| Fishing | 39 | 78 |
| Farming | 9 | 20 |
| Hunting | 1 | 2 |

| | | |
|---|---|---|
| House size (number in person) | | |
| 1-5 | 10 | 20 |
| 5-10 | 15 | 30 |
| 11-15 | 15 | 30 |
| Fishing sites ownership status | | |
| Rented | 0 | 0 |
| communal | 50 | 100 |
| Year of fishing experience | | |
| 1-5 | 4 | 8 |
| 6-10 | 15 | 30 |
| 11-15 | 6 | 12 |
| 16-20 | 10 | 20 |
| 21-30 | 15 | 30 |
| State period of highest fish catch | | |
| Rainy season | 35 | 70 |
| Dry season | 15 | 30 |
| Frequency of fishing per day | | |
| Once | 15 | 30 |
| Twice | 35 | 70 |
| Mode of operation | | |
| Full time | 41 | 82 |
| Part time | 9 | 18 |

The sex of the respondents shows that majority (100%) of the fishermen were male while the remaining 0% were female. Table 1 shows that majority (40%) of the fishermen were single, (30%) were married, (20%) were divorced while the remaining 10% were widow. As shown in Table 1. Majority (50%) have Quranic Education only, 26% have primary education, 20% have secondary education. 4% have tertiary institution. As shown in Table 1. Majority of the fishermen engaged in fishing (80%) only, 18 % farming, 2% civil servant. The ownership of the respondents shows that majority (100%) of the fishermen were communal while the remaining 0% were rented. As shown in Table 1. The number of years of the respondents have been engaged in fishing reveals that majority 40% has more than 21-30years of experience. 20 % have experience between 15-20years in fishing. 10% have experience between 1-5years fishing experience. Table 1 shows that majority (80%) of the fishermen identified rainy season as a season with higher catches, while the remaining 20% identified dry season as a season with higher catches. Table 1 shows that majority (60%) of the fishermen catches fish (fishing) twice per day, while the remaining 40% of the fishermen catches fish (fishing) once per day. As shown in table 1. Majority (80%) of the fishermen engaged in their fulltime activities while the remaining 40% engaged in their part-time activities. This 40% may engaged in other non-fishing activities.

Table 2, shows the arrays of fishing gears used by the fishermen of Garhi, and Makera in Zobe Dam. Majority 20 respondents (30 %) of the fishermen used Gill net only. 20% used Gill net and Hook and line only, 14 % used Cast net only, 14% used Trap, 10% used Gill net only and 2% Hook and line only. This result indicates that Hook and lines was the least gears used. Also, Table 2, shows 60% of the fishermen indicated fish species commonly captured as *Clarias gariepinus*, Tiapia spp and *Bagrus spp*. Table 2, shows the fishing craft used by the fishermen of Garhi, and Makra in Zobe Dam. Majority 30 respondents (60%) used Canoe while 20 respondents (40%) used Gourd.

**Table 2:** Common Fishing Gears employed and commonly caught Fishes in the study area

| Parameter | Respondents | Percentage % |
|---|---|---|
| Common Fishing Gears employed in the study area | | |
| Gill net only | 15 | 30 |
| Hook and line only | 7 | 14 |
| Trap only | 7 | 14 |
| Cast net only | 5 | 10 |
| Traps only | 1 | 2 |
| Gill net and Hook and line only | 10 | 20 |
| Both | 5 | 10 |
| Commonly caught Fishes in the study area | | |
| *Tilapia* spp only | 5 | 10 |
| *Bagrus spp* only | 2 | 4 |
| *Clarias spp* only | 3 | 6 |
| *Tilapia* and *Bagrus spp* only | 8 | 16 |
| *Tilapia* and *Clarias spp* only | 7 | 14 |
| Caught all the species | 25 | 50 |
| Commonly craft used to catch fish in the study area | | |
| Boat | 35 | 70 |
| Guord | 15 | 30 |

Table 3, shows major difficulties facing artisanal fishermen in the Study areas were Distance to market for inputs 34%, Poor boat maintenance 20%, High cost of equipment 14%, Climatic conditions/wind 10%.

**Table 3:** Major difficulties facing artisanal fishermen in the Study Areas

| PARAMETER | RESPONDENT | PERCENTAGE (%) |
|---|---|---|
| Climatic conditions/wind | 5 | 10 |
| Seasonal volume of the reservoir | 2 | 4 |
| Thieving of catch | 2 | 4 |
| High cost of equipment | 7 | 14 |
| Poor boat maintenance | 10 | 20 |
| Poor gear design | 5 | 10 |
| Lack of government support | 2 | 4 |
| Distance to market for inputs | 17 | 34 |
| Lack of storage facilities | 0 | 0 |
| Lack of cooperation among fishermen | 0 | 0 |

## DISCUSSION

It was observed that majority 36% of the respondent of these two (2) studied area (Garhi and Makera) ages between 36 to 45. This implies that most people engaged in fish catching were still active and physically fit to paddle the canoes. The implication is that the respondents are within the productive and economic active age, and could be able to increase fish catch and improve livelihood of the families. The finding was in agreement with those of Dasuki (2014). The result further revealed that artisanal fishing is male dominated as shown in the table. Although the results showed the dominance of the artisanal fisheries sector by men, the contribution of women folk in active fishing cannot be undermined. The finding was in conformity with those of Dasuki (2014). According to Williams (2006), women still use traps and nets to catch fish in most fishing communities in Nigeria. The result showed a marital dominated vocation of the business. Table 1 reveals that majority 40% of the respondents were single. In

this study majority of the respondents had household size of 1-5 (46%) persons while (336%) of the respondent had household size of 6-10 members. The household size is related to the availability of seasonal workforce, the reduction of cost of the production, hence increase profit. The implication of the result is that the lower the number of household size dependent on artisanal fishing the better the fishing performance because less time is spent on family issues and more on fishery.

This work is in agreement with the reports of Olaoye et al. (2013), but contradict the report of Adegbite and Oluwalana, (2014). However, Clark et al. (2015) asserted that the more the household size, the more likelihood for labour efficiency on fisher folks. In the study area, the most common labour source was purely family members. The moderate family size kept by the fisher folks in this study might be because the fisher folks have knowledge of family planning and the campaign for keeping moderate family sizes still continue in each of the health centre's that are within the various communities in these areas. Results showed that all the fishermen have a form of educational exposure, being it Quranic, Primary, Secondary and Tertiary. The study area, all of the respondents were operating on communal site ownership. In this study majority of the respondents were into fishing this implies that fishing is dominant occupation in the study area. The gear types found in this present study are cast net, hook and line (Longline), gill nets, Basket nets, and Traps (Malian or Gura trap). NIFFR, (2002) outlined similar types of gears during previous surveys of the inland water bodies in Nigeria. Hook and line, cast net, traps are the most used fishing gear among the fishers. As has been reported by Tagago *et al.*, (2011), different gears are used for targeting fish because of habitat changes. According to Bankole (2003), fishers used different kind of fishing gear because of seasonal variations in species availability. The present study gave static description of a fishery in the early rainfall, flood season, early dry season, mid dry season and late dry season, it is apparent from other publications that fishers measured seasonal variation and fish species as their main reasons for switching fishing gear Bankole *et al.*, (2003). The craft discovered during the study were locally made canoe made of wood planks and Gourd. As it is apparent in the literature (NIFFR, 2002).

## CONCLUSION

The outcome of this study shows that fishers do not receive adequate extension service- which should have exposed them to better fishing technique, government contribution will be needed through provision of extension services that will educate the fisherfolks on improved fishing gears and fishing practices as well as helping out by supplying gears and crafts that will help the fishing operations.

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# LENGTH-WEIGHT RELATIONSHIP, CONDITION FACTOR, AND MORPHOLOGICAL PARAMETERS OF ADAPTIVE SIGNIFICANCE IN *Pollimyrus isidori* FROM THE BENUE RIVER AND KIRI RESERVOIR, ADAMAWA STATE, NGERIA

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*Morphometric data provide information on fish identification and characterisation for conservation and successful management of fisheries resources. This study presents data on Pollimyrus isidori from the upper Benue River and Kiri Reservoir to document the length-weight relationship and condition factor, and to identify morphological parameters of the fish that are of adaptive significance in these two water bodies. Specimens were sourced from local fishers operating in the two water bodies, and the weight and 26 body measurements were taken for each fish. Log length-log weight data were plotted to obtain the growth pattern. At the same time, the condition factor and coefficient of variation were calculated using the following formulae: $Ko = (W/L^3) \times 100$ and $CV\left(\frac{= SD}{/mean}\right) \times 100$, respectively. The gradients of the Log Length-Log weight relationships of the species in the Benue River and Kiri Reservoir were 3.3 and 3.1, respectively, indicating positive allometric growth, while their respective condition factors in the two water bodies were 1.51 and 1.30, showing a good state of well-being of the species in the river and the reservoir. The coefficient of variation was uniquely high in five and four body parameters in the Benue River and Kiri Reservoir populations, respectively. The results showed that the fish modified some morphological characters in response to riverine or lacustrine ecological factors. The two water bodies are well-suited for the species; however, the ecological conditions of the Benue River appear to be more favourable to the species' growth than those of the Kiri Reservoir.*

**Keywords**: Morphology, Mormyrids, Growth, Bioindicator

## INTRODUCTION

Mormyrids, classified into 22 genera and 230 species (Fricke *et al*., 2025), provide a source of cheap animal protein and means of livelihood for millions of riverine dwellers across tropical Africa who engage in their hunting, processing, and marketing, making them some of the most significant freshwater fish groups in the region (Adjibade *et al*., 2009). Nigerian inland waters are subjected to various anthropogenic activities, including aquatic pollution and overexploitation, which have a significant impact on fish populations. Monitoring Nigerian freshwater ecosystems to ensure they support healthy fish growth is crucial to their sustainable exploitation. Mormyrids are important biomonitoring agents of pollution owing to their active electrolocation capabilities and sensitivity to subtle changes in habitat ecology (Mucha *et al*., 2022; Skeels *et al*., 2023). Growth patterns and condition factors derived from biometric data often reflect the impact of the water body's ecology on fish populations. In addition, such data are significant in sex and species identification, taxonomy, and phylogeny (Diedhiou *et al*., 2007; Boden *et al*., 1997; Dierickx *et al*., 2025).

Moreover, fish are well-known to undergo morphological changes in response to ecological changes in their habitats. If the same fish species occur in riverine and lacustrine environments, their morphologies may change in response to the ecological challenges posed by these environments. Such changes may be detected by finding the coefficient of variation of the morphometric characters, with those of adaptive

significance exhibiting a high coefficient of variation (Yobouo *et al*., 2019)

The Mormyridae genus, *Pollimyrus*, exhibits 18 species. However, only three are represented in Nigeria: *P. petricolus*, distributed in the upper and mid Niger River, and *P. adspersus*, restricted to the lower reaches of Nigerian rivers. *P. isidori* enjoys a wide distribution across Africa and is the only species in the Benue Basin (Bigorne, 2003; Olaosebikan and Raji, 2013; Froese and Pauly, 2025). Few studies have been conducted on the biology of this species in the Benue Basin. This study investigated the length-weigth relatioship and morphological characters of adaptive significance in *P. isidori* from the Upper Benue River and Kiri Reservoir, to assess the species growth pattern, its condition factor, body characters of adaptive significance, and provide data that may be used to monitor the ecological changes in the water bodies and their impacts on the fish species in the upper Benue River and Kiri Reservoir. Ogidiaka and Davies (2019) provided information on the growth characteristics of *P. isidori* in the Warri River, but similar data are lacking for *P. isidori* in the Upper Benue River and Kiri Reservoir; this study provides such data for the fish in the two water bodies, to elucidate the growth pattern, condition, and their morphological characters of adaptive significance.

## MATERIALS AND METHODS

Specimens of *P. isidori* (Plate 1) were sampled from fishers hunting in the Benue River, close to the Benue Bridge at Jimeta, Yola. At the same time, the Kiri Reservoir fish was procured at Babban Daba. The Kiri Reservoir and the Upper Benue River in Yola are significant freshwater bodies within the Upper Benue Basin of Adamawa State, Nigeria. The Kiri Reservoir is an artificial impoundment on the Gongola River constructed in 1982. Hydrological and water quality conditions within the water body are relatively stable, making it suitable for fish growth (Adebayo and Adedire, 2002; Yahaya *et al*., 2015). The reservoir supports diverse fish fauna, dominated by *Clarias gariepinus*, *Oreochromis niloticus*, *Labeo coubie*, *Schilbe mystus*, several *Synodontis* species, and mormyrids. The Upper Benue River, on the other hand, has a comparatively greater seasonal variation in physico-chemical parameters (Mohammed and Ibrahim, 2018). Its ichthyofauna is more diverse, including *Alestes baremoze*, *Hydrocynus forskahlii*, *Labeo senegalensis*, *Brycinus nurse*, several *Synodontis*, and mormyrid species.

The specimens were weighed to the nearest 0.1 g. Twenty-six morphological characters were measured to 0.01cm with a digital calliper. The characters measured were: Total length (TL), Fork length (FL), Standard length (SL), Pre-pectoral length (PPL), Pre-pelvic length (PPLL), Pre-dorsal length (PDL), Pre-anal length (PAL), Anal fin base length (AFBL), Dorsal fin base length (DFBL), Caudal fin length, Pectoral fin length (PECL), Pelvic fin length (PELL), Anal fin length (AFL), Caudal fin length (CFL), Width of the body (WD), Body depth (BD), Dorsal-fin caudal peduncle length (DFCP), Anal-caudal fin base length (ACBL), Pelvic-anal fin length (PAFL), Caudal peduncle length (CPL), Caudal peduncle depth (CPD), Snout length (SNL), Post-orbital length (POO), Eye diameter (ED), Head length (HL), Head depth (HD), and Inter orbital (IO). To reduce allometry due to differences in fish age and size, body measurements of each fish were standardised by dividing them by the fish's standard length, while measured head characters were divided by the head length.

The condition factor (Ko) for each fish was calculated from the relationship between length and weight using the formula Ko = (W/L3) x 100 (Le Cren, 1951), where W = Total Weight (g), L = Total Length (cm). Log W (g) = b Log L (cm) + a, where W = Total Weight, L = Total Length, b = gradient of the plot, and a = intercept on the Y axis. (Le Cren, 1951). The equation enables the estimation of weight based on a specific length. The body parameters of adaptive significance were estimated from the variation coefficient using the formula $CV\left(\frac{= SD}{/mean}\right) \times 100$ A coefficient of variation higher than 10 signifies that the morphometric parameter is of adaptive significance (Yobouo *et al*., 2019)

## RESULTS AND DISCUSSION

The picture of *Pollimyrus isidori* is displayed in Plate 1.




**Plate 1:** *P. isidori* from Benue River, Nigeria.

The Log Length-Log weight relationship for the locations is presented in Figures 1 and 2. There was a high correlation between the two variables. The correlation coefficients ($R^2$) were 0.92 and 0.85 for the Benue and Kiri populations, respectively, indicating that the length measurements may be a good estimator of weight. The species exhibited positive allometric growth in both water bodies, as indicated by growth exponents (b) of 3.3 and 3.1, recorded for the species in the Benue River and Kiri Reservoir, respectively. The ' b 'value differed from a similar study on the *P. isisdori* species in the Warri River, in which a negative allometric 'b' value of 2.72 was reported (Ogidiaka and Davies, 2019). The positive allometric growth shown by the fish recorded in this study suggests that it accumulates more weight as it grows longer than the population reported in the previous study. *P. isidori* from the Benue River and Kiri Reservoir had a respectable condition factor value of 1.51 and 1.30, indicating that the ecology of the water bodies favours its growth. The fish condition factors recorded herein were also higher than the 0.84 reported by Ogidiaka and Davies (2019) for the species in the Warri River, suggesting that *P. isidori* understudy enjoyed a better environment in the water bodies than their counterparts in the Warri River. The above results suggest that the ecological conditions in the Benue River and Kiri Reservoir support a better growth rate of the species.

Coefficient of variation of *P. isidori* in the Kiri Reservoir was uniquely significant in four morphological parameters: DFBL 12.30, AFL 13.75, CPL 10.5, and POO 15.58, while CV was uniquely significant in five body parameters: PECL 10.59, PELL 10.11, ACBL 10.23, ED 14.62, and HD 11.79. These results suggest that morphological characters of adaptive significance in lotic waters differ from those in lentic waters.

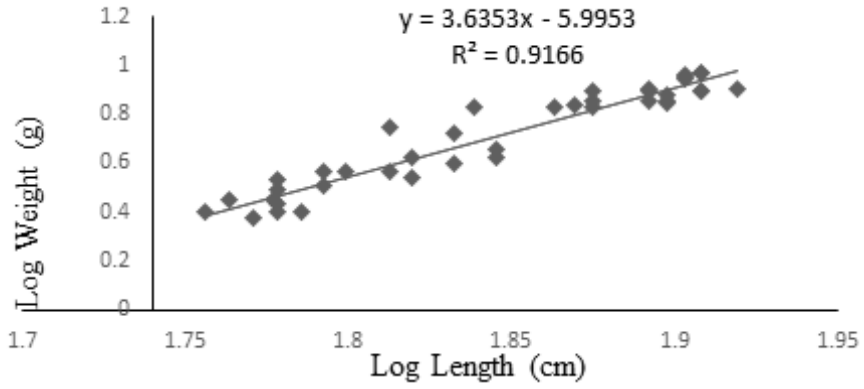



**Figure 1:** Log (wt) - Log (Length) Relationship of *P. isidori* from the Benue River

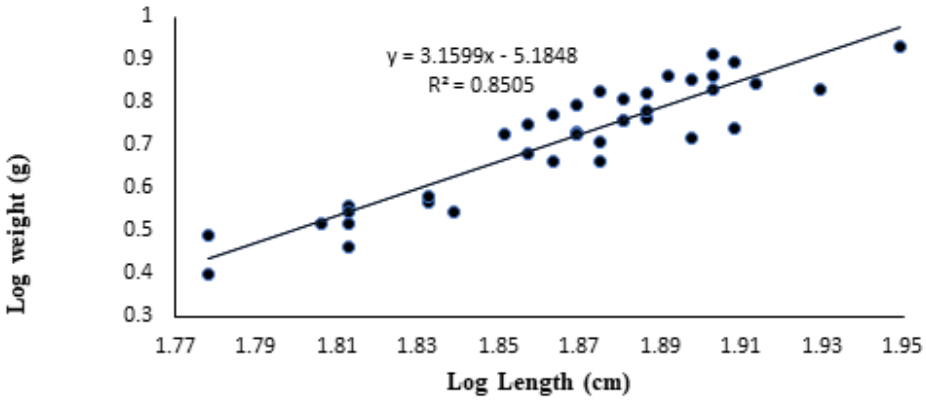



**Figure 2:** Log (wt) - Log (Length) Relationship of *P. isidori* from Kiri Reservoir

## CONCLUSION

The present study shows that the ecology of the Benue River and Kiri Reservoir favours *the growth of P. isidori*. However, the ecological conditions of the Benue River provide a healthier environment for fish growth. The study also revealed that the species manifests differences in its body forms in response to the ecological conditions of its habitat. Water bodies should be well-managed to prevent pollution and other anthropogenic activities that may negatively impact their productivity and the health of their fish populations.

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# STOMACH CONTENTS ANALYSIS OF *Raiamas nigeriensis* (DAGET, 1959) FROM CHAKAWA RESERVOIR, MAYO – BELWA, ADAMAWA STATE NIGERIA

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**ABSTRACT**

*Stomach contents analysis of Raiamas nigeriensis from Chakawa Reservoir, Mayo – Belwa, Adamawa State was evaluated monthly for a period of one year. A total of 72 specimens of R. nigeriensis were collected, washed with clean water and preserved in ice crest to minimize any post-mortem changes, taken to the laboratory for stomach contents analysis, where stomachs were preserved in formalin solution of about four percent (4%). Stomach contents of each specimen were identified and analysed using the numerical and frequency of occurrence methods. The stomach contents of the R. nigeriensis constituted of insects, zooplankton, other materials such as sand particles and unidentified worms, fish materials and phytoplankton. Numerical analysis showed that insects were dominant and composed of 68.59% of the group of food items in the stomach, while phytoplankton were the least with 0.76%. In the frequency of occurrence method insects remains were dominant and found in 78.46% of the stomach, while the least was Oscillatoria spp. in 6.15% Findings from this study indicated that R. nigeriensis is a predatory fish feeding mostly on insects, but also consumes zooplankton, other materials such as sand particles and unidentified worms with also fish parts. Therefore, it could be considered as carnivore-insectivore. Further study should be carried out on the food and feeding habits of R. nigeriensis from other freshwater bodies in Nigeria in other to ascertain the true feeding habits of the fish.*

**Keywords:** Carnivore, Food Items, Frequency, Predatory Fish, Specimens.

## INTRODUCTION

The study of the stomach contents analysis of freshwater fish species is a subject of continuous research because it constitutes the basis for the development of a successful fisheries management programme on fish capture and culture (Thomas and Opeh, 2018). *Raiamas nigeriensis* also knowns as the silver fish belongs to the order Cypriniformes, family Cyprinidae and genus *Raiamas*, the occurrence of only two species of the genus *Raiamas* are reported in the freshwater bodies of Nigeria, these are and *R. nigeriensis* and *R. senegalensis* (according to Olaosebikan and Raji (2013). Olorunpomi et al. (2020) reported the occurrence of these fish species at Ikere Gorge – lake, Oyo State, Southern Nigeria. Olaosebikan and Raji (2013) reported the maximum length of about 103 mm standard length in Nigeria. However, its contribution to the animal protein sources within many freshwater bodies of Nigeria is not significant, but it is widely used in aquarium and aquarium trades. Little or no data has been published concerning the food and feeding habits of *R. nigeriensis* from the freshwater bodies of Nigeria despite the distribution of these fish species in some inland waters of Nigeria. The main objective of this study was to evaluate the stomach contents analysis of *R. nigeriensis* from Chakawa Reservoir, Mayo – Belwa, Adamawa State, Nigeria.

## MATERIALS AND METHODS

### *Study area*

Chakawa Reservoir is located at Mayo – Belwa local government area, Adamawa State of Nigeria. Mayo – Belwa LGA lies within latitude 9° 3' 0' north and longitude 12° 3' 0' east. It covers an area of 1768km$^2$ (682.63 sq. m) and is 75 km away from Yola, the state capital.

### *Specimen collection*

A total of 72 specimens of *R. nigeriensis* were obtained from monthly sampling for a period of one year, from December, 2013 to November 2014. Fishing was done using gill nets as the fishing gear and canoe was used as fishing craft. The fish specimens were washed with clean water and preserved in ice crest to minimize any post-mortem changes and taken to the laboratory for analysis of the food contents.

### *Laboratory analysis of specimen*

Each specimen was weighed to the nearest 0.01g using a top loading Sartorius balance (model BP310S) and standard length was measured in centimetres (cm) using measuring board (Ali et al., 2024a). The specimen's body cavity was opened using a pair of scissors, beginning ventrally from the anus to the mouth, the entire visceral and intestinal organs such as the liver, fat and other organs attached to the intestine and stomach were gently removed and emptied into a dish, the length and weight of the stomach were measured and recorded. Thereafter, the visceral and intestinal organs were kept in formalin solution of four percent (4%) to avoid any form of deterioration and contamination of the stomach contents (Yusuf et al., 2023). The stomach contents were dissected using a pair of scissors and the complete stomach contents were emptied into petri – dish for examination and identification based on the work of Paul et al. (2025). The random samples of the stomach contents were taken and dropped on a slide (counting chamber) with the aid of a dropping pipette and viewed under a light microscope. The general views were made with a binocular dissecting microscope Olympus SZ51 (0.80 – 4x). The stomach contents were studied and recorded. The stomach contents of each of the *R. nigeriensis* samples were analysed using the numerical and frequency of occurrence methods as described by Ali et al. (2024b).

In the numerical method (NM), the number of individuals in each food category was expressed as a percentage of the total individuals in all food categories:

$$NM\ (\%) = \frac{Total\ no.\ of\ a\ particular\ food\ item}{Total\ no.\ of\ all\ the\ food\ items} \times 100$$

In the frequency of occurrence method (FO), all stomach containing food were recorded and expressed as the percentage of the total number of stomachs examined:

$$FO\ (\%) = \frac{No.\ of\ stomach\ with\ a\ particular\ food\ item}{Total\ no.\ of\ fish\ examined\ with\ food\ in\ the\ stomach} \times 100$$

### *Statistical analysis*

Data collected were analysed using descriptive statistics.

## RESULTS

Results from the 72 specimens of *R. nigeriensis* collected from Chakawa Reservoir are given as follows: 38 specimens representing 52.78% had their stomach full with food while 27 individuals representing 37.50% were observed to have a half – filled stomach and 7 individuals representing 9.72% were observed to have an empty stomach (Table 1). The relative contributions of the food items are expressed by the numerical and frequency of occurrence methods. Five major groups of food items constituted the diet of *R. nigeriensis* from Chakawa Reservoir. In the numerical method, insects were the dominant and

composed of 68.59% of the group of food items in the stomach, zooplankton made up 21.11%, other materials (unidentified worms) were 8.32%, fish materials were 1.22% and phytoplankton were the least with 0.76%. In the frequency of occurrence method insects remains were dominant and found in 78.46% of the stomach, while the least was *Oscillatoria spp.* in 6.15% (Table 2).

**Table 1:** Stomach Fullness of *R. nigeriensis* from Chakawa Reservoir

| No. of Full Stomach | Percentage of Full Stomach | No. of Half Stomach | Percentage of Half Stomach | No. of Empty Stomach | Percentage of Empty Stomach |
|---|---|---|---|---|---|
| 38 | 52.78% | 27 | 37.50% | 7 | 9.72% |

**Table 2:** Stomach Contents of *R. nigeriensis* from Chakawa Reservoir

| Food items | Numerical method | | Frequency of occurrence method | |
|---|---|---|---|---|
| | Number of Items | Percentage (%) | Number of stomachs | Percentage (%) |
| **Fish materials:** | | | | |
| *Barbus spp.* | 39 | 0.66 | 21 | 32.30 |
| Fish parts | 33 | 0.56 | 18 | 27.70 |
| **Insects:** | | | | |
| *Anax spp.* nymph | 142 | 2.40 | 27 | 41.53 |
| *Chaoburus spp.* Larvae | 828 | 14.01 | 48 | 73.85 |
| *Chaoburus spp.* Pupae | 384 | 6.50 | 32 | 49.23 |
| *Chironomus spp.* Larvae | 610 | 10.32 | 40 | 61.54 |
| *Chironomus spp.* Pupae | 379 | 6.41 | 30 | 46.15 |
| *Cullicoides spp.* Larvae | 633 | 10.71 | 38 | 58.46 |
| *Cullicoides spp.* Pupae | 237 | 4.01 | 29 | 44.61 |
| Remains of insects | 841 | 14.23 | 51 | 78.46 |
| **Other materials:** | | | | |
| Sand particles | – | – | 22 | 33.84 |
| Unidentified worms | 492 | 8.32 | 34 | 52.30 |
| **Phytoplankton:** | | | | |
| *Diatomella spp.* | 24 | 0.40 | 6 | 9.23 |
| *Oscillatoria spp.* | 21 | 0.36 | 4 | 6.15 |
| **Zooplankton:** | | | | |
| *Arcella spp.* | 180 | 3.04 | 23 | 35.38 |
| *Centropyxis spp.* | 187 | 3.17 | 25 | 38.46 |
| *Daphnia spp.* | 183 | 3.09 | 26 | 40.00 |
| *Diaptomus spp.* | 172 | 2.91 | 20 | 30.77 |
| *Moina spp.* | 175 | 2.97 | 21 | 32.30 |
| *Nauplius spp.* | 181 | 3.07 | 23 | 35.38 |
| *Rotaria spp.* | 169 | 2.86 | 18 | 27.70 |

## DISCUSSION

Analysis of the stomach contents indicated that the food items of *R. nigeriensis* from Chakawa Reservoir consisted mainly of fish materials, insects, other materials such as sand particles and unidentified worms, phytoplankton and zooplankton, with insects were the most preferable food items which was in consisted with the findings of Ali et al. (2024a) on *R. senegalensis* from the same study area. The *R. nigeriensis* should be considered as carnivore with an insectivore tendency. however, a negligible fraction of sand particles was also found in very few stomachs. This could be attributed to the voracious character of the species that swallows some sand when attacking its prey or may be the species is feeding directly on substrates, but the contribution sand to the nutrition of this species is not clear. The Findings from the stomach contents of *R. nigeriensis* from Chakawa Reservoir in this study corroborated the findings of N'zi et al. (2014) who reported that diet of *R. senegalensis* from Bandama River Côte d'Ivoire composed of two categories of preys: fish and insects. However, this study indicates that juveniles and adults of *R. senegalensis* utilize insects, phytoplankton and zooplanktons as food while adults also consumed fish. The observed variations in the food items of adults and juveniles indicated age-specific dietary preferences in order to avoid intra-specific competition for available food. This is possibly an important strategy for survival and an advantage over the fish species competing for a specific food item. Ali et al. (2024a) reported that as fish grow, they are able to feed on bigger preys, and larger prey becomes more profitable. In the process of fish growth, increasing prey size often resulted to taxonomic changes and these changes are revealed as ontogenetic diet switches (N'zi et al., 2014).

## CONCLUSION AND RECOMMENDATION

Findings from this study indicated that the *R. nigeriensis* from Chakawa Reservoir is a predatory fish which feed mostly on insects, but also consumed zooplankton, other materials (sand particles and unidentified worms) and also fish materials as second preys (food items) in their diets. However, they are considered as carnivore with an insectivore tendency. Further study should be carried out on the food and feeding habits of *R. nigeriensis* from other freshwater bodies in Nigeria in other to ascertain the true feeding habits of the fish.

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# FISH DISEASES
# AND
# PATHOLOGY – FDP

# EFFECT OF -GLUCAN ON IMMUNOPATHOGENESIS AND IMMUNOPROTECTION IN NILE TILAPIA INFECTED WITH PATHOGENIC *AEROMONAS VERONII*

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**ABSTRACT**

*Immunostimulants have been utilised as dietary supplements to enhance growth performance and feed efficacy with resistance to diseases in farmed fish. The purpose of this investigation was to assess the effects of dietary β-glucan (BG) on immunological status, the expression of immunological and oxidative genes. Four groups of 240 tilapia fish were fed different diets supplemented with 1, 2, and 3 mg kg−1 of BG, with the 0mg kg−1 group serving as the control. The results showed that dietary β-glucan significantly reversed alterations in biochemical markers in the serum of fish dosed with A. veronii. β-glucan prevented the decline in antioxidant enzyme activity caused by A. veronii, but protein levels showed a reverse trend. Nutritional supplementation with β-glucan alleviated A. veronii oxidative stress by reducing GSR mRNA expression in the muscle and gills and increasing GPx expression in the muscle of O. niloticus. Overall, dietary β-glucan treatment could strengthen fish's innate defences and antioxidant capabilities, reducing the growth of A. veronii attacks and cell apoptosis after exposure to the pathogen.*

**Keywords**: *Oreochromis niloticus*, *Aeromonas veronii*, β-glucan, immunostimulant, oxidative, stress.

## INTRODUCTION

Disease outbreaks are a major challenge limiting aquaculture growth and causing economic losses(FAO, 2010). Many of these diseases result from immune suppression in cultured fish due to stress from high-density stocking (Austin and Austin, 1999). To prevent disease, farmers have traditionally relied on antibiotics and chemotherapeutics; however, these methods have led to the emergence of drug-resistant pathogens, bioaccumulation of residues in fish tissues, environmental pollution, and risks to consumer health. Although vaccination remains a strong preventive measure, developing effective vaccines for diverse pathogens is difficult.

Recent studies have highlighted the benefits of natural products in improving fish growth, immune and antioxidant systems, and the expression of immune-related cytokine and chemokine genes (Meena et al., 2013). Among these, polysaccharides such as β-glucan are widely recognized immunostimulants in fish diets (Meena et al., 2013). Because they occur naturally and pose minimal environmental risk, β-glucans are preferred alternatives to antibiotics (Yano et al., 1991). β-glucan (BG) has demonstrated strong antibacterial and immunomodulatory properties in mammals (Sherwood et al., 1987) and fish, enhancing complement activation, lysozyme levels, and macrophage activity (Engstad et al., 1992; Jeney and Anderson, 1993; Jørgensen et al., 1993). Moreover, BG administration improves vaccine efficacy and bacterial resistance (Yano et al., 1991) and has been shown to strengthen immune responses and disease resistance in species such as coho salmon and rainbow trout (Cornet et al., 2021). In this study, Nile tilapia (*Oreochromis niloticus*) challenged with pathogenic *Aeromonas veronii* were used to evaluate the beneficial effects of dietary β-glucan supplementation on immune responses, oxidative and immune gene expression, in vital organs.

## MATERIALS AND METHODS

Experimental diets were formulated by incorporating β-glucan powder (Bioven Ingredients, India) into a commercial tilapia feed (CIFRI Feed, India) at concentrations of 0.1%, 0.2%, and 0.3%. The mixtures were made into dough (20% water), pelletized (2 mm die), freeze-dried, and stored at 4 °C. The control diet contained only the commercial feed mixed with distilled water. A total of 270 Nile tilapia (35 ± 2.32 g) were acclimated for 15 days before being randomly assigned to four treatment groups (I–IV) with triplicates (20 fish/tank). Fish were reared for 56 days in 250 L flow-through tanks and fed experimental diets at 3% body weight twice daily (07:30 and 16:00 h). *A. veronii* (strain ON346527) isolated from moribund fish was cultured in tryptic soy broth and pelleted (3000 × g, 10 min, 4 °C). The $LD_{50}$ (96 h) was determined as $10^6$ CFU/fish through intraperitoneal injections ($5 \times 10^5$–$5 \times 10^7$ CFU/fish). The pathogen was used for post-feeding challenge trials. Ten fish per treatment were anaesthetized with MS-222 and blood samples were drawn from the ventral vein using 2 mL syringes. Samples were centrifuged (5000 × g, 12 min) and serum. Serum biochemical parameters; ALP, ALT, AST, protein, and glucose,were quantified using an Erba EM200 analyzer. The Nonspecific immune assays included: NBT test for respiratory burst activity, SOD activity (Misra & Fridovich, 1972), Catalase (Takahara et al., 1960), and Total protein (Lowry et al., 1951). Expression of immune (IL-8, TGF-β) and antioxidant (GSR, GPX) genes was quantified using SYBR Green real-time PCR. Total RNA was extracted from liver, muscle, and gill tissues using TRIzol, and cDNA synthesized from 1 $\mu$g RNA. Gene expression was normalized to β-actin using the $2^{-}\Delta\Delta Ct$ method (Karsi et al., 2004). Primer sequences and annealing temperatures are provided in Table 1. Data were analyzed using GenStat v13.3. Differences among treatment means were determined using the New Duncan Multiple Range Test (NDMRT) at $P < 0.05$. Gene expression data were summarized using descriptive statistics.

**Table 1.** Primers and the sequences used for the gene transcription

| Gene of Interest | | Target sequence | Optimum Tm | References |
|---|---|---|---|---|
| IL-8 | IL-8 F | CTGTTCGCCACCTGTGAAGG | 61.2 | NM_001279704.1 |
| | IL-8 R | ATGTGGCGGCCAATAGGTTT | | |
| GSR | GSR-F | GACTGGTTCCCAACGTGTCA | 60.2 | XM_005467348.4 |
| | GSR-R | CGCCACCTATCACCAGGAAG | | |
| GPX | GPX-F | GCACCAGTTTGGACACCAAG | 60.2 | DQ355022.1 |
| | GPX-R | CGAAATTCCAGGACACGTCATTC | | |
| TGF | TGF-β F | GATGGCCTGCTACTCACCAG | 60.3 | NM_001311325.1 |
| | TGF-β R | TGTGACAAAGCGAGATGCCA | | |
| β-actin | β-actin-F | CTACGAGGGTTATGCCCTGC | 62.0 | XM_003443127.5 |
| | β-actin-R | ATGTCACGCACGATTTCCCT | | |

## RESULTS

The study found significant variations in immunological and antioxidant parameters in serum between the BG-enriched and control groups (Table 1). AST, ALT, ALP, NBT, SOD, and CAT activities decreased with BG inclusion, while glucose, ALP, SOD, and lysosome levels increased. SOD activity significantly increased among BG-included groups between 1 and 3mg/kg, while catalase activity was higher in control and 1mg/kg BG inclusion levels. NBT had elevated values in 1mg/kg BG

**Table 3.** Haematological and Biochemical parameters of O. *niloticus* fed with various inclusions of β-glucan after intraperitoneal injection of *A. veroni*

| Parameters | 0 mg/Kg | 1 mg/Kg | 2 mg/Kg | 3 mg/Kg |
|---|---|---|---|---|
| Glucose ($mgdl^{-1}$) | $41.30\pm 2.18^{c}$ | $47.80\pm 2.13^{b}$ | $68.30\pm 1.23^{a}$ | $49.60\pm 1.13^{b}$ |
| AST(UL-1 | $52.00\pm 2.13^{a}$ | $50.90\pm 1.73^{b}$ | $49.80\pm 2.33^{c}$ | $51.4\pm 2.53^{a}$ |
| ALT (UL-1) | $3.50\pm 0.73^{a}$ | $3.30\pm 0.19^{c}$ | $3.10\pm 0.58^{d}$ | $3.40\pm 0.62^{a}$ |
| ALP (UL-1) | $46.01\pm 3.13^{d}$ | $48.02\pm 4.11^{b}$ | $47.12\pm 3.62^{c}$ | $48.71\pm 2.68^{a}$ |
| Protein (mg ml−1) | $1.41\pm 0.11^{a}$ | $1.33\pm 0.13^{b}$ | $1.18\pm 0.19^{c}$ | $1.07\pm 0.23^{d}$ |
| NBT (OD values) | $0.21\pm 0.10^{b}$ | $0.24\pm 0.12^{a}$ | $0.21\pm 0.15^{b}$ | $0.13\pm 0.11^{c}$ |
| SOD(μ/ml) | $0.421\pm 0.13^{b}$ | $0.427\pm 0.17^{a}$ | $0.429\pm 0.10^{a}$ | $0.437\pm 0.14^{a}$ |
| Catalase (UL-1) | $1.68\pm 0.14^{a}$ | $1.68\pm 0.24^{a}$ | $1.62\pm 0.21^{b}$ | $1.49\pm 0.19^{c}$ |
| Lysozyme activity (Units/ng Bal protein) | $63.31\pm 0.13^{c}$ | $68.15\pm 0.15^{b}$ | $74.21\pm 0.16^{a}$ | $73.52\pm 0.19^{a}$ |

The same letter is used to indicate that there is no significant variation in the means ($P > 0.05$).

Aspartate transaminase (AST), alkaline phosphatase (ALP), Alanine Aminotransferase (ALT), and nitro blue tetrazolium (NBT) Superoxide dismutase (SOD)

The impact of dietary BG on immunological and antioxidant-related mRNA expression following post-challenge of Nile tilapia with *A. veronii* is presented in Figs. 1. The comparative expression levels of TGF-β in the liver of O. *niloticus* fed BG-included diets were markedly increased in comparison to the control, while down-regulation was observed in T4 (3mg/kg) for IL-8. However, GPx showed up-regulation in T2 (1mg/kg BG) and in T2 and T4 revealed up-regulation in GSR transcription in the liver of O. *niloticus*

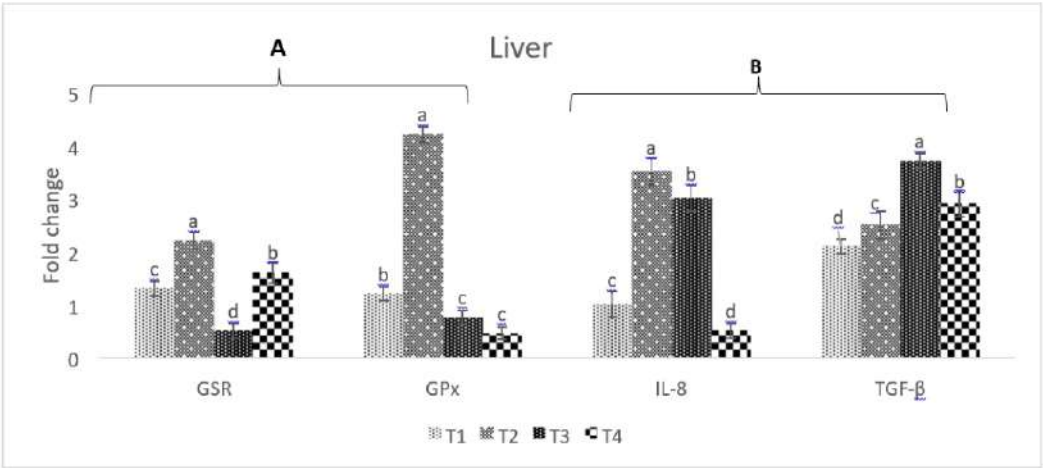



**Figure 1:** Effects of β-glucan on GSR, GPx, IL-8, and TGF- relative expression levels in the livers of Nile tilapia following *A. veronii* infection. The bars represent the mean ± SD (n=3). A / antioxidant-related genes, B / immune-related genes. The contrast letters designate significant

## DISCUSSION

Elevated transaminase enzymes are commonly used as indicators of poor animal health (Wang et al., 2019). Aspartate aminotransferase (AST) and alanine aminotransferase (ALT) reflect liver dysfunction and cellular damage and can also indicate the health of tissues such as the kidney, spleen, and blood (Giri et al., 2016). In this study, Nile tilapia treated with β-glucan (T2–T4) following *A. veronii* infection exhibited significantly lower AST levels, suggesting reduced stress and hepatic damage. Similar reductions in transaminase levels have been reported by Ma et al. (2018), indicating β-glucan's role in enhancing immunity against *A. veronii*. Elevated alkaline phosphatase (ALP) in β-glucan-fed groups

further confirmed the immunostimulatory mitigation of bacterial effects.
Serum protein, a physiological indicator of health and immune status (Yang et al., 2020), declined slightly ($P > 0.05$) in β-glucan-fed infected tilapia, possibly due to β-glucan's immune-enhancing role offsetting stress-induced increases (Montero et al., 1999). Similar decreases were observed in golden pompano, common carp, and Asian sea bass (Adineh et al., 2019), whereas increased serum protein was reported in Ayu and Amur sturgeon under stress (Iguchi et al., 2003; Ni et al., 2014). Such variations may depend on species, rearing conditions, type of immunostimulant, and pathogen virulence.

Fish immunity involves phagocytic activation and respiratory burst activity (Gültepe et al., 2014), assessed via the NBT test (Fischer et al., 2006). In this study, β-glucan diets enhanced respiratory burst activity in *O. niloticus* exposed to *A. veronii* up to T3 (2 mg/kg). Reduced NBT activity in stressed or high-density systems has been noted previously (Haridas et al., 2017), while Ray et al. (2016) also identified 2 mg/kg as the optimum dose for *L. rohita*.

Antioxidant enzymes such as superoxide dismutase (SOD) and catalase play crucial roles in neutralizing reactive oxygen species (ROS) and protecting against oxidative stress (Zahran and Risha, 2014). In this study, β-glucan-supplemented fish showed slightly elevated SOD and reduced catalase levels compared to controls, with no significant differences, indicating stable antioxidant defense. Similar findings were observed in gilthead seabream infected with *Shewanella putrefaciens* (Cordero et al., 2016) and in high-density C*yprinus carpio* (Hoseini et al., 2019). These results suggest that β-glucan supplementation (1–2 mg/kg) effectively enhances immune and antioxidant responses in *O. niloticus* against *A. veronii* infection.

This study investigated the influence of β-glucan on the transcription of immune and antioxidant genes (GSR, GPx, TGF-β, and IL-8) in the liver of juvenile O*reochromis niloticus* exposed to *Aeromonas veronii*. The results showed that β-glucan-enriched diets significantly upregulated these genes, particularly IL-8, indicating enhanced immune regulation and resistance to infection. Similarly, IL-8 upregulation was previously observed in Atlantic cod treated with mannan-based oligosaccharides (Lokesh et al., 2012). However, excessive β-glucan (3 mg/kg) led to IL-8 downregulation, possibly due to immunosuppression from overstimulation (Giri et al., 2016). Overall, fish fed β-glucan diets showed higher expression levels of antioxidant and immune genes than controls, supporting earlier findings that β-glucan enhances short-term infection resistance in several aquatic species (Ortuo et al., 2002).

## CONCLUSION

The present study demonstrates that dietary β-glucan supplementation effectively enhances immune and antioxidant responses in O*reochromis niloticus* challenged with *Aeromonas veronii*. The upregulation of key immune (IL-8, TGF-β) and antioxidant (GSR, GPx) genes across vital tissues such as the gills, liver, and muscles indicate that β-glucan promotes both local and systemic defense mechanisms. However, excessive supplementation may trigger immunosuppressive effects, highlighting the importance of optimal dosage. Overall, β-glucan serves as a potent natural immunostimulant capable of strengthening disease resistance and oxidative balance in Nile tilapia, supporting its potential application as a sustainable alternative to antibiotics in aquaculture health management.

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# EFFECTS OF BITTER LEAF (*Vernonia amygdalina*) EXTRACT ON EGG HATCHABILITY AND LARVAL SURVIVAL OF CATFISH (*Clarias gariepinus*)

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**ABSTRACT**
*This study evaluated the effects of Vernonia amygdalina (bitter leaf) extract on the hatchability of Clarias gariepinus eggs and its potential as a water disinfectant during larval rearing. The experiment was conducted at the wet laboratory of Nnamdi Azikiwe University, Awka, using three feed treatments: Black Soldier fly larva meal (T1), Artemia (T2), and zooplankton (T3). Bitter leaf extract was prepared in cold water at concentrations of 5 g/L, 10 g/L, and 20 g/L, with borehole water as the control. Fertilized eggs (1 g per replicate) were incubated in 20 L of treated water. After hatching, larvae were reared for 10 days and fed the different diets. Culture water was disinfected once using 5 g/L extract for two hours. Parameters assessed using standard methods included water quality, hatchability, survival, weight gain, specific growth rate (SGR), condition factor (K), thermal growth coefficient (TGC), and daily mortality. Temperature (22.43–23.86°C) was the only water parameter with a significant difference ($P<0.05$). SGR ranged from 39.52g ±10.34 (T1) to 138.93g ±69.34 (T3); survival rate from 1.06±0.53% (T2) to 3.17±2.42% (T3); and weight gain from 1,825.33g ±594.94 to 19,650g ±7,150. T3 (zooplankton) showed the best growth and survival. Bitter leaf extract did not enhance egg hatchability at the tested concentrations but showed potential as a larval disinfectant. Therefore, the use of* V. amygdalina *as a disinfectant for* Clarias gariepinus *eggs is not recommended, as it proved ineffective in promoting hatchability and may be toxic to embryos. Further studies with lower concentrations are recommended to determine optimal safe dosages for hatchery application.*

**Keywords:** Bitter leaf extract, Hatchability, Larval rearing, Growth parameters, Water disinfection, Clarias gariepinus

## INTRODUCTION

The African catfish (*Clarias gariepinus*) is a highly valued food fish in Nigeria and globally due to its fast growth, omnivorous feeding habits, tolerance to poor water quality, and ability to thrive in high-density systems. It naturally inhabits lakes, rivers, swamps, floodplains, and even urban sewage systems (Shrestha and Niraula, 2020). These traits, along with ease of reproduction and live marketability, make it ideal for smallholder aquaculture (Musa et al., 2012). In Nigeria, fish is widely consumed due to its availability, affordability, and nutritional benefits (Eseoghene and Ekelemu, 2016; FAO, 2003). However, aquaculture faces significant constraints, particularly the inadequate supply of quality fish seed (Otubusin, 1998). Despite advances in breeding techniques, fish seed supply is still heavily dependent on wild stocks and natural spawning cycles (George *et al.*, 2010). Effective hatchery systems aim to maximize fingerling production from broodstock, but high mortality at egg and larval stages remains a challenge, often due to microbial infections (FAO, 1987). This highlights the need for natural, eco-friendly disinfectants to improve hatchability and survival without introducing harmful residues. *Vernonia amygdalina* (bitter leaf), a widely cultivated West African plant from the Asteraceae family, is traditionally used to treat a variety of ailments (Abdullahi *et al.*, 2019). It has shown promise in poultry as an antimicrobial, antioxidant, growth promoter, and immune booster (Okukpe *et al.*, 2018). Its leaves, rich in bioactive compounds, could offer similar benefits in aquaculture. Given its antimicrobial

properties, bitter leaf extract may serve as an effective natural disinfectant in catfish hatcheries. This study therefore seeks to assess the effects of *V. amygdalina* as a biotic disinfectant on egg hatchability and fry survival in C. *gariepinus*, incorporating *Artemia*, zooplankton, and black soldier fly maggot meal in the nursery phase.

## MATERIALS AND METHODS

This experimental study was conducted at the wet laboratory of the Department of Fisheries and Aquaculture Management, Nnamdi Azikiwe University, Awka, Anambra State. Fresh *Vernonia amygdalina* (bitter leaf) was harvested from the university's Crop Science Department and prepared in concentrations of 5 g/L, 10 g/L, and 20 g/L. Leaves were washed, blended, filtered with muslin cloth, and the extracts stored in labeled airtight containers at 4°C (Omoregie, 2019). These extracts were used as treatment media, while plain borehole water served as the control.

**Spawning tanks** (20 L capacity) were labeled according to treatments and filled with the respective extract solutions or control. Mature C*larias gariepinus* broodstock (1.5 kg female and 1.6 kg males) were procured and subjected to artificial propagation. The female was induced with Ovaprim hormone and stripped after 12 hours, while male testes were dissected for milt extraction (FAO, 2007). Eggs (1 g ≈ 650 eggs) were fertilized using the wet method and immersed in treatment media for up to 24 hours to evaluate hatchability.

In **Experiment 1**, water quality parameters, temperature, pH, dissolved oxygen, and conductivity were measured using standard techniques (Boyd, 1981).

**Experiment 2** involved larval feeding trials. Sixty-three larvae per tank were fed with either zooplankton, *Artemia* (INVE Aquaculture, 2021), or black soldier fly larva meal. Zooplankton (mainly rotifers and paramecium) was harvested from on-site ponds, while blackfly larvae were processed by drying, freezing, milling, and sieving (Ovie and Egborge, 2002).

**Experiment 3** assessed bitter leaf extract (4 mL/20 L) as a larval water disinfectant, applied for two hours and then drained. Growth and survival parameters such as mean weight gain, specific growth rate (SGR), percentage survival, condition factor (K), and thermal growth coefficient (TGC) were calculated using standard biometric formulas (Bagenal, 1978).

## RESULTS AND DISCUSSION

The experiment evaluated the effects of *Vernonia amygdalina* (bitter leaf) extract on egg hatchability, as well as the growth performance and survival of C*larias gariepinus* larvae fed with three different diets: *Artemia*, zooplankton, and black soldier fly larva meal. The physicochemical parameters of the culture water, hatchability and survival percentages, proximate composition of the feed, and various growth indices were analyzed.

### Water Quality Parameters (Table 1)

The temperature in the experimental tanks ranged from 22.43 ± 0.60°C to 23.86 ± 0.39°C. A significant difference was found only in the temperature values, with Treatment 3 (zooplankton) being significantly lower ($p < 0.05$). Dissolved oxygen levels were sub-optimal, ranging from 0.43 ± 0.10 to 0.96 ± 0.36 mg/L, which is below the WHO-recommended 5 mg/L for aquaculture (W.H.O., 1987). This could be due to poor water circulation and borehole water limitations, as also observed by James et al. (2017). The pH values (7.62–7.81) and conductivity (1472.36–1508.48 $\mu$S/cm) were within acceptable ranges, although conductivity exceeded the ideal threshold of 1000 $\mu$S/cm (Ross, 2000).

**Table 1:** Physico-chemical parameters of water used for culture

| Water parameter | T1<br>Blackfly larvae meal | T2<br>*Artermia* feed | T3<br>Zooplankton |
|---|---|---|---|
| Temperature (°C) | $23.3^{b}\pm0.41$ | $23.86^{b}\pm0.39$ | $22.43^{a}\pm0.60$ |
| Dissolved Oxygen (mg/l) | $0.43^{a}\pm0.10$ | $0.96^{a}\pm0.36$ | $0.78^{a}\pm0.27$ |
| pH | $7.81^{a}\pm0.03$ | $7.73^{a}\pm0.03$ | $7.77^{a}\pm0.03$ |
| Conductivity | $1472.36^{a}\pm28.34$ | $1506.3^{a}\pm27.71$ | $1508.46^{a}\pm20.84$ |

*Means with different superscript is statistically different from each other at ($p< 0.05$)*

**Hatchability and Bitter leaf Extract (Table 2)**

The application of bitter leaf extract at different concentrations failed to support successful hatching. Fertilized eggs in all treatments containing the extract developed until the 18th hour and subsequently died. Conversely, the control group (no bitter leaf) achieved 60.96 ± 0.65% hatchability and 33.33 ± 0.77% survival. This suggests that bitter leaf extract, despite its known antimicrobial properties, may be toxic to developing C. *gariepinus* embryos. This contradicts previous reports of its beneficial use in aquaculture, such as its successful use in juvenile rearing as reported by Okukpe *et al*. (2018).

**Table 2:** Hatchability and Survival percentage of Fish larvae production using Bitter leaf extract as a disinfectant

| Parameters | Hatchability (%) | Survival (%) |
|---|---|---|
| Water (control) | 60.96±0.65 | 33.33±0.77 |
| Treatment 1(bitter leaf extract 5g/L) | 0.00±0.00 | 0.00±0.00 |
| Treatment 2 (bitter leaf extract 10g/L) | 0.00±0.00 | 0.00±0.00 |
| Treatment 3 (bitter leaf extract 20g/L) | 0.00±0.00 | 0.00±0.00 |

**Proximate Composition of Feed**

Black soldier fly larva meal had the highest moisture (8.0%), crude fibre (21.9%), and fat/oil (10.43%) content, indicating its high energy potential. Artemia feed had the highest protein (29.89%) and ash content (11.6%), while zooplankton had the highest carbohydrate content (56.08%). These variations in composition influenced the growth and survival performance of the larvae fed on the respective feeds.

**Table 3:** Proximate formulation of experimental feed (%)

| Parameters | Zooplankton | *Artemia* | Black fly larvae |
|---|---|---|---|
| Moisture content | 6.0 | 6.73 | 8.0 |
| Ash content | 8.1 | 11.6 | 10.87 |
| Crude fibre content | 1.28 | 4.48 | 21.9 |
| Fat/oil content | 10.43 | 9.9 | 17.2 |
| Crude protein content | 18.28 | 29.89 | 21.7 |
| Carbohydrate content | 56.08 | 46.92 | 20.33 |

**Growth and Survival Performance**

The specific growth rate (SGR) was highest in fries fed with zooplankton (138.93 ± 69.34), although no significant differences were observed across treatments. Artemia-fed fries recorded the highest weight gain (19650 ± 7150), followed by blackfly (10533.33 ± 6382.88) and zooplankton (1825.33 ± 594.94). However, zooplankton-fed fries had the highest survival rate (3.17 ± 2.42), which might be linked to the significantly lower culture temperature in Treatment 3 and a condition factor value (0.52 ± 0.22) closer to the ideal of 1. Conversely, Artemia-fed larvae had the lowest survival (1.06 ± 0.53) and the highest mortality rate (6.23 ± 2.10), despite achieving the highest thermal growth coefficient (0.19 ± 0.03).

**Table 4:** Growth Performance, Survival and Mortality Indices

| Growth parameter | T1<br>Blackfly larvae meal | T2<br>*Artemia* feed | T3<br>Zooplankton |
|---|---|---|---|
| Specific growth rate (%/day) | $39.32^{a}\pm10.34$ | $52.1^{a}\pm3.84$ | $138.93^{a}\pm69.34$ |
| Condition factor | $18.95^{a}\pm12.84$ | $33.74^{a}\pm3.02$ | $0.52^{a}\pm0.22$ |
| Percentage weight gain (%) | $10533.33^{a}\pm6382.88$ | $19650^{a}\pm7150$ | $1825.33^{a}\pm594.943$ |
| Percentage survival (%) | $1.59^{a}\pm0.92$ | $1.06^{a}\pm0.53$ | $3.17^{a}\pm2.42$ |
| Thermal growth coefficient | $0.10^{a}\pm0.04$ | $0.19^{a}\pm0.03$ | $0.06^{a}\pm0.02$ |
| (%) Mortality | $6.20 \pm 2.45$ | $6.23 \pm 2.10$ | $6.10 \pm 1.99$ |

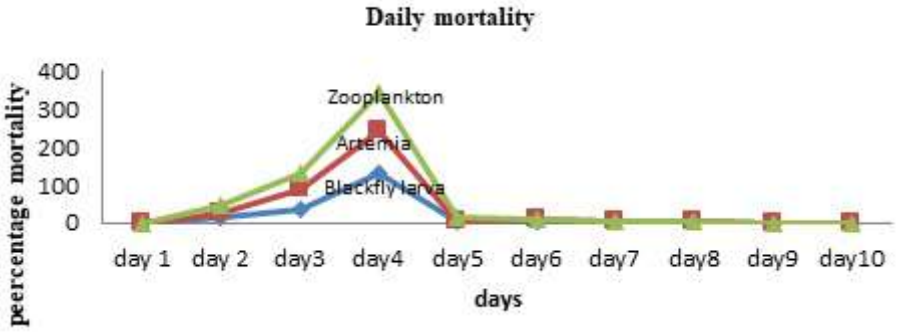



**Figure 1:** *Daily mortality*

These findings show an apparent trade-off between growth rate and survival. Although Artemia has a high protein content that likely contributes to better weight gain, it may simultaneously lead to stress or physiological imbalances resulting in higher mortality. Similar observations were made by Abubakar *et al*. (2013), who noted the performance boost Artemia provides, but also acknowledged challenges related to survival. In contrast, zooplankton appears to provide a more balanced nutritional profile conducive to steady growth and better survival, as supported by findings from Adande *et al*. (2017).

## CONCLUSION AND RECOMMENDATION

This study concludes that while bitter leaf extract is ineffective for egg disinfection and hatchability enhancement, it could still be explored in post-hatch larval rearing. Among the feed types tested, zooplankton offered the best results in terms of specific growth and survival, while Artemia promoted greater weight gain but was associated with higher mortality. Future studies could explore combining feeds to balance growth and survival while optimizing water quality management to mitigate low dissolved oxygen levels. Therefore, the use of *V. amygdalina* as a disinfectant for *Clarias gariepinus* eggs is not recommended, as it proved ineffective in promoting hatchability and may be toxic to embryos.

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# AFLATOXIN TOXICITY AND AMELIORATIVE POTENTIAL OF *Allium sativum* IN *Oreochromis niloticus*: A HISTOPATHOLOGICAL ASSESSMENT

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**ABSTRACT**
*Aflatoxins toxic metabolites produced by Aspergillus flavus, pose serious health risks in aquaculture, compromising fish health and productivity. This study evaluated the histopathological impacts of aflatoxin-contaminated diets and the ameliorative effects of Allium sativum (garlic) supplementation in juvenile Oreochromis niloticus. A 10-week feeding trial was conducted using five dietary treatments: a control (uncontaminated feed), aflatoxin-contaminated feed, and three levels of garlic-supplemented contaminated diets (20 g/kg, 40 g/kg, and 60 g/kg). Aflatoxin contamination was induced through the deliberate fermentation of feed with cultured A. flavus, and garlic inclusion was tested for its mitigating potential. Histopathological assessments were performed on liver and kidney tissues using hematoxylin and eosin staining. Fish fed with aflatoxin- contaminated feed (TD2) exhibited severe necrosis in hepatocytes and renal tubular and glomerular epithelial cells, confirming the toxic effects of aflatoxin. Garlic supplementation at increasing concentrations showed a dose-dependent protective effect. While moderate necrosis was observed at 20 g/kg inclusion (TD3), fish fed with 40 g/kg (TD4) and 60 g/kg (TD5) garlic diets showed mild necrotic changes, comparable to the control group (TD1). These findings highlight the potential of dietary garlic as a natural and effective intervention against aflatoxicosis in aquaculture, promoting fish health and feed safety.*

**Keywords:** Aflatoxin, Garlic, *Oreochromis niloticus*, Histopathology

## INTRODUCTION

Aflatoxins has been known as a toxic secondary metabolites secreted mainly by *Aspergillus flavus* and *A. parasiticus*
(Shabeer *et al*., 2022; Dhakal *et al*., 2023), pose a substantial hazard to aquaculture due to their frequent prevalence in contaminated feed materials (Bashorun *et al*., 2023). These mycotoxins are known to elicit hepatotoxic, immunosuppressive, and carcinogenic effects on a number of aquatic organisms, including *Oreochromis niloticus* (Nile tilapia) (Bhatt and Pandey, 2022). *Oreochromis niloticus* is a widely cultured freshwater fish species in tropical and subtropical regions. Long-term exposure to aflatoxins in fish feeds can cause pathological changes in important organs, including the liver, kidney, and gill tissues, as well as decreased growth performance and weakened health (Agbon *et al*., 2013).

In recent years, significant emphasis has been given towards natural feed additives as potential mitigants of mycotoxin- induced toxicity (Ilesanmi *et al*., 2024). Among these, *Allium sativum* (garlic) has acquired attention due to its broad- spectrum antibacterial, antioxidant, and immunostimulatory characteristics (Subroto *et al*., 2021). Garlic possesses bioactive ingredients like ajoene, diallyl sulfides, and allicin that have shown to improve detoxification, scavenge free radicals, and shield cellular structures from oxidative damage (Shang *et al*., 2019). Garlic has been shown to have therapeutic benefits but little is known about how it can help fish against histopathological damage from aflatoxicosis (El-Barbary *et al*., 2016; Shang *et al*., 2019; Tesfaye, 2021).

This study is to assess the ameliorative ability of dietary *A. sativum* supplementation and examine the histopathological consequences of aflatoxin-contaminated diets on O. *niloticus*. This study sheds light on

the pathogenic effects of aflatoxicosis and the defense mechanisms of garlic in a commercially significant aquaculture species by evaluating essential organs.

## MATERIALS AND METHODS

### Experimental site

The experiment was carried out in the Department of Biology, Federal College of Education, Osiele Abeokuta, Ogun State. The experiment was conducted in a circular concrete tanks (0.5 m depth and 0.58 m diameter).

### Inclusion of Aflatoxin in the formulated feed

The feed ingredients were purchase at Agro-Allied Company mill in Odo Eran, Abeokuta, Ogun State. The feed production and formulation was done in the laboratory as shown in Table 1. Distilled water was added to the compounded feed to moisten it and followed by mixing together with cultured strain of *Aspergillus flavus* from the Microbiology Department, University of Lagos. For seventy-two hours, a plastic bag was placed over the feed mixtures to promote the formation of mold. The fresh garlic bulb were bought, dried, and ground at Kebbi State. The experimental feed was mixed appropriately based on treatment. A completely randomized design (CRD) was used with five dietary treatments (TRT), these include TD 1 (uncontaminated/mold-free feed), TD 2 (contaminated feed of *A. flavus*), TD 3 (20 g of garlic/kg of moldy feed), TD 4 (40 g of garlic/kg of moldy feed) and TD 5 (60 g of garlic/kg of moldy feed). (TD1–TD5: control, contaminated, contaminated + garlic at 20, 40 and 60 $gkg^{-1}$) and three replicates per treatment.

**Table 1.** The dietary composition of formulated feed used for the experiment

| Ingredient | Feed (kg) |
|---|---|
| Maize | 22.5 |
| Groundnut cake | 30.50 |
| Fishmeal | 15.50 |
| Soya-bean meal | 30.50 |
| Mineral premix | 0.50 |
| Methionine | 0.25 |
| Lysine | 0.25 |
| Total | 100 |

A pelleting machine was used to pelletize the compounded feeds, and they were then promptly sundried. The feed was then stored in an airtight container. The proximate analysis of the experimental feed was determined by AOAC (2006) method.

### Determination of Aflatoxin

The mycotoxin analysis of each feed treatment was done at Nigerian Stored Product Research Institute, Ilorin Laboratory before the commencement of the experiment with High-Performance Liquid Chromatography (HPLC) (Hart & Scott, 1995).

### Experimental procedure

12-week-old healthy juvenile *O. niloticus* (17.18±0.798 g) were selected and arranged in a group of 10 juvenile per tank, giving n = 30 fish per treatment and N = 150 fish total. The 1.2 $m^3$ circular concrete tanks used were 24 for the experiment for 10 weeks. The juvenile *Oreochromis niloticus* were obtained from Taiwo Farm, Ndele Ota Ogun State, acclimated to the experimental environment for 7 days, and maintained on Top® feed (45% CP) before the treatments.

Fish in every treatment group received 3% body weight of the prepared diet. The fish were fed the experimental diets twice a day at 9:00 am and 4:00 pm. The pond water was changed every two days. After 10 weeks, the potential effects of garlic on aflatoxin-induced feed was studied based on observed experimental histological characteristics.

**Histopathology Examination**

Liver and kidney histo-examinations were performed at the Pathology Department, Faculty of Veterinary Medicine, Federal University of Agriculture, Abeokuta. The selected fish for the histopathology were dissected with a surgical knife while the organs used were removed into 10% formalin solution before the processing. These organs were subjected to microscopic and gross tests (Comanescu *et al.*, 2012).

**Statistical Analysis**

Data were analyzed using statistical analysis software (SAS, 1999). One-way ANOVA was applied to continuous variables to
evaluate significant differences ($\alpha = 0.05$), Duncan's Multiple Range Test (DMRT) was used for multiple comparisons.

**RESULTS**

The histological examination of the O. *niloticus* fed with TD1 for 70 days revealed that there was a mild necrosis of hepatocytes as shown in the Plate 1 and 2. But Plate 3 and 4 which happened to be the liver of O. *niloticus* fed with TD 2 showed severe necrosis of hepatocytes. The microscopic examination of the liver of O. *niloticus* fed with TD3, TD4, and TD5 show moderate necrosis of hepatocytes (Plate 5 and 6). At the 20% inclusion level of Turmeric (TD6) the liver of Likewise O. *niloticus* showed marked vacuolar degeneration and necrosis of hepatocytes.

The kidney of the TD1 showed mild necrosis of tubular and glomerular while severe necrosis of tubular and glomerular was seen in the experimental fish fed with TD2 and TD3. Meanwhile, moderate necrosis of tubular and glomerular was seen at the TD4 and some samples of TD5 (two out of five samples examined). Other samples from TD5 showed mild necrosis of tubular and glomerular epithelial cells. The TD6, TD7 and TD8 also showed mild necrosis of tubular and glomerular epithelial cells. The liver of Likewise O. *niloticus* showed marked vacuolar degeneration and necrosis of hepatocytes.

**Plate 5 and 6**: Section of the liver of O. *niloticus* fed with **Td3 Plate 7 and 8**: Section of the liver of O. *niloticus* fed with **TD4**

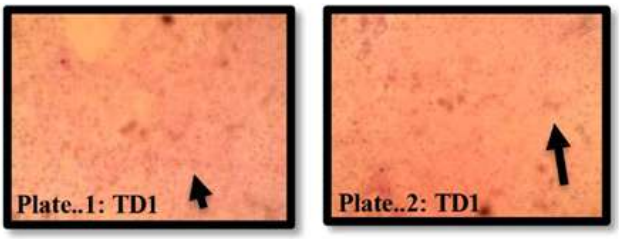



**Plate 1 and 2**: Section of the liver of *O. niloticus* fed with **TD1** showing mild necrosis of hepatocytes (arrow)

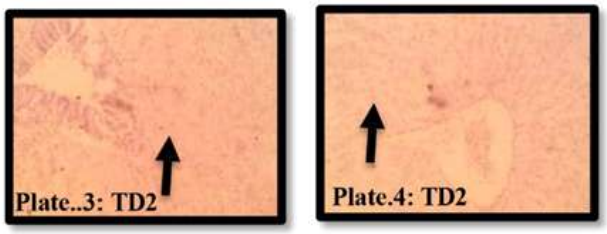



**Plate 3 and 4**: Section of the liver of *O. niloticus* fed with **TD2** showing severe necrosis of hepatocytes (arrow) (x400; H & E)

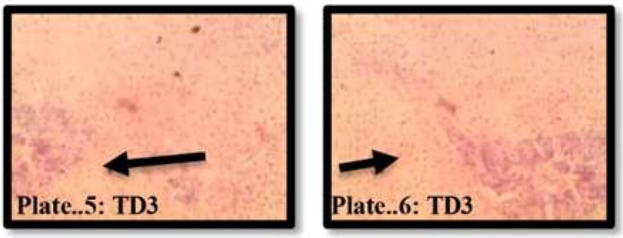



**Plate 5 and 6**: Section of the liver of *O. niloticus* fed with **TD3**

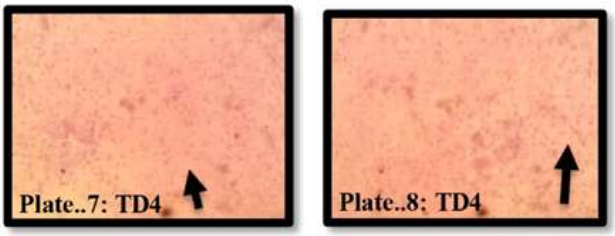
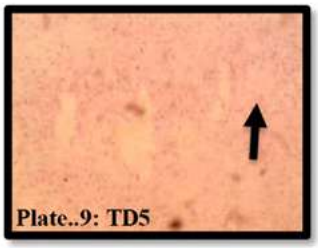



**Plate 7 and 8**: Section of the liver of *O. niloticus* fed with **TD4**

## DISCUSSION

The reults of this study have significant implications for aquaculture feed formulation, fish health management, and food safety. The effects of aflatoxicosis were obvious from the result of this experiment. The liver is a major organ that is the target of aflatoxicosis in an organism (Dhakal *et al.*, 2023). The liver of O. *niloticus* fed with **TD1** (Control free from contamination) showed mild necrosis of hepatocytes. This represents a less severe form, according to Given *et al*. (2008), mild conditions or symptoms are generally controllable and may not necessitate substantial therapy. This mild effect may be the effect of low concentration of total aflatoxin observed in the TD1. The severity observed at TD2 might be as a result of flatoxicosis due to the contamination of the feed this is because liver is one of the vital or suseptible to aflatoxicosis according to Zychowski *et al*. (2013). This severe impact of aflatoxicosis is also similar to the histopathological damages in liver of O*reochromis niloticus* reported by Mahfouz and Sherif (2015) and C*yprinus carpio* by Shahafve *et al*. (2017).

Moderate necrosis of hepatocytes was recorded in the liver of O. *niloticus* after feeding with TD3 which denotes a medium level of severity. On the other hand, TD4 and TD5 showed mild necrosis of hepatocytes, comparing the severity of TD2 to the moderate and mild effect recorded in the diet with the inclusion of garlic this may be the mitigating effect of garlic on aflatoxin. Al-Salahy and Mahmoud (2003) also noticed similar result with C*yprinus carpio* when garlic improves the liver the amount of collagenous fibres in both liver. The higher inclusion level of garlic may explain the reason while RD4 and TD5 were mild compared to the moderate reported for TD3. From this study *Allium sativum*, has been shown to mitigate aflatoxin-induced tissue damage in O*reochromis niloticus*. This shows that adding natural bioactive substances to the diet can be a sustainable substitute for artificial feed additives.



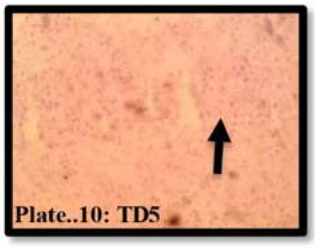




**Fig. 9 and 10**: Section of the liver of *O. niloticus* fed with **TD5** showing mild necrosis of hepatocytes (arrow) (x400; H & E)



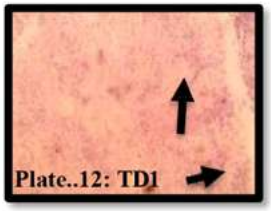




**Fig. 11 and 12**: Section of the kidney of *O. niloticus* fed with **TD1** showing mild necrosis of tubular (arrow) and glomerular (arrow) epithelial cells (x400; H & E)

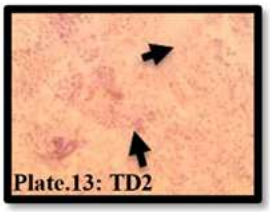
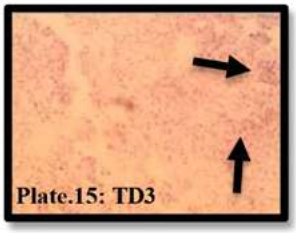






**Fig. 13 and 14**: Section of the kidney Section of the kidney of *O. niloticus* fed with **TD2** showing severe necrosis of tubular (arrow) and glomerular (arrow head) epithelial cells (x400; H & E)



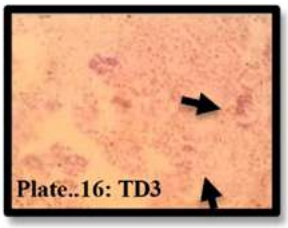
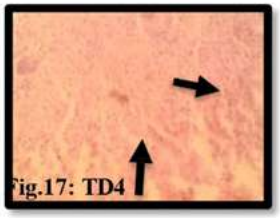




**Fig. 15 and 16**: Section of the kidney of *O. niloticus* fed with **TD3** showing severe necrosis of tubular (arrow) and glomerular (arrow head) epithelial cells (x400; H & E)



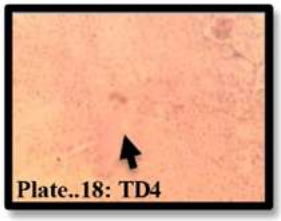




**Fig. 17 and 18**: Section of the kidney of *O. niloticus* fed with **TD4** showing moderate necrosis of tubular (arrow) and glomerular (arrow head) epithelial cells (arrow) (400; H & E)

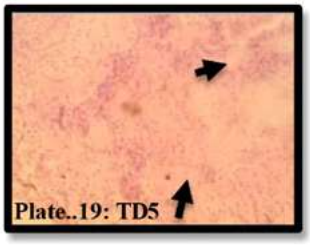



**Plate 19**: Section of the kidney of *O. niloticus* fed with **TD5** showing moderate necrosis of tubular(arrow) and glomerular (arrow) epithelial cells (400; H & E)

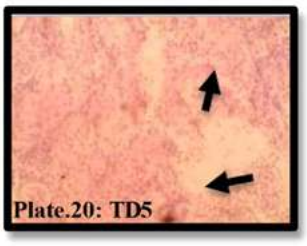



**Plate 20**: Section of the kidney of *O. niloticus* fed with **TD5** showing mild necrosis of tubular (arrow) and glomerular (arrow head) epithelial cells (arrow) (x400; H & E)

## CONCLUSION

The findings of this study demonstrated that aflatoxin-contaminated diets has a detrimental histopathological effects on the liver and kidney tissues of *Oreochromis niloticus*. Fish fed with aflatoxin-contaminated feed (TD2) exhibited severe necrosis, however, the inclusion of garlic in the diet exhibited a dose-dependent ameliorative effect.

Histopathological examination revealed that higher garlic inclusion levels (TD4 and TD5) significantly mitigated tissue damage, with only mild necrosis observed compared to the untreated group. These results suggest that dietary garlic supplementation can play a protective role against aflatoxin-induced organ damage, likely due to its antioxidant and detoxifying properties. Therefore, garlic may serve as a natural and effective feed additive in aquaculture to enhance fish resilience against mycotoxins, improving both fish health and food safety.

## ACKNOWLEDGEMENT

Prof. Ajayi, Prof. Musa and Mr. Rahaman of Veterinary Medicine, FUNAAB. Also Tetfund for funding the research under the Institution Based Research (IBR).

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# PARASITIC BURDEN IN *Heterotis niloticus* FROM KALGWAI RESERVOIR, JIGAWA STATE: IMPLICATIONS FOR FISH HEALTH AND ECOSYSTEM BALANCE

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**ABSTRACT**
*A study of parasites in 120 Heterotis niloticus specimens from Kalgwai Reservoir was conducted between January 2022 and December 2023 to evaluate the occurrence and distribution of parasitic infections. Fish specimens were collected using different types of nets and were transported either alive or fresh on ice to the Biology Laboratory of Binyaminu Usman Polytechnic, Hadejia. Identification was carried out based on morphological features, while sex was determined through visual inspection of the urogenital papilla. Morphometric measurements, including weight and length, were recorded. Ectoparasites were examined using a hand lens and gill dissections, whereas endoparasites were identified through dissection of the gastrointestinal tract in male fish, Lernaea spp. exhibited the highest infection rate at 35.29%, whereas Rhabdochona spp. had the lowest at 15.68%. In females, the highest infection rate was recorded with Rhabdochona spp at 45%, contrasting with the lowest rate for Trichodina spp at 25%. Prevalence was categorized by the site of infestation: ectoparasites (on the skin and gills) and endoparasites (in the intestine, stomach, and blood). Among males, Trichodina spp. was recorded with the highest number and percentage of skin and gill infestations (5, 100% each), while the intestine had the highest endoparasite infestation with 22 cases (55%). Similar patterns were observed in females, with Trichodina spp. dominating skin and gill infestations (5, 100% each) and Rhabdochona spp. exhibiting the highest percentage of endoparasite infestations in the stomach (55.55%).*

**Keywords:** Helminth diversity, Gastrointestinal parasites, Gill infestation, Host–parasite interaction, Morphometric assessment, Prevalence rate.

## INTRODUCTION

The African bony tongue, *Heterotis niloticus* (Cuvier, 1829), is a freshwater fish widely distributed in tropical rivers and freshwater lakes of Western and Central Africa, and the Nile Basin, where it supports important commercial and subsistence fisheries **(**Gbaguidi *et al* 1996). In Nigeria, it constitutes an important part of inland fisheries resources, particularly in reservoirs such as Kalgwai in Jigawa State. However, like many freshwater fishes, *H. niloticus* is vulnerable to parasitic infestations, which may significantly affect fish health, survival, and productivity.

Parasites, especially helminths (including cestodes, nematodes, and acanthocephalans), are commonly reported in freshwater fishes across Nigeria. Their presence is influenced by ecological factors, host physiology, and environmental quality (Ekanem *et al.*, 2011; Oniye *et al.*, 2004). Infected fish often show signs of anemia, reduced growth, altered behavior, and even mortality, which collectively reduce the economic and ecological viability of the fish population (Ekanem and Eyo, 2011).
Despite the ecological and economic importance of *H. niloticus*, little is known about its parasitic burden in Kalgwai Reservoir. This study aims to investigate the prevalence, intensity, and types of parasites infecting *H. niloticus* in Kalgwai Reservoir, and assess their implications for fish health and ecosystem stability.

## MATERIALS AND METHODS

### Study area Description

Kalgwai Dam is situated about 50 metres from Kalgwai village in Auyo Local Government Area of Jigawa State, Nigeria. Constructed in 1984 across the Hadejia River under the Hadejia Valley Irrigation Project by the Federal Government, it is managed by the Hadejia-Jama'are River Basin Development Authority (Matthes, 1990). The dam spans approximately 3,800 km$^2$, positioned at latitude 12°35′N and longitude 10°7′E. It functions primarily as a storage reservoir, receiving inflows from upstream sources such as the Challawa and Tiga Dams in Kano State. Water is released into irrigation canals to support agriculture and domestic use.

The region experiences a tropical climate with an average annual temperature of 37.0°C. It has two distinct seasons: the wet season (May to September) and the dry season (October to April). The dry season includes the Harmattan period (November to February), during which temperatures may fall to as low as 10.0°C, particularly in December and January (Edegbene, 2018).

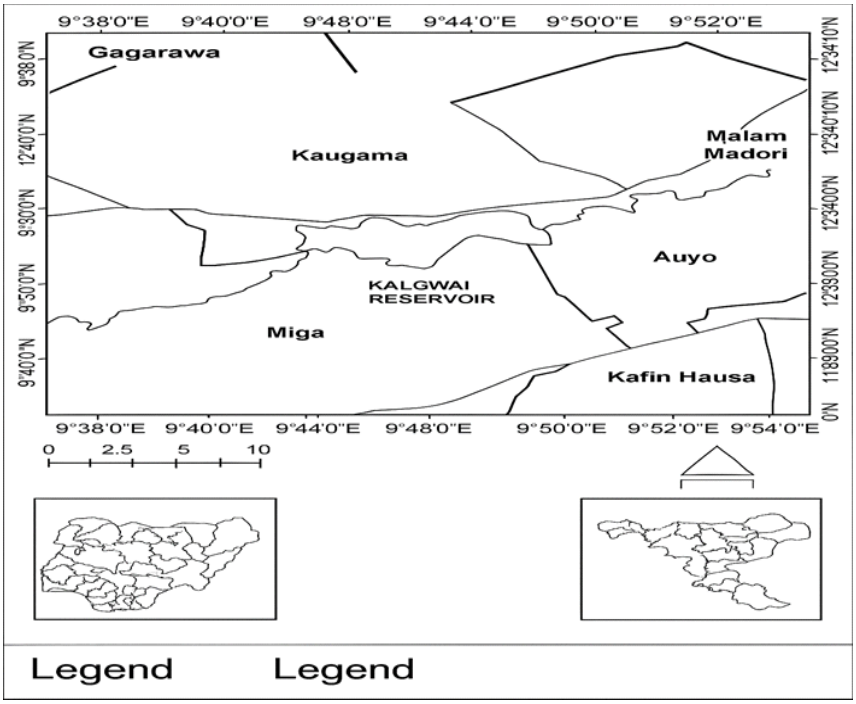



**Figure 1:** Map of Jigawa showing Kalgwai Reservoir

### Fish Collection and Parasitological Examination Methods

A total of 120 *Heterotis niloticus* specimens were randomly collected from Kalgwai, between January 2022 and December 2023 using various fishing gears. Fresh samples were preserved on ice, while live specimens were transported in water-filled containers to the Biology Laboratory of Binyaminu Usman Polytechnic, Hadejia.

Fish were identified using morphological features (Olaosebikan and Raji, 2013), and sex was determined by examining the urogenital papilla. Morphometric data body weight, total length, and standard length—were recorded using standard tools (Idris *et al.*, 2025a).

Ectoparasites were detected by inspecting the skin, fins, and gills with a hand lens, and gill samples were examined in Petri dishes (Paperna, 1991). Skin mucus scrapings were also analyzed in saline solution (Bichi *et al.*, 2009). For endoparasites, the gastrointestinal tract was dissected, segmented, and examined under a dissecting microscope. Parasites were identified, counted, preserved in formalin, and stained for further analysis.

## RESULTS AND DISCUSSION

The distribution pattern of parasitic infection in *Heterotis niloticus* from Kalgwai Reservoir is presented in Table 1. Statistical analysis using descriptive tools and percentage prevalence revealed variations between sexes. Among the male specimens, *Lernaea* spp. exhibited the highest infection rate (35.29%), whereas *Rhabdochona* spp. showed the lowest (15.68%). Conversely, female fish recorded a higher infestation by *Rhabdochona* spp. (45%) and the least occurrence of *Trichodina* spp. (25%). The chi-square test indicated a noticeable difference in infection prevalence between the sexes, suggesting a possible influence of physiological or behavioral factors.

**Table 1:** Prevalence of parasites of *Heterotis niloticus* from Kalgwai reservoir

| Sex | Parasite | No. of parasite recovered | % of infection |
|---|---|---|---|
| (Male) | *Trichodina spp* | 11 | 21.57 |
| | *Procervoid* | 14 | 27.46 |
| | *Lernaea sp* | 18 | 35.29 |
| | *Rhabdochona spp* | 8 | 15.68 |
| | **Total** | **51** | **100** |
| (Female) | *Trichodina spp* | 10 | 25 |
| | *Ergasilus* | 12 | 30 |
| | *Rhabdochona spp* | 18 | 45 |
| | **Total** | **40** | **100** |

The peak prevalence value of 35.29% observed in this research is lower than the infection levels reported in related works—53.49% by Bichi and Ibrahim (2009) in *Clarias gariepinus* at Tiga, 60.66% by Nmor et al. (2003) on cichlid parasites in River Orogodo, 38.59% by Idris et al. (2025a) in *Clarias* species from Kalgwai, and 52.38% by Idris et al. (2025d) from Kitiri Reservoir, Jigawa State. Nonetheless, the current values exceed those recorded by Oribhabor et al. (2012) (15.80%) on threadfin fish from the Niger Delta, Bekele and Hussien (2015) (20.83%) on *Oreochromis niloticus* and *Clarias gariepinus* in Lake Ziway, and Edeh and Solomon (2016) (29.17%) in *Clarias* species inhabiting Utako flowing gutter. These variations across studies could be attributed to ecological conditions, host species differences, and environmental parameters affecting parasite transmission dynamics.

.

**Table 2:** Prevalence of parasites of *Heterotis niloticus* from Kalgwai reservoir in relation to site of infestation

| Sex/Parasite | Ectoparasite<br>Skin<br>Gills | Endoparasite<br>Intestine<br>Stomach | Haemo parasite<br>Blood |
|---|---|---|---|
| *Heterotis niloticus* (Male) | | | |
| *Trichodina* | 5(100)<br>6(100) | 0<br>0 | 0 |
| *Procervoid* | 0(0)<br>0 | 7(31.81)<br>7(31.88) | 0 |
| *Copepods* | 0(0)<br>0 | 11(50)<br>7(38.88) | 0 |
| *Rhabdochona spp* | 0(0)<br>0 | 4(18.18)<br>4(22.22) | 0 |
| **Total** | **5(45.45)**<br>**6(54.54)** | **22(55)**<br>**18(45)** | **0(0)** |
| *Heterotis niloticus* (Female) | | | |
| *Trichodina* | 5(100)<br>5(100) | 0<br>0 | 0 |
| *Copepods* | 0<br>0 | 8(44.44)<br>9(52.94) | 0 |
| *Rhabdochona spp* | 0<br>0 | 10(55.55)<br>8(47.05) | 0 |
| **Total** | **5(50)**<br>**5(50)** | **18(51.42)**<br>**17(48.57)** | **0(0)** |

Table 2 presents the prevalence of parasites in *Heterotis niloticus* from Kalgwai Reservoir, categorized by infestation site: ectoparasites (skin and gills), and endoparasites (intestine, stomach, and blood). In male specimens, *Trichodina* was the most prevalent ectoparasite, recorded in both the skin and gills with 100% occurrence (5 cases each), while the intestine showed the highest endoparasitic load with 22 cases (55%). A similar trend was observed in female fish, where *Trichodina* also dominated ectoparasitic infestations (5 cases, 100% each for skin and gills), and *Rhabdochona* spp. accounted for the highest endoparasite presence in the stomach (55.55%).

These finding is in s consistent with Idris *et al.* (2025a), who also identified *Trichodina* as the sole ectoparasite found in C*larias gariepinus*. However, the results contrast with Sadauki *et al.* (2022), who reported no ectoparasitic infestations in the skin or gills of C*larias gariepinus*. The endoparasites recovered from the gastrointestinal tract of *Heterotis niloticus* in this study included protozoans (*Trichodina*), nematodes (*Rhabdochona*, *Ascaris* eggs), digeneans (*Astiotrema*), and cestodes (pleurocercoid larvae). This differs from the report by Idris *et al.* (2025a), who documented *Procervoid* and copepod species as the endoparasites identified.

## CONCLUSION

The present investigation demonstrated varying degrees of parasitic infestation in *Heterotis niloticus* inhabiting the Kalgwai Reservoir, with clear distinctions between sexes and sites of infection. *Trichodina* spp. emerged as the most dominant ectoparasite, while *Rhabdochona* and *Lernaea* spp. were the leading endoparasites in females and males, respectively. These results reflect the diversity and distribution of both external and internal parasites, underscoring the importance of continuous surveillance to preserve fish health and maintain ecological stability within the reservoir.

Future research should focus on assessing seasonal fluctuations in parasite load, exploring the relationships between physicochemical parameters and parasitic abundance, and employing molecular tools for accurate parasite identification. In addition, investigations into host immune response, parasite transmission dynamics, and potential impacts on fish productivity would provide valuable insights for sustainable fisheries management and disease control strategies in the region

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# ANTIBIOTIC-RESISTANT STREPTOCOCCUS SPECIES IN AQUACULTURE SYSTEMS: IMPLICATIONS FOR FISH HEALTH AND PUBLIC SAFETY IN RIVERS STATE, NIGERIA

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**ABSTRACT**

*This study investigated the bacterial loads, morphological and biochemical characteristics, and antibiotic resistance profiles of bacteria isolated from aquaculture systems in Rivers State, Nigeria. Fish pond water and catfish samples were collected from African Regional Aquaculture Center (ARAC), Umuechi, and Obigbo, and analyzed using standard microbiological techniques. Results revealed high colony counts ranging from $3.8 \times 10^6$ to $1.76 \times 10^7$ CFU/mL, indicating significant microbial contamination of aquaculture environments. Morphological and biochemical characterization identified* Streptococcus *spp. isolates, with* Streptococcus *spp. of particular concern due to its zoonotic potential. Antibiotic susceptibility testing demonstrated high levels of multi-drug resistance, with isolates showing consistent resistance to sulfonamides, cephalosporins, tetracyclines, azithromycin, and cefepime. In contrast, sensitivity was observed to gentamicin, imipenem, and ciprofloxacin across most isolates. These findings revealed the role of aquaculture systems as reservoirs for antibiotic-resistant bacteria, posing risks to fish health, aquaculture productivity, and public health. The study emphasized the need for prudent antibiotic use, stricter regulatory enforcement, improved biosecurity practices, and public awareness to mitigate the emergence and spread of resistant pathogens in aquaculture systems.*

**Keywords**: *Streptococcus spp.*; antibiotic resistance; multi-drug resistance; zoonotic pathogens

## INTRODUCTION

Aquaculture has emerged as a critical contributor to global food security, providing affordable sources of protein and supporting livelihoods in many developing countries, including Nigeria. However, the rapid intensification of aquaculture has been accompanied by rising concerns over bacterial infections and the emergence of antibiotic resistance. Fishpond environments provide favorable conditions for rapid microbial proliferation, and pathogenic organisms such as *Streptococcus* spp. and *Aeromonas* spp. are commonly associated with fish diseases, often leading to significant mortality and substantial economic losses (Akinsanya et al., 2020; Onuoha et al., 2022). This raises significant concerns for public health, as resistant pathogens can be transmitted through fish consumption or via water systems to humans, exacerbating the global antimicrobial resistance (AMR) crisis (Okpalanwa *et al*., 2021; Akinbowale *et al*., 2022). Recent studies highlight that aquaculture systems act as reservoirs of resistance genes, accelerating the exchange of resistance traits among bacterial populations (Nwankwo *et al*., 2021; Eze *et al*., 2023). In Nigeria, catfish farming is one of the most important aquaculture ventures, yet it is highly vulnerable to bacterial infections that compromise productivity. *Streptococcus* spp., in particular, have gained attention due to their zoonotic potential and ability to cause systemic infections in both fish and humans (Akinsanya *et al*., 2020; Ajani *et al*., 2021). The emergence of antibiotic-resistant *Streptococcus* in aquaculture systems not only undermines treatment options but also poses risks to food safety and environmental health.

## MATERIALS AND METHODS

### Experimental design

A total of 72 samples were collected (16 catfish and 8 pond water samples respectively in each of the 3 locations)

The sample size (n = 72) was selected to ensure representation across the three major aquaculture locations while allowing comparison of pond water and fish samples. Multiple samples were collected per location to capture within-site variability due to differences in pond management practices, stocking density, and water quality. The samples were subsequently transported to microbiology laboratory using sterile bags and containers respectively for analysis. The commercial fish farms within the study area (ARAC, Umuechi and Obigbo metropolis), which is one of the major locations with commercial fish farms, were selected at random

### Samples collection and preparation

Water sample collection: Exactly 90 ml of composite water samples (from the fish ponds) were collected in sterile bottles. With gloved hands, a clean rope was tied around the neck of the sterile bottle and dipped at four different points in the fish pond to collect the water samples which was pulled together for each pond to form a composite sample. The samples were taken to the Microbiology laboratory of Ebonyi State University, Abakaliki for bacteriological analysis (Oko *et al.*, 2019; Agwu *et al.*, 2021)

Fish sample collection: In each of the selected fish ponds, catfish samples weighing between 0.5 – 3 kg were harvested with the help of the fish farmers using scooping net to scoop the fish into a clean bucket and then selected by size using weighing balance. With gloved hands, the samples were put in sterile polyethylene bags and labelled with masking tape, after which they were taken to the Microbiology laboratory of Ebobyi, State University for bacteriological analysis. (Oko *et al.*, 2019)

### Demobilization and dissection of the catfish samples

The catfish samples that were still alive and active were demobilized using table salt at the concentration of 0.5g salt to 5kg fish in a sterile polyethylene bag and covered until the catfish was totally inactive. After this, the fish was taken out and placed dorsal upwards on sterile dissection white paper and surgical blade was used to eviscerate the intestine and swab stick soaked in sterile peptone water was used on each sample to swab the intestine and used for inoculation. (Oko *et al.*, 2019)

### Isolation and enumeration of bacterial counts of the water samples

Ten (10) folds serial dilutions were carried out following standard microbiological procedures, by using 1ml of each water samples in 9 mL of distilled water. After the dilution, the fifth dilution ($10^{-5}$) was used and 0.5 mL of the diluted water sample was transferred to each sterile petri dish before pouring a sterilized plate count agar. The plates were incubated at 37°C for 24 hours. Each colony was picked from the agar plate and sub-cultured onto differential agar for proper isolation and identification. A single bacteria colony from predominant morphologically similar colonies was picked from each selective and differential agar plate and subculture in nutrient agar plate and colony count was done using conventional colony counting machine (Iroha *et al.*, 2019).

### Biochemical Test

The following biochemical tests were carried out: oxidase, catalase, coagulase, indole, citrate utilization and carbohydrate fermentation tests according to the method of Cheesebrough (2008).

### Antimicrobial Susceptibility Testing

Antimicrobial susceptibility testing was conducted using the **Kirby–Bauer disk diffusion method** on Mueller–Hinton agar following **Clinical and Laboratory Standards Institute (CLSI) guidelines**. Fresh

colonies were emulsified in sterile saline and adjusted to **0.5 McFarland** turbidity standard. Sterile swabs were used to evenly inoculate Mueller–Hinton agar plates, and antibiotic disks were aseptically placed on the inoculated surface. Plates were incubated at **37°C for 16–18 hours**. Zones of inhibition were measured in millimeters using a calibrated ruler, and isolates were categorized as **susceptible (S)** or **resistant (R) b**ased on CLSI interpretive criteria. The antibiotics tested were; Amikacin (10 $\mu$g), Azithromycin (30 µg), Ciprofloxacin (30 µg), Gentamicin, (30 µg), Ceftriaxone (30 $\mu$g), Sulthamethoxazole/trimethoprim (30 $\mu$g), Meropenem (30$\mu$g), imipenem (30 $\mu$g), tetracycline (30 µg), Cefepime (30µg) as placed on the inoculated agar using sterile forceps and incubated at 37 $^{O}$C for 16 to 18 h. The inhibition zone of each antimicrobial agent was measured using a Millimeter ruler and the results was interpreted according to the CLSI (2019) standards.

**Data Analysis**

The descriptive statistics of the microbial count data of the zoonotic pathogens from the catfish and pond water samples drawn from three locations within Rivers State were analyzed using Phyton statistical software.

## RESULTS

**Morphological and Biochemical Characteristics of Zoonotic Bacteria Isolated from Fish and Fishpond Water from Rivers State**

Two main bacterial groups were identified: *Streptococcus* species and *Aeromonas* species. *Streptococcus* species were characterized as spherical, gray colonies on Blood Agar and Gram-positive in reaction. They tested positive for citrate, glucose and sucrose fermentation, catalase, Voges-Proskauer, and methyl red tests, while negative for motility, oxidase, indole, and lactose fermentation. *Aeromonas* species were identified as rod-shaped bacteria producing dark green colonies on Aeromonas Isolation Agar and were Gram-negative. Biochemically, they tested positive for indole, citrate, oxidase, sugar fermentations, catalase, Voges-Proskauer, and methyl red, but negative for motility Table1.

**Table 1:** Morphological and Biochemical characteristics of bacteria isolated from catfish and water samples from Rivers State, Nigeria

| Morphological characteristics | | | | Biochemical Tests | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Sugar Fermentation Test | | | | | | |
| Shape | Colour | G /R | Motility test | Citrate Test | Oxidase Test | Indole Test | Lactose | Glucose | Sucrose | Catalase Test | VP | Methyl Red | Probable Organism |
| Spherical | Gray on BA | + | - | - | + | - | + | + | + | + | - | + | *Streptococcus species* |
| Rod | Dark green on AIA | - | - | + | + | + | + | + | + | + | + | + | *Aeromonas species* |

**1.3.2 Bacteria loads of fishpond water samples from Rivers State**

At ARAC, the bacterial load ranged from 5.6×1065.6 \times 10^65.6×106 to 1.54×1071.54 \times 10^71.54×107 CFU/mL. The lowest count was observed at serial number 4, while the highest was recorded at serial number 6. The Umuechi samples showed bacterial counts between 3.8×1063.8 \times 10^63.8×106 and 1.44×1071.44 \times 10^71.44×107 CFU/mL. The lowest colony count was obtained at serial number 2, and the highest at serial number 6. Compared to ARAC, Umuechi generally exhibited slightly lower bacterial loads, except in a few instances where the values were close to those of ARAC. Obigbo water samples had the highest range of bacterial counts, from 7.8×1067.8 \times 10^67.8×106 to 1.76×1071.76 \times 10^71.76×107 CFU/mL. The lowest count was observed at serial number 2, while the highest was also recorded at serial number 6 (Table 2)

**Table 2:** Colony Counts of Fish Pond Water Samples from Rivers State of Nigeria

| ARAC CFU/mL | Umuechi CFU/mL | Obigbo CFU/mL |
|---|---|---|
| $8.4 \times 10^6$ | $8.4 \times 10^6$ | $1.34 \times 10^7$ |
| $9.6 \times 10^6$ | $3.8 \times 10^6$ | $7.8 \times 10^6$ |
| $1.18 \times 10^7$ | $8.2 \times 10^6$ | $8.4 \times 10^6$ |
| $5.6 \times 10^6$ | $8.2 \times 10^6$ | $8.8 \times 10^6$ |
| $7.6 \times 10^6$ | $6.4 \times 10^6$ | $9.4 \times 10^6$ |
| $1.54 \times 10^7$ | $1.44 \times 10^7$ | $1.76 \times 10^7$ |
| $1.38 \times 10^7$ | $1.36 \times 10^7$ | $1.44 \times 10^7$ |
| $1.12 \times 10^7$ | $9.0 \times 10^6$ | $1.40 \times 10^7$ |
| $1.22 \times 10^7$ | $1.08 \times 10^7$ | $1.20 \times 10^7$ |
| $7.0 \times 10^6$ | $7.6 \times 10^6$ | $8.6 \times 10^6$ |

**Antibiotic profile of multi-drug resistance zoonotic *Streptococcus spp* isolates from pond water samples drawn from the major aquaculture zones of Rivers State**

At ARAC, isolates were fully susceptible (100%) to meropenem, gentamicin, imipenem, and ciprofloxacin. However, complete resistance (100%) was observed against sulfamethoxazole-trimethoprim, ceftriaxone, amikacin, tetracycline, azithromycin, and cefepime. In Umuechi, isolates also displayed full susceptibility to imipenem and ciprofloxacin, while two-thirds of isolates were susceptible to meropenem and amikacin. Resistance was complete (100%) against sulfamethoxazole-trimethoprim, ceftriaxone, tetracycline, azithromycin, and cefepime, consistent with the resistance trend observed at ARAC. Obigbo isolates exhibited the highest susceptibility, showing 100% sensitivity to imipenem, ciprofloxacin, and sulfamethoxazole-trimethoprim. However, there was marked resistance to ceftriaxone, amikacin, tetracycline, azithromycin, and cefepime, with all isolates showing 100% resistance. Interestingly, two-thirds of the isolates were susceptible to meropenem (Table 3)

**Table 3:** Antibiotic profile of multi-drug resistance *strept spp* isolates from pond water samples drawn from the major aquaculture zones of Rivers State

| | Rivers State | | | | | |
|---|---|---|---|---|---|---|
| | ARAC (WS) (n=2) | | Umuechi (WS) (n=3) | | Obigbo(WS) (n=3) | |
| Antibiotic (µg) | S (%) | R (%) | S (%) | R (%) | S (%) | R (%) |
| MEM (10) | 2(100) | 0(0.0) | 2(66.7) | 1(33.3) | S (%) | 2(66.7) |
| CN (30) | 2(100) | 0(0.0) | 3(100) | 0(0.0) | 1(33.3) | 0(0.0) |
| IPM (10) | 2(100) | 0(0.0) | 3(100) | 0(0.0) | 3(100) | 0(0.0) |
| CIP (30) | 2(100) | 0(0.0) | 3(100) | 0(0.0) | 3(100) | 0(0.0) |
| SXT (125) | 0(0.0) | 2(100) | 0(0.0) | 3(100) | 3(100) | 3(100) |
| CRO (30) | 0(0.0) | 2(100) | 0(0.0) | 3(100) | 0(0.0) | 3(100) |
| AK (30) | 0(0.0) | 2(100) | 2(66.7) | 1(33.3) | 0(0.0) | 3(100) |
| TE (30) | 0(0.0) | 2(100) | 0(0.0) | 3(100) | 0(0.0) | 3(100) |
| AT (30) | 0(0.0) | 2(100) | 0(0.0) | 3(100) | 0(0.0) | 3(100) |
| FEP (30) | 0(0.0) | 2(100) | 0(0.0) | 3(100) | 0(0.0) | 3(100) |

**Antibiotic profile of multi-drug resistance zoonotic *Streptococcus spp* isolates from Catfish samples from Rivers State (Table 4)**

At ARAC, isolates showed complete susceptibility (100%) to gentamicin, imipenem, and ciprofloxacin. Partial susceptibility was observed for amikacin (66.7%), while one-third of isolates displayed resistance.

However, total resistance (100%) was recorded against sulfamethoxazole-trimethoprim, ceftriaxone, tetracycline, azithromycin, and cefepime. Two-thirds of isolates also showed resistance to meropenem, suggesting emerging carbapenem resistance within this zone. In Umuechi, isolates were completely susceptible to gentamicin and imipenem. Four out of five isolates (80%) were susceptible to ciprofloxacin, while two isolates (40%) showed susceptibility to meropenem and amikacin. Nevertheless, high resistance levels were detected, with all isolates (100%) resistant to sulfamethoxazole-trimethoprim, ceftriaxone, tetracycline, azithromycin, and cefepime.Obigbo isolates displayed complete susceptibility to gentamicin, imipenem, and ciprofloxacin. However, full resistance was observed against sulfamethoxazole-trimethoprim, ceftriaxone, tetracycline, azithromycin, and cefepime. Half of the isolates were resistant to meropenem, while both isolates were resistant to amikacin (Table 4).

**Table 4:** Antibiotic profile of multi-drug resistance zoonotic *Streptococcus spp* isolates from Catfish samples from the major aquaculture zones of Rivers State

| | Rivers State | | | | | |
|---|---|---|---|---|---|---|
| | ARAC (FS) (n=3) | | Umuechi (FS) (n=5) | | Obigbo (FS) (n=2) | |
| Antibiotic (µg) | S (%) | R (%) | S (%) | R (%) | S (%) | R (%) |
| MEM (10) | 1(33.3) | 2(66.7) | 2(40) | 3(60) | 1(50) | 1(50) |
| CN (30) | 3(100) | 0(0.0) | 5(100) | 0(0.0) | 2(100) | 0(0.0) |
| IPM (10) | 3(100) | 0(0.0) | 5(100) | 0(0.0) | 2(100) | 0(0.0) |
| CIP (30) | 3(100) | 0(0.0) | 4(80) | 2(40) | 2(100) | 0(0.0) |
| SXT (125) | 0(0.0) | 3(100) | 0(0.0) | 5(100) | 0(0.0) | 2(100) |
| CRO (30) | 0(0.0) | 3(100) | 0(0.0) | 5(100) | 0(0.0) | 2(100) |
| AK (30) | 2(66.7) | 1(33.3) | 2(40) | 3(60) | 0(0.0) | 2(100) |
| TE (30) | 0(0.0) | 3(100) | 0(0.0) | 5(100) | 0(0.0) | 2(100) |
| AT (30) | 0(0.0) | 3(100) | 0(0.0) | 5(100) | 0(0.0) | 2(100) |
| FEP (30) | 0(0.0) | 3(100) | 0(0.0) | 5(100) | 0(0.0) | 2(100) |

## DISCUSSION

Bacterial isolates in aquaculture systems of Rivers State, Nigeria, with a particular focus on antibiotic-resistant *Streptococcus* spp. Morphological and biochemical tests (Table 1) confirmed the presence of *Streptococcus* and *Aeromonas* species, organisms frequently associated with zoonotic infections in fish and humans. The identification of *Streptococcus* spp. aligns with reports by Dong *et al*. (2019), who documented streptococcosis outbreaks in aquaculture systems as a significant threat to fish health and food safety. Colony counts from pond water samples (Table 2) revealed high bacterial loads across ARAC, Umuechi, and Obigbo, ranging from $3.8 \times 10^6$ to $1.76 \times 10^7$ CFU/mL, suggesting substantial microbial contamination. Similar high loads were described in Nigerian aquaculture by Akinyemi *et al*. (2019), who linked poor pond management and antibiotic misuse to elevated bacterial density and resistance spread.The antibiotic susceptibility patterns (Tables 3 and 4) further confirm widespread multidrug resistance (MDR) among *Streptococcus* spp. isolates from both water and fish samples. Isolates were consistently susceptible to gentamicin, imipenem, and ciprofloxacin, but resistant to sulfamethoxazole-trimethoprim, ceftriaxone, tetracycline, azithromycin, and cefepime. Alarmingly, partial resistance to meropenem and amikacin was also noted, particularly in catfish isolates. These results mirror the observations of Onohuean *et al*. (2022), who reported zoonotic *Streptococcus* with MDR profiles in West African aquaculture systems, raising concerns about public health risks via the food chain.

## CONCLUSION

Aquaculture environments assessed in Rivers State showed **high bacterial loads** and the presence of **potentially zoonotic bacteria,** notably *Streptococcus* spp. and *Aeromonas* spp. The *Streptococcus* isolates exhibited **multidrug resistance**, including resistance to commonly used antibiotic classes, which may compromise treatment outcomes, reduce productivity, and elevate food safety and public health risks. These results emphasize the need for routine microbiological monitoring and antibiotic stewardship within fish production systems.

**Recommendations**.

It is recommended that antibiotics should be used prudently under veterinary guidance, while farmers adopt alternative disease control strategies such as vaccination, probiotics, and improved pond management. Regular monitoring of bacterial loads and resistance patterns should be institutionalized, and policies governing antibiotic use in aquaculture should be strengthened in line with international standards

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# PREVALENCE OF GASTROINTESTINAL PARASITES IN C*larias gariepinus* ON RIVER WUSE, NASARAWA STATE, NIGERIA

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**ABSTRACT**

*This study investigated the gastrointestinal parasites of Clarias gariepinus in River Wuse, Nasarawa State, Nigeria. Sixty (60) fresh samples of fish were collected for 8 weeks from late August 2023 to October, 2023 from fishers at landing site on the river. They were taken to the laboratory at National Institute for Pharmaceutical Research and Development, Abuja where fish body measurements and parasites analysis were carried out using standard methods. Two (2) species of nematodes - Procamallanus laeviconchus and Paracamallanus cyathopharynx, and a Cestode - Diphylobothrium latum were recorded in nine individuals infected during the study. P. laeviconchus and D. latum each with 6.67% and 1.67% respectively, while P. cyathopharynx with 6.67%. Female had higher prevalence (17.5%) than male (10.0%). Infection rate increased with increase in fish weight and total length. Stomach recorded higher prevalence of nematode and cestode (11.66%) than the intestine (3.33%). No infection of helminth parasites was recorded in the Oesophagus. Helminths parasite even though low in prevalence is of health concern to humans. Therefore, there is need to develop effective control measures and good culinary practices to decimate their potential risks. Fishers and consumers should be sensitized on fish parasites to curtail the infection. Training should also be provided to fishers and processors on proper fish handling.*

**Keywords**: C*larias gariepinus*, Helminths, River Wuse, Nasarawa State

## INTRODUCTION

Fish is a rich source of food that is gotten from the wild or cultured to meet the nutrition and health benefits of consumers. C*larias gariepinus*, the family C*laridae* is considered as one of the most important tropical catfishes common in swamps, lakes and rivers throughout Africa and as well as fishers catch (Ayanda, 2009). Fish from the wild need to be healthy to avoid contamination because disease is an important factor militating against fish production. Fish parasites are of great importance since they are capable of causing reduced growth and productivity, increased susceptibility to other diseases, varying degrees of mechanical injuries and mortality (Bichi and Yelwa, 2010). Parasites attack fish causing destruction of skin and gill epithelium, injury to tissues or organs in the process of burrowing or consuming food. Parasitic infections often give an indication of the quality of water, since parasites generally increase in abundance and diversity in more polluted waters (Avenant-Oldewage, 2002). Like humans and other animals, fishes suffer from various disease and parasite infections (Bamidele, 2015). Helminths are parasitic worms commonly found in C. *gariepinus* and can be broadly categorized into trematode (fluke worm), cestode (tapeworm) and nematode (roundworms). This parasite can affect the health of the fish and in some cases, pose a risk to human health if the fish is consumed (Bichi and Yelwa, 2010). Various studies have been conducted on intestinal of fish including C*larias gariepinus*. however, there is paucity of information on helminth parasite of C. *gariepinus* hence this study was conducted to determine the prevalence of gastrointestinal helminth parasites in the study area with the view of quantifying the helminthic burden and to control the spread.

## MATERIALS AND METHODS

**Study Area**:

River Wuse is found in Awe town which is situated on longitude 08°30 East and latitude 08°32 North. The area is located in middle climatic belt of Nigeria that is generally very warm and humid with dry and rainy seasons. It has a mean temperature range of 26°C-30°C and mean rainfall range of 1120mm to 1150mm. the major source of water supply for River Wuse is underground, water from borehole and deep wells which are from the aquifers, in addition to the River Wuse. Present of extensive salt deposits in the area, usually mined in commercial quantities (Ambo, 2005).

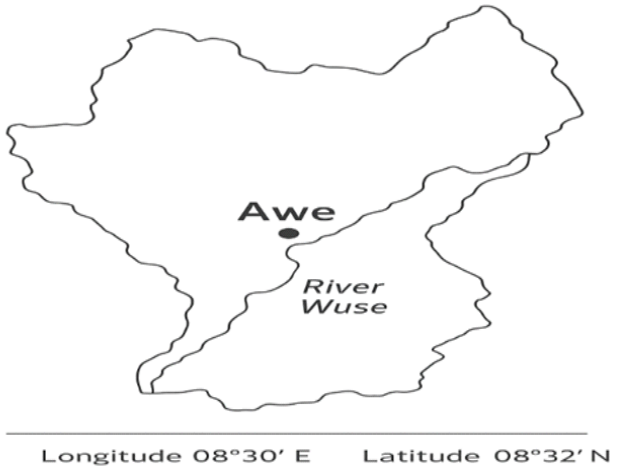



**Figure 1:** Map Showing River Wuse, Nasarawa State, Nigeria
*Source: ChatGPT*

### Sample Collection

Sixty (60) fresh samples of C. *gariepinus* were purchased randomly from different fishermen at the landing site weekly from late August, 2023 to October, 2023. Samples was stored inside a plastic container, cooled with ice to maintain freshness and transported to National Institute for Pharmaceutical Research and Development (NIPRD), Abuja for analysis.

### Identifications and Fish Body Measurements

Identification of fish was carried out according to William *et al* (1994) and Olaosebikan *et al* (1998). The weight of each fish was measured to the nearest 0.1 gram on a top loading weighing balance. The standard length was measured from the tip of the snout to the end of the base of caudal peduncle and the total length was from the tip of the snout to the extreme end of caudal fin using a measuring board (Biu and Akorede, 2013).

### Examination of the Parasite

This was done according to Salawu *et al.* (2013). The fish was carefully handled prior to dissection on a dissecting board. The fish were dissected through the abdomen by making a longitudinal slit on the ventral surface from the anus to a point level with the pectoral fins using a surgical blade. The gastrointestinal tract was isolated, stretched out and grouped into Oesophagus, Stomach and Intestine. Sections were placed into three petri-dishes, each section was slit longitudinal and washed with sodium chloride and identified based on their morphological features as described by Kabata (1985).

### Determination of parasitic prevalence

The percentage (%) prevalence of parasite was determined using the formular:

$$\text{Prevalence } (\%) = \frac{Number\ of\ fish\ infected}{Number\ of\ fish\ examined}\ X\ 100$$

**Statistical Analysis**
Descriptive statistics used to analyse the data obtained and prevalence were expressed in percentage. Data analysed were presented in tabular form.

## RESULTS AND DISCUSSION

Table (1) one shows Species of helminths obtained were *Procamallanus Laeviconchus*, *Paracamallanus cyathopharynx*, and *Diphylobothrium latum* respectively. *P. laeviconchus* and *D. latum* was dominant with 6.67% infected rates while *P. cyathopharynx* was recessive with 1.67%. The infection rate evaluated in this study was lower than 38.0% reported by Biu *et al.* (2013), 19.17% by Oniye *et al.* (2004) and Ayanda (2009). This indicates that the distribution of parasites varied from one habitat to the other which could be attributed to host-parasite relationship and some abiotic factors like dissolved oxygen, temperature and pH. This is corroborated by Ekanem *et al.*, (2011) who also reported low infection rate of 3.33%, which could be attributed to the sanitary condition of the study areas, the location of the river from living place, number and classes of people visiting the river and their purposes. Helminths parasite has a significant effect on fish productivity, marketability, palatability, and death of a good number of fishes especially in the wild as well as the potential zoonotic effect on the consumers (Ekanem *et al.*, 2011)

**Table 1:** Prevalence of Helminths species in infected C. *gariepinus*

| Species Identified | Taxonomic group | Number of fish examined | Number of fish infected | % of infection |
|---|---|---|---|---|
| *Procamallanus laeviconchus* | Nematode | 20 | 4 | 6.67% |
| *Paracamallanus cyathopharynx* | Nematode | 18 | 1 | 1.67% |
| *Diphylobothrium latum* | Cestode | 22 | 4 | 6.6 7% |
| **Total** | | **60** | **9** | **15.0%** |

Table (2) two shows the prevalence of helminths parasites in relation to sex. It was observed that female C. *gariepinus* had higher prevalence (17.5%) than the male (10.0%). This result is in agreement with the findings of God'spower *et al.*, (2016), Emere and Dibal (2014) that recorded significant difference in the prevalence of infection between the sexes. Factors such as reproductive stress, metabolic differences, and availability of intermediate host harboring the infective larval during feeding or foraging (Lagrue *et al.*, 2018).

**Table 2:** Prevalence of helminths parasites of C*larias gariepinus* in relation to sex

| Sex | Number of Fish examined | Numbers of fish infected | % |
|---|---|---|---|
| Male | 20 | 2 | 10.0 |
| Female | 40 | 7 | 17.5 |
| **Total** | **60** | **9** | **27.5** |

It was also observed in this study that percentage infection increased with increase in size (weight and length) of the fish as shown in table (3) three: Ayanda (2009) and Biu *et al.* (2013) also made similar observation and argued that bigger fish has larger surface area, and therefore more susceptible to parasitic infection.

**Table 3:** Prevalence of helminths parasites of C. *gariepinus* based on weight (g) and total length (cm)

| Weight (g) | Nematode | Cestode | Total | Percentage (%) |
|---|---|---|---|---|
| 60.0 - 80.9 | 1 | 0 | 1 | 1.66 |
| 81.0 - 100.9 | 0 | 0 | 0 | 0.00 |
| 101.0 - 120.9 | 0 | 0 | 0 | 0.00 |
| 121.0 - 130.9 | 4 | 4 | 8 | 13.33 |
| Total Length (cm) | | | | |
| 14.0 - 21.9 | 1 | 0 | 1 | 1.66 |
| 22.0 - 29.9 | 0 | 2 | 2 | 3.33 |
| 30.0 - 37.9 | 4 | 2 | 6 | 10.0 |

Prevalence of helminths parasites was higher in the stomach (11.66%), while intestine harboured 3.33% as shown in table (4) four. This was in contrast to the findings of Bichi and Yelwa (2010) which could be due to differences in their nutritional and respiratory requirements that influence their choice of habitat.

**Table 4:** Prevalence of helminths in C. *gariepinus* in gastro-intestinal part

| Gastro-intestinal part | Nematode | Cestode | Total | % |
|---|---|---|---|---|
| Oesophagus | 0 | 0 | 0 | 0.00 |
| Stomach | 4 | 3 | 7 | 11.66 |
| Intestine | 1 | 1 | 2 | 3.33 |

necessary to develop effective control measures and good culinary practices should be adopted to decimate the potential risks to human health. Nearby fishers and the consumers around should be sensitized of fish parasites to curtail the infection. In addition, training should be provided to fisher and processors on proper handling of fish by washing with brine water properly before cooking and smoking.

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# OCCURRENCE OF PARASITES INFESTATION IN *Clarias gariepinus* AND *Oreochromis niloticus* IN LAKE NWONYO, IBI LOCAL GOVERNMENT AREA, TARABA STATE, NIGERIA

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**ABSTRACT**
*This study was conducted at Lake Nwonyo, Ibi Local Government Area, Taraba State, Nigeria, to compare the incidence of parasitic infestation in Clarias gariepinus (African catfish) and Oreochromis niloticus (tilapia) between September and November 2024. A total of 60 fish (30 of each species) were sampled, with 10 specimens collected monthly from each species. Parasites were identified using direct wet mount microscopy, stained smears, and morphological keys. The results revealed a high parasitic prevalence, with Clarias gariepinus showing 90% infestation and Oreochromis niloticus exhibiting 93.3%. The most prevalent parasites included Capillaria sp. (20%), Contracaecum sp. (16.67%), and Dactylogyrus sp. (23.33%) in African catfish, while tilapia was predominantly infected by Contracaecum sp. (23.33%), Dactylogyrus sp. (20%), and Trichodina sp. (20%). Nematodes were the most common taxonomic group in both species (36.67% in catfish, 40% in tilapia), with the highest infections recorded in the intestines (47.73%) of catfish and gills (22.95%) of tilapia. Statistical analysis showed no significant difference ($p > 0.05$) in overall parasitic prevalence between the two species. However, female catfish had higher infection rates (61.9%) than males (38.1%), while male tilapia were more infected (58.3%) than females (41.7%). Water quality parameters, include pH (6.8–7.1), dissolved oxygen (4.8–5.2 mg/L), and ammonia (0.35–0.42 mg/L), influenced parasite dynamics, with peak infections occurring in October under moderate turbidity (3.29 NTU). The study highlights the high parasitic burden in Lake Nwonyo's fish populations, emphasizing the need for improved aquaculture management and regular parasite surveillance to mitigate economic and public health risks.*

**Keywords:** Parasitic infestation, incidence, *Clarias gariepinus*, *Oreochromis niloticus*, Lake Nwonyo, Nigeria.

## INTRODUCTION

African catfish (*Clarias gariepinus*) and tilapia (*Oreochromis niloticus*) are two of the most widely distributed and commercially important fish species found in various natural aquatic habitats, including rivers, lakes, and reservoirs in Nigeria (Akpa *et al.*, 2020). These species are known for their adaptability and fast growth rates, making them crucial for both artisanal fishing and the wider aquaculture industry. However, despite their importance, these species are vulnerable to a wide range of parasitic infections that can significantly impact their health and survival in natural ecosystems. Poor environmental conditions and pollution which often result in reduced immunity in fish and higher susceptibility to parasites and diseases are among the problems facing the major fish sector (Dar *et al.*, 2020).

Parasites of fish are a concern since they often produce a weakening of the host`s immune system thereby increasing their susceptibility to secondary infections, resulting in the nutritive devaluation of fish and subsequent economic losses (Okon *et al.*, 2023). Parasites also compete for food, thereby depriving fish

of essential nutrients and inhibiting growth leading to morbidity and mortality with consequent economic losses (Amos *et al.*, 2018).

## MATERIALS AND METHODS

### Experimental Site

This study was carried out at Lake Nwonyo, Ibi Local Government Area, one of the 16 LGAs in Taraba State, it has it headquarters in Ibi town and is situated between latitudes 7°00'–8°10'N and longitudes 11°10'–12°10'E (Akoga, 2012). Covering 2,728.87 km² with a 2006 population of 84,407, the area lies approximately 350 meters above sea level. It consists mainly of plain, fertile land suitable for cultivating crops such as rice and sugarcane. The region is drained by the River Benue and its tributaries, including Shimakar, Gishiri, and Wase, as well as several natural ponds and lakes, such as Nwonyo, Isini, Awo, and Sai. Ibi experiences a tropical climate with a rainy season from April to October and a dry season from November to March, peaking in January and February with dusty north-east trade wind

### Sample Collection and Analysis

A total of 30 samples each of African catfish (C*larias gariepinus*) and tilapia (O*reochromis niloticus*) were obtained from artisanal fishermen at their landing site for a period of three (3) months. The collected fish were placed in clean, labeled, airtight jerry cans and transported to the Biology Laboratory, Faculty of Biosciences, Federal University Wukari, for analysis. The Formol-Ether concentration technique was employed for examination, following the methods described by Cheesbrough (2009) and Gracia (2017). skin, and fins (for ectoparasite detection), were homogenized in 10% formol saline and filtered through gauze into test tubes. The mixtures were then centrifuged at 4,000 revolutions per minute (rpm) for ten minutes, after which the supernatant was decanted. Subsequently, three milliliters of formol saline and one milliliter of ether were added to each tube, mixed thoroughly, and centrifuged again at 4,000 rpm for ten minutes. The debris adhering to the tube walls was loosened, the supernatant was discarded, and the sediment was resuspended. A drop of the resuspended sediment was placed on a grease-free glass slide, covered with a cover slip, and examined microscopically under ×10 and ×40 objective lenses. Lugol's iodine solution was used to enhance the visibility of parasitic structures

### Sexing and Measurement of fish

Sex was determined by examining the urogenital papilla, which is long and distended in males and round and reddish in mature females. Visual inspection of the gonads (testes for males, ovaries for females) provided additional confirmation (Imam & Dewu, 2010). The standard length was measured using a meter rule, and body weight was recorded with a sensitive top-loading balance (Model: Mettler Toledo) (Sogbesan et al., 2020).

### Blood Sample Collection

A fresh blood sample was collected from the fish's caudal artery (and, where appropriate, the heart) and smeared onto a glass microscope slide. The smear was air-dried, fixed (e.g, in methanol), and stained (e.g, with Giemsa). Prepared slides were then examined under a microscope using a 100× oil-immersion objective lens to detect blood parasites (Shahi *et al.*, 2013).

### Determination of condition factor (K)

The condition factor (K) of each fish was determined using **Fulton's Condition Factor**, calculated as:

$K = (W / L^3) \times 100$

where $W$ is the body weight (g) and $L$ is the standard length (cm) of the fish (**Fulton, 1904).**

Data Analysis

Descriptive statistics, including mean, standard deviation, and percentage values, were computed to summarize the parasitological data. Prevalence and percentage infection were calculated using the following formulas:

**Prevalence (%) = (Number of infected hosts / Total number of hosts examined) × 100**

**Percentage infection (%) = (Number of parasites / Number of infected hosts) × 100**

Differences in parasitic prevalence between the two fish species were assessed using the **Chi-square ( ∀) test**, which is appropriate for comparing proportions between independent groups. Statistical significance was evaluated at the **95% confidence level ($p < 0.05$)**. All analyses were conducted following standard parasitological statistical procedures (Zar, 2010).

## RESULT AND DISCUSSION

**Prevalence and Frequency of Parasitic Infestations of African Catfish (*Clarias gariepinus*)**

Table 1 shows that *Clarias gariepinus* had a high overall parasitic prevalence of **90%**. The most common parasite was ***Dactylogyrus sp.*** (23.33%), mainly infecting the gills, followed by ***Capillaria sp.*** (20%) and ***Contracaecum sp***. (16.67%), both predominantly occurring in the intestine. ***Trichodina sp.*** and ***Trypanosoma sp.*** occurred at lower prevalence rates of 10% and 6.67%, affecting the skin and blood, respectively. The high gill infection by *Dactylogyrus sp.* supports findings by Mgbemena et al. (2020), while the occurrence of *Trypanosoma sp.* aligns with Sadauki et al. (2024), who associated its presence with environmental stress and reduced immunity in fish.

**Prevalence and Frequency of Parasitic Infestations of Tilapia (*Oreochromis niloticus*)**

Table 2 shows that *Oreochromis niloticus* was infected by several parasites, with ***Contracaecum sp.*** being the most prevalent (23.33%), mainly occurring in the intestine. ***Dactylogyrus sp.*** and ***Trichodina sp***. each had a prevalence of 20%, with *Dactylogyrus* primarily affecting the gills and *Trichodina* occurring on the skin, fins, and gills. ***Trypanosoma sp.*** infected 13.33% of the fish, mostly in the blood, while ***Trichuris sp.*** had a prevalence of 10%, found in the intestine and skin. The high occurrence of *Contracaecum sp.* agrees with Zacharia et al. (2019), who reported its common presence in freshwater fish due to environmental contamination by fish-eating birds. The presence of *Dactylogyrus sp.* also supports earlier findings by Mgbemena et al. (2020) linking gill parasites with crowded or low-oxygen aquatic conditions.

**Table 1:** Prevalence and Frequency of Parasitic Infestations of African Catfish (*Clarias gariepinus*)

| Parasites | Number of fish Infected | Gills | % | Fins | % | Skin | % | Intestine | % | Stomach | % | Blood | % | Prevelence (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Capillaria Sp.* | 6 | - | - | - | - | - | - | 16 | 23.88 | - | - | - | - | 20.00% |
| *Contracaecum sp.* | 5 | - | - | - | - | - | - | 13 | 19.40 | - | - | - | - | 16.67% |
| *Acanthocephalus lucii* | 4 | - | - | - | - | - | - | 6 | 8.96 | - | - | - | - | 13.33% |
| *Dactylogyrus Sp.* | 7 | 11 | 16.40 | - | - | - | - | - | - | - | - | - | - | 23.33% |
| *Trichodina sp.* | 3 | 2 | 2.99 | 7 | 10.45 | 6 | 8.96 | - | - | - | - | - | - | 10.00% |
| *Tryponosoma Sp.* | 2 | - | - | - | - | - | - | - | - | - | - | 6 | 8.96 | 6.67% |
| ***Total:*** | 27 | 13 | | 7 | | 6 | | 35 | | | | 6 | | |

**Prevalence of Parasites of African Catfish (*Clarias gariepinus*) and Tilapia (*Oreochromis niloticus*) in Relation to Sex, Length, Weight, and Condition Factor (K)**

Tables 3 and 4 show notable gender differences in parasitic prevalence, with female *Clarias gariepinus* exhibiting higher infection rates (61.9%) than males (38.1%), while male *Oreochromis niloticus* showed higher prevalence (58.3%) compared to females (41.7%). These patterns may reflect physiological and

hormonal variations that influence immune responses, as noted by Obiageli et al. (2022). Length and weight data also revealed that larger fish had higher parasite loads, supporting findings by Mgbemena et al. (2020) and Amos et al. (2020), who reported increased parasitic susceptibility in older, larger, and more mature fish due to greater surface area and internal space available for parasite colonization.

**Table 2:** Prevalence and Frequency of Parasitic Infestations of Tilapia (*Oreochromis niloticus*)

| Parasites | Number of fish Infected | Gills | % | Fins | % | Skin | % | Intestine | % | Stomach | % | Blood | % | Prevelence (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Capillaria Sp.* | 2 | - | - | - | - | - | - | 8 | 13.12 | - | - | - | - | 6.67% |
| *Contracaecum sp.* | 7 | - | - | - | - | - | - | 11 | | - | - | - | - | 23.33% |
| *Trichuris Sp.* | 3 | - | - | - | - | - | - | 4 | 6.56 | 2 | 3.28 | - | - | 10.00% |
| *Dactylogyrus sp.* | 6 | 14 | 22.95 | - | - | - | - | - | - | - | - | - | - | 20.00% |
| *Trichodina sp.* | 6 | 3 | 4.92 | 4 | 6.56 | 7 | 11.48 | - | - | - | - | - | - | 20.00% |
| *Trypanosoma sp.* | 4 | - | - | - | - | - | - | - | - | - | - | 8 | 13.12 | 13.33% |
| Total: | 28 | 17 | | 4 | | 7 | | 23 | | 2 | | 8 | | |

**Table 3:** Prevalence of Parasitic Infestations in African Catfish (*Clarias gariepinus*) and Tilapia (*Oreochromis niloticus*) in Relation to Sex, Length, Weight, and Condition Factor (K)

| Category | *Clarias gariepinus* | | | *Oreochromis niloticus* | | |
|---|---|---|---|---|---|---|
| | Frequency | Number of infected | Prevalence (%) | Frequency | Number of infected | Prevalence (%) |
| **Sex** | | | | | | |
| Male | 13 | 8 | 38.1 | 16 | 14 | 58.3 |
| Female | 17 | 13 | 61.9 | 14 | 10 | 41.7 |
| **Total:** | **30** | | | **30** | | |
| **Length (cm)** | | | | | | |
| 15-17cm | 9 | 4 | 44.44 | 21 | 16 | 76.16 |
| 18-21cm | 17 | 13 | 76.4 | 9 | 8 | 88.89 |
| 22-24cm | 4 | 4 | 100 | - | - | - |
| **Total:** | **30** | | | **30** | | |
| **Weight (g)** | | | | | | |
| 54-74g | 10 | 8 | 80% | 15 | 12 | 92.31% |
| 75-95g | 19 | 12 | 63.16% | 10 | 6 | 60% |
| 96-116g | 1 | 1 | 100% | 5 | 5 | 100% |
| **Total:** | **30** | | | **30** | | |

**Table 6:** Condition Factor (K)

| Species | Average Length (cm) | Average Weight (g) | Condition Factor (K) |
|---|---|---|---|
| *Clarias gariepinus* | 18.92 | 78.7 | 1.16 |
| *Oreochromis niloticus* | 17.05 | 78.0 | 1.57 |

## CONCLUSION

This study found a high parasitic burden in both *Clarias gariepinus* (90%) and *Oreochromis niloticus* (93.3%) from Lake Nwonyo. Nematodes, especially *Capillaria sp.* and *Contracaecum sp.*, were the dominant parasites, mainly infecting the intestines of catfish and the gills of tilapia. Although overall prevalence did not differ significantly between the species ($p > 0.05$), sex-based differences were evident, with higher infections in female catfish and male tilapia. Water quality factors such as pH, dissolved oxygen, and ammonia also influenced parasite occurrence, with peak infections recorded in October under moderate turbidity.

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# ZOONOTIC DISEASES OF FROZEN FISH SOLD IN CALABAR SOUTH LOCAL GOVERNMENT AREA, CROSS RIVER STATE, NIGERIA

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**ABSTRACT**

*Fish-borne zoonotic diseases continue to pose significant challenges to public health and the aquaculture industry worldwide. This study investigated the presence of zoonotic parasites in frozen fish sold in Calabar South Local Government Area of Cross River State, Nigeria. A total of 250 frozen fish samples—comprising 40 Bobo Croaker (Pseudotolithus elongatus), 80 Grey Mullet (Mugil cephalus), and 130 Horse Mackerel (Trachurus trachurus)—were purchased from Watt and Mbukpa markets between May and July 2021. Samples were collected from the skin, gills, fins, muscle, and gut and examined for ectoparasites and endoparasites using standard parasitological methods. No parasites were detected in P. elongatus. In contrast, 20 (15.4%) of T. trachurus were infested with 18 endoparasites, while 30 (37.5%) of M. cephalus were infested with 65 ectoparasites. A total of 83 parasites were recovered from 50 infested fish. Parasite abundance was highest in M. cephalus (0.81), followed by T. trachurus (0.14), and zero in P. elongatus. Prevalence followed a similar trend, with M. cephalus at 37.5%, T. trachurus at 15.4%, and P. elongatus at 0%. In T. trachurus, the highest prevalence (20.0%) occurred in the 30.0–39.9 cm size class, while in M. cephalus, the 50.0–59.9 cm class showed the highest prevalence (40.0%). Organ-specific analysis revealed that parasites in T. trachurus were confined to the intestine, whereas in M. cephalus, they were concentrated in the gills. Overall, the study revealed that Grey Mullet and Horse Mackerel sold in Calabar South were infested with zoonotic parasites, posing potential public health risks. To prevent transmission of these parasites to humans, frozen fish should not be consumed raw or undercooked.*

**Keywords:** Zoonotic diseases, frozen fish, parasites, Calabar South

## INTRODUCTION

Zoonotic diseases are infectious conditions that can be transmitted from animals to humans. These diseases are caused by a variety of agents including bacteria, viruses, parasites, and fungi. Transmission may occur through ingestion, penetration of wounded or abraded skin, animal bites, inhalation of respiratory particles, contact with mucous membranes, or via insect vectors (Gauthier, 2015; Rahman *et al*., 2020). Han *et al*. (2016) emphasized that zoonoses account for a significant portion of emerging infectious diseases globally, while Wolfe *et al*. (2007) noted that pathogens typically found in animals can infect humans either directly or through vectors.

In aquatic environments, zoonotic infections are often associated with the consumption of raw or inadequately cooked fish, as well as unhygienic handling during processing and distribution. These risks are particularly relevant in regions where frozen fish is widely sold and consumed without sufficient safety oversight. This study was conducted to examine frozen fish sold in Calabar South Local Government Area of Cross River State for the presence of parasites or pathogens capable of causing zoonotic diseases.

The investigation focused on three commonly consumed species: Grey Mullet (*Mugil cephalus*), also known as flathead mullet, a marine ray-finned fish belonging to the family Mugilidae; Horse Mackerel

(*Trachurus trachurus*), a species of marine ray-finned fish from the family Carangidae; and Bobo Croaker (*Pseudotolithus elongatus*), a member of the Sciaenidae family. These species were selected based on their availability and popularity in local markets.

## MATERIALS AND METHOD

### Study area

The research work was carried out in Calabar South, L. G. A., Cross River State. Calabar South is a local government in Cross River State with administrative headquarters in the town of Anantigha. Calabar South local government area covers an area of 264km.

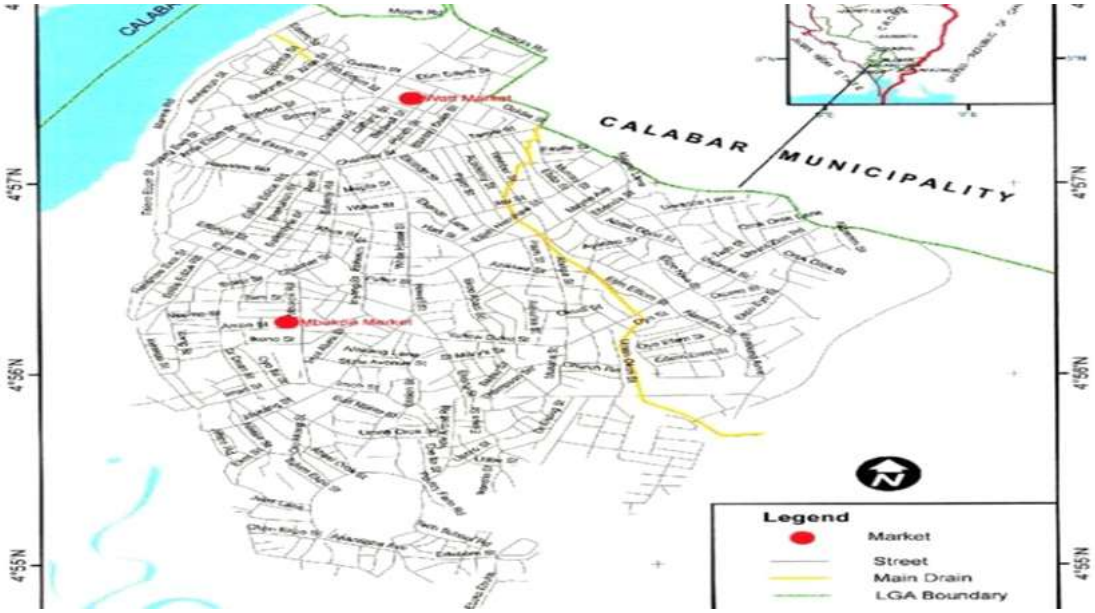



**Fig. 1:** Map of study area

*Sample collection*

The sample species were collected from cold rooms at Watt and Mbukpa markets and were conveyed in a cooler to keep the ice in the fish from melting and prevent the bacterial from multiplying. The fish samples were taken immediately to the Fisheries and Aquaculture laboratory for analysis.

### Identification and of collected fish species

The experimental fish (Bobo Croaker, Grey Mullet and Horse Mackerel) were identified using Fishcer (1981) identification key.

### Laboratory examination of fish for parasites

### Ectoparasites examination

The fish specimens were analyzed for ectoparasites following the methods described by Roohi et al. (2014). For each specimen, the fins, gills, and skin were examined. Mucus scrapings were collected from the dorsal, pelvic, pectoral, and caudal fins; from the lateral body surface for skin; and from the gill arches and filaments for gill examination. Wet mounts prepared from these samples were examined under a binocular microscope (Olympus CX23, magnification ×100 and ×400) to detect ectoparasites. For identification, observed parasites were sketched and compared with the pictorial guide of fish parasites provided by Parpena (1996). Additionally, the presence of protozoan cysts on the gills was examined using a stereo microscope (Leica EZ4, magnification ×40). All parasites observed were counted and recorded.

**Endoparasites examination**
Endoparasites recovered from carton fish sold in major markets in Calabar South L.G.A. were treated, preserved and stained according to Eyo *et al.*, (2013) as follows.

**Nematodes**
Nematodes were fixed in 70% ethyl alcohol for 2 hours, decanted and stored in 5% glycerin. Thereafter, they were stained with Eosin (E) and mounted on a clean glass slide with Canada balsam.

**Evaluation of parasitological indices**
They were examined using the following formulae below

1. Prevalence (%) $= \frac{No.of\ fish\ host\ infected}{\text{Total no of fish host examined}} \times 100$

2. Parasite load (Dominance) (%) $= \frac{\text{No.of each parasite}}{\text{Total no of parasites examined}} \times 100$

3. Mean intensity $= \frac{\text{Total no.of parasites}}{\text{Number of fish infected}}$

**Statistical analysis**
Inferential statistics were applied to assess differences in parasite infestation among fish species. The chi-square ($\chi^2$) test was used to determine the significance of observed variations in infestation rates. A p-value less than 0.05 was considered statistically significant.

## RESULTS AND DISCUSSION

**Number of imported fish samples infested with parasites in Calabar South L.G.A.**
A total of 250 imported fish samples belonging to three species were examined: 40 Bobo Croaker (*Pseudotolithus elongatus*, 16%), 130 Horse Mackerel (*Trachurus trachurus*, 52%), and 80 Grey Mullet (*Mugil cephalus*, 32%). No parasites were detected in *P. elongatus*. Among *T. trachurus*, 20 individuals (15.4%) were infested, yielding 18 endoparasites. In *M. cephalus*, 30 individuals (37.5%) were infested, with a total of 65 ectoparasites (Table 1). Overall, 50 fish were infested, and 83 parasites were recovered.

**Table 1:** Number of imported fish samples infested with parasites in Calabar South L.G.A.

| Common Name | Scientific Name | No. of Fish Examined (%) | No. of Fish Infested (%) | No. of Parasites Collected | Statistics |
|---|---|---|---|---|---|
| Bobo Croaker | *Pseudotolithus elongatus* | 40 (16%) | 0 (0%) | 0 | $\chi^2 = 6.13$, df = 2, p = 0.047 |
| Horse Mackerel | *Trachurus trachurus* | 130 (52%) | 20 (15.4%) | 18 | |
| Grey Mullet | *Mugil cephalus* | 80 (32%) | 30 (37.5%) | 65 | |
| **Total** | | 250 (100%) | 50 (100%) | 83 | Significant |

**Abundance, intensity and prevalence of parasites in in relation to size class**
Parasite metrics varied across size classes (Tables 2 and 3). In *P. elongatus*, no parasites were recorded in either the 30.0–39.9 cm or 40.0–49.9 cm size classes. For *T. trachurus*, the 30.0–39.9 cm class showed the highest abundance (0.17), intensity (0.83), and prevalence (20.0%), while the 40.0–49.9 cm class had lower values (abundance: 0.11; intensity: 1.00; prevalence: 11.4%). In *M. cephalus*, the 50.0–59.9 cm class had the highest abundance (0.90) and prevalence (40.0%), while the 40.0–49.9 cm class had slightly

lower abundance (0.67) and prevalence (33.3%). Intensity was highest in the 50.0–59.9 cm class (2.25) and slightly lower in the 40.0–49.9 cm class (2.00). The overall prevalence of 20% observed in this study is higher than the 3.33% reported by Ekanem et al. (2011) for landed fishes from the Great Kwa River, 14.00% reported by Eyo et al. (2018) for ectoparasite infestation of *Synodontis schall* from the Cross River Estuary but lower than 30% reported by Onyishi and Aguzie (2018) in the Ebonyi River. This suggests that frozen fish sold in urban markets may carry a higher zoonotic risk, possibly due to handling, storage, or sourcing practices.

**Table 2:** Abundance, intensity, and prevalence of parasites in imported fish sold in Calabar South L.G.A.

| Common Name | Scientific Name | No. of Fish Examined (%) | No. of Fish Infested (%) | No. of Parasites Collected | Abundance | Intensity | Prevalence (%) | Statistics |
|---|---|---|---|---|---|---|---|---|
| Bobo Croaker | *Pseudotolithus elongatus* | 40 (16%) | 0 (0%) | 0 | 0.00 | 0.00 | 0.00 | $\chi^2 = 6.57$, df = 2, p = 0.038 |
| Horse Mackerel | *Trachurus trachurus* | 130 (52%) | 20 (15.4%) | 18 | 0.14 | 0.90 | 15.4 | |
| Grey Mullet | *Mugil cephalus* | 80 (32%) | 30 (37.5%) | 65 | 0.81 | 2.17 | 37.5 | |
| Total | | 250 (100%) | 50 (100%) | 83 | 0.33 | 1.66 | 20.0 | Significant |

**Table 3:** Parasite metrics in relation to fish size class

| Species | Size Class (cm) | No. Examined (%) | No. Infested (%) | Parasites Collected | Abundance | Intensity | Prevalence (%) |
|---|---|---|---|---|---|---|---|
| Bobo Croaker | 30.0–39.9 | 10 (25%) | 0 | 0 | 0.00 | 0.00 | 0.00 |
| | 40.0–49.9 | 30 (75%) | 0 | 0 | 0.00 | 0.00 | 0.00 |
| Horse Mackerel | 30.0–39.9 | 60 (46.2%) | 12 | 10 | 0.17 | 0.83 | 20.0 |
| | 40.0–49.9 | 70 (53.8%) | 8 | 8 | 0.11 | 1.00 | 11.4 |
| Grey Mullet | 40.0–49.9 | 30 (37.5%) | 10 | 20 | 0.67 | 2.00 | 33.3 |
| | 50.0–59.9 | 50 (62.5%) | 20 | 45 | 0.90 | 2.25 | 40.0 |
| **Total** | | 250 (100%) | 50 | 83 | — | — | — |

**Statistics:** $\chi^2 = 7.21$, df = 2, p = 0.027 (significant difference in parasite distribution by size class)

**Abundance, intensity and prevalence of parasites in relation to organ specificity**

No parasites were found in any organs of *P. elongatus*. In *T. trachurus*, parasites were localized in the intestine, with three *Contracaecum* sp. and three *Pseudoterranova decipiens* recovered. Each species had an abundance of 0.23, intensity of 1.50, and prevalence of 15.4%. In *M. cephalus*, 77 protozoan cysts were recovered from the gills, with an abundance of 0.81, intensity of 2.17, and prevalence of 37.5%. No parasites were found in the skin or intestine of *M. cephalus* (Table 4).

Previous studies have highlighted the zoonotic potential of various fish-associated pathogens. Bae (2011) reported that species of *Mycobacterium* such as *M. marinum*, *M. fortuitum*, and *M. chelonei* are commonly found in fish and can cause chronic infections in humans, particularly through contact with contaminated water or fish. These infections may manifest as skin ulcers or granulomas, especially in immunocompromised individuals (Boylan, 2011). The World Health Organization (2018) has also identified *Streptococcus iniae* as a zoonotic pathogen carried by both freshwater and marine fish. It can cause severe conditions such as cellulitis, arthritis, and meningitis in humans, typically through wounds incurred during fish handling. Similarly, *Erysipelothrix rhusiopathiae*, a soil and water-borne bacterium, may infect humans through skin abrasions, leading to localized or systemic infections.A study by Inyang-Etoh *et al.* (2022) revealed that parasites were found in the intestines of mackerel fish only; nematode 4(13.3%) and E. Histolytica 2(6.7%).

Boylan (2011) further emphasized the role of *Vibrio* species—including *V. cholerae*, *V. parahaemolyticus*, *V. vulnificus*, and *V. damsela*—in fish-associated zoonoses. These bacteria are commonly transmitted through the consumption of raw or undercooked seafood and can cause gastrointestinal symptoms such

as diarrhea, vomiting, and dehydration. Transmission may also occur through direct contact with contaminated fish or water via broken skin. The findings of this study reinforce the importance of proper handling and thorough cooking of frozen fish to prevent zoonotic transmission. Public health awareness and routine inspection of fish products are essential to mitigate risks associated with fish-borne parasites and pathogens.

**Table 4:** Parasite metrics in relation to organ specificity

| Fish Species | No. Examined | No. Infested | Parasite Species | Parasites Collected | Organ | Abundance | Intensity | Prevalence (%) |
|---|---|---|---|---|---|---|---|---|
| Bobo Croaker | 40 | 0 | Nil | 0 | — | 0.00 | 0.00 | 0.00 |
| Horse Mackerel | 130 | 20 | *Contracaecum* sp., *Pseudoterranova* sp. | 18 | Intestine | 0.14 | 0.90 | 15.4 |
| Grey Mullet | 80 | 30 | Protozoan cysts | 65 | Gills | 0.81 | 2.17 | 37.5 |

**Statistics:** $\chi^2 = 29.00$, df = 1, $p < 0.001$ (significant difference in organ-specific parasite distribution)

## CONCLUSION

This study revealed that imported frozen fish sold in Calabar South Local Government Area were infested with zoonotic parasites, specifically endoparasites in Horse Mackerel (*Trachurus trachurus*) and ectoparasites in Grey Mullet (*Mugil cephalus*). No infestation was observed in Bobo Croaker (*Pseudotolithus elongatus*). Parasite prevalence and abundance were highest in *M. cephalus*, with parasites concentrated in the gills, while *T. trachurus* showed lower infestation levels, with parasites localized in the intestine. Infestation patterns varied with fish size, with higher prevalence observed in larger size classes of *M. cephalus* and smaller size classes of *T. trachurus*.

These findings underscore the potential public health risks associated with consuming infested frozen fish. To reduce the risk of zoonotic transmission, frozen fish should be properly cooked and hygienically handled before consumption. Strengthening inspection protocols for imported fish at points of entry is recommended to ensure parasite-free products reach consumers.

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# ISOLATION AND MOLECULAR CHARACTERIZATION OF BACTERIA FROM THE GUT OF *Chrysichthys nigro*digatus (SILVER CATFISH) FROM OYAN DAM, OGUN STATE

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**ABSTRACT**
*Fish serve as a major protein source and are susceptible to microbial contamination from aquatic environments. Bacterial infections in fish can affect both fish health and human consumers. Thewas aimed at isolating, identifying, and characterizing culturable bacteria present in silver catfish (Chrysichthys nigrodigitatus) from Oyan Dam, Abeokuta, Ogun State. Total bacteria count and the bacteria present in the internal organs (gut, liver, and gills) of the fish were determined. The bacteria were characterized, and the most prevalent was identified via molecular methods. The antibiotic susceptibility pattern of the bacteria was also examined. The results revealed that the liver harboured the highest bacterial load ($5.95 \times 10^7$ CFU/mL), followed by the gills ($3.748 \times 10^7$ CFU/mL) and gut ($3.587 \times 10^7$ CFU/mL). Morphological and biochemical analyses revealed the presence of Staphylococcus spp. (22.22%), Enterobacter spp. (22.22%), Enterococcus spp., Streptococcus spp., Klebsiella spp., Escherichia spp., and Proteus spp. (11.11% each). Molecular sequencing confirmed the identity of the dominant isolate as Staphylococcus vitulinus. Phylogenetic analysis grouped it with Mammaliicoccus vitulinus, supporting recent taxonomic reclassification.*

**Keywords:** Gut, silver catfish, Abeokuta, bacteria, isolates, dam

## INTRODUCTION

The silver catfish, C*hrysichthys nigrodigitatus*, is a crucial species in Oyan Dam, Abeokuta, providing protein and supporting economic activities like aquaculture and fishing (Idowu *et al.*, 2018). Fish are often contaminated with pathogenic bacteria due to deteriorating water quality, eutrophication, pollution, and nutrient runoff

## MATERIALS AND METHODS

### Study Area

The study was conducted at Oyan Dam, a vital freshwater reservoir located in Abeokuta, Ogun State, Nigeria. Despite its importance, Oyan Dam faces challenges related to microbial contamination due to agricultural runoff, untreated sewage, and human activities (Idowu, 2018).
Molecular Characterization of the Bacteria Isolates

### DNA Sequencing

The PCR product was purified using the Bio-Rad PCR Kleen clean-up kit according to the manufacturer's protocol to eliminate residual primers, nucleotides, and enzymes. Purified amplicons were subjected to Sanger sequencing. The resulting nucleotide sequences were analysed using the NCBI BLASTn tool to identify closely related organisms by comparing them against entries in the GenBank database.

## RESULTS

### Molecular Identification of the Most Prevalent Bacteria Isolated from C*hrysichthys nigrodigitatus*

Table 1 presents the molecular identification result of the most prevalent bacterial isolate from C*hrysichthys nigrodigitatus*. The isolate with the code CFG suspected to be *Staphylococcus* spp. was

identified as *Staphylococcus vitulinus*, showing a 95.78% sequence similarity to reference sequences in the GenBank database. The corresponding GenBank accession number is EU652825.1.

Figure 1 shows the phylogenetic relationship of *Staphylococcus vitulinus* strain CUAB-CFG with related strains from GenBank. CUAB-CFG clusters closely with *Mammaliicoccus vitulinus* strains Dog047, DSM 15615, and Ani LG-101, supported by a bootstrap value of 82. Internal branches in this clade have strong support (100). *Mammaliicoccuss ciuri* WT1781 is a sister group. Other *Staphylococcus vitulinus* strains (CIP 104850, PCM 2470) and *Mammaliicoccus vitulinus* Tienloo1 appear more distantly related. The tree suggests that CUAB-CFG aligns more with *Mammaliicoccus* than other *Staphylococcus* strains. *Meanwhile, Mammaliicoccus vitulinus* is a later synonym for *Staphylococcus vitulinus*.

**Table 1:** Molecular Identification of the Most Prevalent Bacteria Isolated from *Chrysichthys nigrodigitatus*

| Isolate Code | Organism Name | % Similarity | GenBank Accession Number |
|---|---|---|---|
| CFG | *Staphylococcus vitu linus* | 95.78% | EU652825.1 |

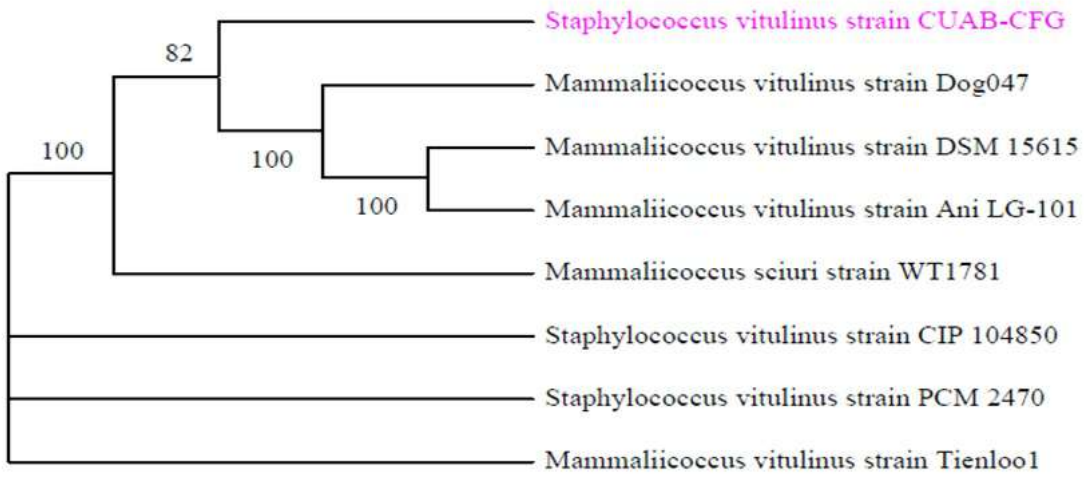



**Figure 1:** Phylogenetic Tree Showing the Relationship of *Staphylococcus vitulinus* strain CUAB-CFG with Reference Sequences from the NCBI Database

## DISCUSSION

The findings of this study provide critical insights into the microbial ecology of Chrysichthys nigrodigitatus from Oyan Dam and highlight potential public health risks associated with bacterial contamination in freshwater ecosystems. The higher bacterial load observed in the liver 5.95 × 1 0 7*CFU /mL* 5.95×10 7 CFU/mL compared to the gills and gut suggests that internal organs may act as reservoirs for microbial proliferation, possibly due to nutrient accumulation or compromised immune responses in stressed fish populations. This aligns with studies linking organ-specific bacterial colonization to environmental stressors (e.g., pollution, hypoxia) in aquatic habitats (Smith et al., 2020).

The dominance of Staphylococcus vitulinus (95.78% similarity to GenBank EU652825.1) underscores its ecological adaptability in freshwater fish. Phylogenetic analysis revealing its clustering with Mammaliicoccus vitulinus strains (Figure 1) supports recent taxonomic revisions reclassifying certain Staphylococcus species into the Mammaliicoccus genus. This reclassification, validated by strong bootstrap values (82–100), emphasizes the need for updated genomic databases to reflect evolving

bacterial nomenclature. The presence of Staphylococcus spp. in fish tissues raises concerns about zoonotic transmission, as these bacteria are known opportunistic pathogens in humans, particularly in immunocompromised individuals.

The diversity of isolates—including Enterobacter, Klebsiella, and Escherichia spp.—points to fecal contamination likely originating from agricultural runoff and untreated sewage, consistent with Oyan Dam's documented pollution challenges. These Enterobacteriaceae members are indicators of water quality deterioration and pose risks of antibiotic resistance dissemination. While antibiotic susceptibility patterns were not detailed here, prior studies associate such genera with multidrug resistance in aquatic systems, necessitating stricter antimicrobial stewardship in aquaculture.

## CONCLUSION

The isolation of pathogenic and opportunistic bacteria in C. nigrodigitatus underscores the interconnectedness of aquatic ecosystem health and food safety. Regular monitoring of Oyan Dam's water quality and targeted policies to reduce anthropogenic pollution are imperative to safeguard both aquatic biodiversity and human consumers.

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# PARASITIC INFESTATIONS IN TILAPIA (*Oreochromis niloticus)* FROM KALGWAI RESERVOIR, JIGAWA STATE

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**ABSTRACT**
*A total of 120 Oreochromis niloticus specimens were collected from Kalgwai Reservoir using combination of gill nets, cast nets and longlines, transported to the Biology Laboratory, Binyaminu Usman Polytechnic, Hadejia. Fish were identified morphologically, sexed via urogenital papilla examination, and measured for total length and weight. Ectoparasites were examined using a hand lens and gill dissections, whereas endoparasites were identified through dissection of the gastrointestinal trac. Six parasite taxa were recorded, with Gyrodactylus (38.99%) most prevalent in males and Trichodina spp. (37.74%) in females. Males showed a significantly higher prevalence (50%) than females (30%) ($\chi^2 = 5.000$; $p = 0.025$). Infection peaked in the 15.1–20.0 cm length class (52.17%) and 31.0–50.0 g weight class (56%), with rates across locations ranging from 25% (Marke) to 50% (Dingare). Findings indicate sex-related susceptibility and variable parasite distribution, highlighting the need for targeted management strategies.*

**Keyword:** Aquatic ecology; Epidemiological assessment; Gill pathology; Host–parasite interaction; Prevalence analysis.

## INTRODUCTION

Nile tilapia is recognized for its rapid growth, reaching market size of 1–2 kg within 8 to 10 months (Mary King, 2000). Today, tilapia ranks as the second most farmed fish in the world after salmon, with annual production estimated at nearly two billion pounds. Specifically, Nile tilapia is regarded as one of the most valuable freshwater aquaculture species, with global production reaching 1.22 million metric tonnes in 2002. It is cultured in at least 50 countries, 19 of which produce at a commercial scale exceeding 1,000 metric tonnes annually (FAO, 2004).

Tilapia is sometimes referred to as the "aquatic chicken" due to its fast growth and ease of culture, but it is also known by other names such as St. Peter's fish, Nile perch, and Hawaiian sunfish. A member of the Cichlid family, tilapia originated in Africa and has adapted well to diverse habitats. It is highly hardy and thrives in fresh, brackish, or even saline waters. Its external appearance varies widely, with skin coloration ranging from golden red, pale red, and white, to gray, blue-gray, dark blue, and black (Thomas and Michael, 1999).

These findings underscore the urgent need for systematic assessment of parasitic occurrence and impact in tilapia populations in Kalgwai Reservoir, Jigawa State, Nigeria.

## MATERIALS AND METHODS

### Study Area and Duration

Kalgwai Dam is situated approximately 50 meters from Kalgwai village within Auyo Local Government Area of Jigawa State, Nigeria. The dam was constructed in 1984 across the Hadejia River by the Federal Government of Nigeria, the dam forms part of the Hadejia Valley Irrigation Project under the management of the Hadejia–Jama'are River Basin Development Authority (H.J.R.B.D.A). The reservoir extends over an estimated surface area of about 3,800 km² (Solomon *et al.*, 2018). Geographically, it lies between latitude 12°35′N – 10°7′E and longitude 12.230°N – 10.022°E.

Functionally, the dam acts as a water storage structure for the Hadejia River system. Its inflow primarily originates from the upstream Challawa and Tiga Dams in Kano State. Water is regulated through control

gates and channeled into irrigation canals, providing a vital supply for farmlands and surrounding settlements used for both domestic and agricultural purposes.

The region experiences a tropical climate, with mean annual temperatures averaging around 37°C. Two distinct climatic periods are observed: a rainy season extending from May to September, and a dry season spanning October to April (Edegbene, 2018). During the dry months, the harmattan period occurring between November and February brings cooler air, and temperatures may fall to approximately 10°C, particularly in December and January (Edegbene, 2018).

**Fish Collection and Parasitological Examination Methods**

A total of 120 specimens of *Oreochromis niloticus* were obtained from Kalgwai Reservoir between January 2022 and December 2023 using a variety of conventional fishing gears. Freshly caught samples were kept on ice to maintain quality, while live individuals were transported in water-filled containers to the Biology Laboratory of Binyaminu Usman Polytechnic, Hadejia.

Identification of specimens was performed based on external morphological characteristics following the description of Olaosebikan and Raji (2013). Sex determination was achieved through examination of the urogenital papilla. Morphometric measurements—including total length, standard length, and body weight—were taken using appropriate measuring instruments as outlined by Idris *et al.* (2025a).

For ectoparasite detection, the skin, fins, and gills were carefully inspected with the aid of a hand lens, while gill tissues were observed in Petri dishes as described by Paperna (1991). Mucus scrapings from the skin were further examined in saline solution following the method of Bichi *et al.* (2009). Examination of endoparasites involved dissection and sectioning of the gastrointestinal tract, with contents observed under a dissecting microscope. Parasites encountered were isolated, counted, preserved in formalin, and stained for detailed identification and further analyses.

## RESULTS AND DISCUSSION

Table 1 summarizes the prevalence of parasitic infection in male and female *Oreochromis niloticus* obtained from Kalgwai Reservoir, including the number of parasites recovered and their corresponding infection percentages. Among the male specimens, *Gyrodactylus* recorded the highest prevalence at 38.99%, while *Philonema* spp. showed the lowest occurrence at 15.25%. The overall infection rate reported in this study differs from the findings of Idris *et al.* (2025d) at Kitiri Reservoir, who documented a higher prevalence of 52.38%. However, it closely aligns with the observation of Idria *et al.* (2025b), who reported a similar rate of 38.59% in the same water body.

**Table 1:** Prevalence of parasites of *Oreochromis niloticus* from Kalgwai reservoir

| Sex | Parasite | No. of parasite recovered | % of infection |
|---|---|---|---|
| (Male) | *Trichodina spp* | 13 | 22.03 |
| | *Gyrodactylus* | 23 | 38.99 |
| | *Rhabdochona spp* | 14 | 23.73 |
| | *Philonema spp* | 9 | 15.25 |
| | **Total** | **59** | **100** |
| (Female) | *Trichodina spp* | 20 | 37.74 |
| | *Gyrodactylus* | 17 | 32.08 |
| | *Monogeneaans* | 16 | 30.18 |
| | **Total** | **53** | **100** |

**Table 2:** Prevalence of parasites of O*reochromis niloticus* from Kalgwai reservoir in relation to site of infestation

| Sex/Parasite | Ectoparasite | | Endoparasite | | Haemo parasite |
|---|---|---|---|---|---|
| | Skin | Gills | Intestine | Stomach | Blood |
| (Male) | | | | | |
| *Trichodina* | 6(31.57) | 7(41.17) | 0 | 0 | 0 |
| *Gyrodactylus* | 13(68.42) | 10(58.82) | 0 | 0 | 0 |
| *Rhabdochona spp* | 0 | 0 | 8(61.53) | 6(60) | 0 |
| *Philonema spp* | 0 | 0 | 5(38.46) | 4(40) | |
| **Total** | **19(52.77)** | **17(47.22)** | **13(56.52)** | **10(43.45)** | **0(0)** |
| (Female) | | | | | |
| *Trichona* | 12(66.66) | 8(42.10) | 0 | 0 | 0 |
| *Gyrodactylus* | 6((33.33) | 11(57.89) | 0 | 0 | 0 |
| Total | **18(48.64)** | **19(51.35)** | **0(0)** | **0(0)** | **0(0)** |

Table 2 presents the distribution of parasitic infections in O*reochromis niloticus* obtained from Kalgwai Reservoir, classified according to the site of infestation—comprising ectoparasites (skin and gills), endoparasites (intestine and stomach), and haemoparasites. Among the male specimens, *Gyrodactylus* recorded the highest rate of skin infestation, accounting for 13 cases (68.42%). This observation aligns with the findings of Rubio *et al*. (2015) and Mohammed et al. (2010), who also identified *Gyrodactylus* as a predominant ectoparasite infecting both tilapia and African catfish species. In addition, *Rhabdochona* spp. dominated intestinal infections with a prevalence of 61.53%. In contrast, female O. *niloticus* exhibited no endoparasitic or haemoparasitic infestations. The most common ectoparasite among females was *Trichodina*, representing 12 cases (66.66%), corroborating the report by Idris et al. (2024), which documented the absence of haemoparasitic infection in similar specimens.

Table 3 presents the prevalence of parasitic infections in O*reochromis niloticus* from Kalgwai Reservoir, categorized according to sex. The results show that male specimens recorded a prevalence rate of 50%. Statistical analysis revealed a significant association between sex and the occurrence of parasitic infection in O. *niloticus*. This finding contrasts with the report of Idris *et al.* (2025b), who documented an equal percentage of infection but observed it in the female population from the same water body.

**Table 3:** Prevalence of parasites of the O*reochromis niloticus* from Kalgwai reservoir in relation to sex

| Sex | No. examined | No. infected | Prevalence (%) | $X^2$ value | P-value |
|---|---|---|---|---|---|
| Male | 60 | 30 | 50.00 | 5.000 | 0.025* |
| Female | 60 | 18 | 30.0 | | |
| **Total** | **120** | **48** | **40** | | |

Table 4 presents the prevalence of parasitic infections in O*reochromis niloticus* from Kalgwai Reservoir in relation to body length. The length group ranging from 15.1–20.0 cm recorded the highest prevalence rate of 52.17%. This observation differs from the findings of Idris *et al.* (2025d), who reported the 10.0–15.0 cm length group as exhibiting the highest infection rate. Conversely, individuals within the 31.0–45.0 cm range showed the lowest prevalence, accounting for 12.5% of the total infections recorded.

**Table 4:** Prevalence of parasites of *Oreochromis niloticus* from Kalgwai reservoir in relation to Length

| Fish length | No. examined | No. infected | Prevalence (%) | $X^2$ value | P-value |
|---|---|---|---|---|---|
| 10.0-15.0 | 32 | 15 | 46.87 | 5.650 | 0.227 |
| 15.1-20.0 | 23 | 12 | 52.17 | | |
| 20.1-25.0 | 35 | 11 | 31.42 | | |
| 25.0-30.0 | 22 | 9 | 40.90 | | |
| 31.0-45.0 | 8 | 1 | 12.5 | | |
| **Total** | **120** | **48** | **40** | | |

Table 5 presents the prevalence of parasitic infections in *Oreochromis niloticus* from Kalgwai Reservoir in relation to body weight. The weight group ranging from 31.0–50.0 g recorded the highest prevalence rate of 56%, which is consistent with the findings of *Idris et al.* (2025d). In contrast, the 51.0–70.0 g weight range exhibited the lowest prevalence at 29.62%. This observation differs from the report of Idris *et al.* (2025b), who recorded the highest infection rate within the 10.1–30.0 g weight category.

**Table 5:** Prevalence of parasites of *Oreochromis niloticus* from Kalgwai reservoir in relation to weight

| Fish weight | No. examined | No. infected | Prevalence (%) | $X^2$ value | P-value |
|---|---|---|---|---|---|
| 10.1-30.0 | 36 | 12 | 33.33 | 4.896 | 0.298 |
| 31.0-50.0 | 25 | 14 | 56 | | |
| 51.0-70.0 | 27 | 8 | 29.62 | | |
| 71.0-90.0 | 15 | 6 | 40 | | |
| 91.0-110.0 | 17 | 8 | 47.05 | | |
| **Total** | **120** | **48** | **40** | | |

Table 6 presents the prevalence of *Oreochromis niloticus* from Kalgwai Reservoir, categorized according to sampling locations. The highest infection rate for *O. niloticus* was recorded in Dingare (50%), while *Heterotis niloticus* exhibited a slightly higher prevalence in Marke (55%). Statistical analysis revealed no significant association between species and parasitic infection at the Kalgwai and Dingare sites. However, a significant association was observed between species and parasitic infection in samples collected from Marke.

**Table 6:** Prevalence of parasites of *Oreochromis niloticus* from Kalgwai reservoir in relation to sample location

| Location | No. examined | No. infected | Prevalence (%) | $X^2$ value | P-value |
|---|---|---|---|---|---|
| Kalgwai | 40 | 17 | 42.5 | | |
| Dingare | 40 | 20 | 50 | | |
| Marke | 40 | 10 | 25 | | |

## CONCLUSION

The findings of this study reveal that *Oreochromis niloticus* from Kalgwai Reservoir harboured a diverse assemblage of parasites, indicating active host–parasite interactions within the ecosystem. Infection patterns varied across sex, size, and sampling locations, with males exhibiting a higher prevalence than females. The predominance of *Gyrodactylus* in males and *Trichodina* spp. in females suggests differences in physiological or behavioural susceptibility linked to sex and size class. Variations in prevalence across sites further imply that environmental conditions, host density, and water quality may influence

infection rates. Overall, the results underscore the ecological importance of continuous parasitological monitoring in Kalgwai Reservoir to safeguard fish health, ensure sustainable fisheries, and maintain ecosystem stability

## RECOMMENDATION

Regular parasitological monitoring, combined with the implementation of targeted control strategies at high-prevalence sites and among susceptible fish groups, is crucial for mitigating infection risks and preserving overall fish health. Sustained surveillance and timely intervention will not only minimize parasite transmission but also enhance the productivity and ecological balance of Kalgwai Reservoir's fisheries resources.

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# IN VITRO EVALUATION OF NEEM LEAF EXTRACTS AS A NATURAL ANTIMICROBIAL AGENT FOR PREVENTING *Aeromonas hydrophilia* INFECTION IN NILE TILAPIA *(Oreochromis niloticus)* LINNAEUS 1758

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**ABSTRACT**
*Aeromonas hydrophilia is a pathogenic bacterium causing severe economic losses in tilapia aquaculture. This study evaluated the antimicrobial potential of Neem (Azadirachta indica) leaf extract as a natural alternative to antibiotics. Ten tilapia samples were screened for A. hydrophilia, and bacterial isolates were subjected to agar well diffusion tests with varying extract concentrations (5–20 mg/L). Neem extract demonstrated antimicrobial activity with maximum inhibition at 20 mg/L (10 mm zone), compared to gentamicin (15 mm). Results highlight Neem's potential as a sustainable antimicrobial for aquaculture. Further studies on dosage optimization and in vivo trials are recommended.*

**Keywords**: Neem leaf extract, *Aeromonas hydrophilia*, *Oreochromis niloticus*, Antimicrobial activity.

## INTRODUCTION

Aquaculture remains one of the fastest-growing food production sectors worldwide, contributing significantly to food security and nutrition. However, intensified aquaculture practices often predispose cultured fish species to disease outbreaks, particularly those caused by bacterial pathogens (Abdel-Tawwab *et al*., 2017). Nile tilapia *(Oreochromis niloticus)* is among the most cultured freshwater fish in Africa, yet it is vulnerable to *Aeromonas hydrophilia*, the causative agent of motile *Aeromonas septicemia* (Akinyemi *et al*., 2018).

The indiscriminate use of antibiotics in fish farming has led to antimicrobial resistance, bioaccumulation in aquatic environments, and potential public health concerns (FAO, 2020). Consequently, there is an urgent need to explore natural, eco-friendly alternatives. Medicinal plants such as neem (*Azadirachta indica*) have demonstrated antimicrobial, antifungal, and immunostimulant properties in aquaculture (El-Sayed *et al*., 2019).

This study evaluates the antimicrobial activity of neem leaf extract as a natural alternative for preventing *Aeromonas hydrophilia* infections in Nile tilapia.

## MATERIALS AND METHODS

**Study Area:** This study was conducted at the Veterinary Laboratory, University of Maiduguri, Borno State, Nigeria. The University is located along Bama Road, Maiduguri, Borno State.

### Sample Collection

Unhealthy Nile tilapia showing clinical signs of bacterial infection such as fin rot, hemorrhagic lesions on the skin, exophthalmia, abdominal swelling and sluggish movement were collected from local fish farms. Samples from gills, mouth, and skin were aseptically obtained and transported to the laboratory in sterile containers for microbiological analysis.

### Preparation of Neem Extract

Fresh neem leaves were collected, washed, shade-dried, ground into fine powder, and extracted using the aqueous method.

**Isolation of Pathogen**
Out of 10 sampled, *Aeromonas hydrophilia* was isolated from the gills in 50% and mouth and skin 33%. Fish samples were inoculated on selective media to isolate *Aeromonas hydrophilia*, following standard microbiological protocols as prescribed by Austin and Austin (2016).

**Antimicrobial Assay**
The agar well diffusion method was used to test antimicrobial activity. Neem extract concentrations of 5, 10, 15, and 20 mg/L were tested. Gentamicin (20 $\mu$g) served as the positive control, while sterile distilled water was the negative control.

**Statistical Analysis**
Data obtained from antimicrobial assay, specifically the mean of inhibition zone diameters(mm)of *Aeromonas hydrophilia* exposed to various concentrations of Neem extract subjected to one-way ANOVA. Differences among means were separated using Least Significant Difference (LSD) test at a significance level of $p < 0.05$.

## RESULTS AND DISCUSSION
In Isolation of *Aeromonas hydrophilia* the gills recorded the highest frequency of isolation (50%), followed by the mouth and skin (33.3% each). This is consistent with Abdel-Tawwab *et al*. (2017), who reported that the gills are often the primary site of bacterial colonization in fish due to direct contact with the external aquatic environment.

**Table 1.** Isolation of *Aeromonas hydrophilia* from different sites in Nile tilapia

| Sample site | Number of isolates | Percentage (%) |
|---|---|---|
| Mouth | 3 | 33.3 |
| Gills | 4 | 50.0 |
| Skin | 3 | 33.3 |

Zone of Inhibition shows: the neem extract displayed antimicrobial activity in a concentration-dependent manner. No inhibition was observed at 5 and 10 mg/L, while significant inhibition occurred at 15 mg/L (7.00) and 20 mg/L (10.00). Gentamicin, the positive control, produced the highest inhibition (15.00). These findings agree with Akinyemi *et al*. (2018), who also reported that neem extract is effective only at higher concentrations.

**Table 2.** Antimicrobial activity of neem extract against Aeromonas hydrophilia

| Treatment | Concentration (mg/l) | Mean zone (mm) | Significance (LSD,p<0.05) |
|---|---|---|---|
| Neem extract | 5 | 0.00 | D |
| Neem extract | 10 | 0.00 | D |
| Neem extract | 15 | 7.00 | C |
| Neem extract | 20 | 10.00 | B |
| Gentamicin | 20ug | 15.00 | A |

## DISCUSSION
Neem extract demonstrated dose-dependent antimicrobial activity against *Aeromonas hydrophilia*, suggesting that its bioactive compounds (azadirachtin, nimbin, and quercetin) may disrupt bacterial membranes and metabolic pathways. Similar findings were reported by El-Sayed *et al*. (2019) and Abdel-Tawwab *et al*. (2017), who highlighted neem's efficacy in controlling fish bacterial diseases.

These results reinforce the potential of neem as a natural antimicrobial agent in aquaculture, reducing reliance on synthetic antibiotics and promoting sustainable fish health management. Some synthetic drugs cause varying degrees of side effects, hence there is need for the development of plant-based compounds which could be useful in meeting the demand for newer drugs with minimal side effects. In the present study, it was found out that aqueous extract of neem leaf had appreciable effect on Tilapia.

This study is in agreement with the work of Hala and Alfadhi (2015) who reported that neem leaf inhibited the growth of some bacterial pathogens. Several studies have indicated that the ethanol extract of plant parts was more inhibitory than the aqueous extract. This is as a result of ethanol being a better extractant (Ke-qiary *et al.,* 2001) The efficacy of the treatment used in this study was determined by measuring the zones of inhibition produced by different neem leaf extracts against bacterial pathogens. The results demonstrated that neem leaf extract effectively inhibited the growth of certain bacterial species, consistent with previous findings by Hala and Alfadhi (2015). The observed intermediate effects at 15mg/l aligns with results from Aly *et al.,* (2008) who reported that sub lethal concentrations of neem could suppress bacterial growth but might not fully eliminate pathogenic activity, hence the importance of optimizing dosage for practical application.

Aqueous extract of the neem leaves had appreciable effect on the *Aeromonas hydrophilia* (Table4.2). Raja and his Colleague compared the antimicrobial efficacy of aqueous extract of leaf of *Azadirachta indica* against human pathogenic bacteria. They found out that leaf extract exhibited strong antimicrobial activity against these bacteria at all the concentration tested. This study is also in agreement with the works of Autade (2015); Yerima (2012); who stated that the leaf of this plant has inhibitory effect on *Pseudomonas aeruginosa*.

## CONCLUSION

Neem leaf extract demonstrated significant antibacterial activity against *Aeromonas hydrophilia* at concentrations ≥15 mg/L, with the highest effect observed at 20 mg/L. Neem extract thus presents a promising natural alternative to synthetic antibiotics in tilapia aquaculture.

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# QUANTITATIVE ASSESSMENT OF MESOPHILIC BACTERIA IN FRESH, SUN-DRIED, AND SHADE-DRIED *Clarias gariepinus* USING BIOCHEMICAL METHODS

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**ABSTRACT**

*This study investigated bacterial load and prevalence in Clarias gariepinus (African catfish). Biochemical tests, including Gram staining, catalase, oxidase, and indole reactions, were used to identify bacterial isolates. Bacterial identification revealed that Bacillus subtilis (22.45%) and Corynebacterium spp. (20.41%) were the most prevalent bacteria across all treatments, while Aeromonas spp. was the least detected (2.04%). When comparing sample types, fresh fish had the highest bacterial prevalence (40.81%), followed by sun-dried (30.61%) and shade-dried samples (28.57%). Fresh samples exhibited the highest mean bacterial count ($4.0\times10^3$ CFU/g), whereas shade-dried samples showed the lowest ($2.8\times10^3$ CFU/g). Bacillus subtilis was Gram-positive and showed positive reactions for catalase and oxidase. Corynebacterium spp. was also Gram-positive and catalase-positive but oxidase- and indole-negative. Aeromonas spp., a Gram-negative bacterium, tested positive for catalase, oxidase, and indole. The study found that raw, shade-dried, and sun-dried Clarias gariepinus can harbour pathogenic bacteria that cause fish diseases such as skin ulcers, septicaemia, fin rot, and haemorrhages. Some of these bacteria are zoonotic, leading to human infections like UTIs, respiratory infections, and sepsis.*

**Keywords:** Mesophilic, Bacteria, Shade-dried, *Escherichia coli*, *Clarias gariepinus*

## INTRODUCTION

*Clarias gariepinus*, a key freshwater fish species, is economically significant in Africa and Asia due to its nutritional value and adaptability (Chakraborty, 2025, Khedkar *et al*., 2024). Despite its importance, fish is highly perishable and susceptible to bacterial contamination, which can pose significant health risks if not preserved properly (Luqman *et al*., 2024; Rahman *et al*., 2020).

Traditional preservation methods, such as sun-drying and shade-drying, are commonly used to extend shelf life (Gbaior *et al*., 2024). These techniques, however, vary in their effectiveness at minimizing microbial load. Sun-drying, which involves direct exposure to sunlight at temperatures typically between 35 to 42°C, effectively reduces bacterial contamination (Løvdal, 2015). However, shade-drying occurs at lower temperatures ( 630°C), which may permit the survival of pathogenic microorganisms (Eze and Uzochukwu, 2019). This study aimed to quantitatively assess mesophilic bacteria in fresh, sun-dried, and shade-dried C. *gariepinus* using biochemical methods and to compare the efficacy of these preservation techniques in minimizing bacterial contamination.

Mesophilic bacteria are those bacteria that grows best at moderate temperatures (20 to 45 °C) such as *E. coli*, *S. aureus*, *S. pneumoniae*, *L. spp.*, *P. aeruginosa*, *B. subtilis*, *S. spp.*, *L. monocytogenes*, *C. botulinum*, *M. tuberculosis* (Pankowski *et al.*, 2016).

## MATERIALS AND METHODS

The study was conducted at the Fish Health and Disease Laboratory, Department of Fisheries, University of Maiduguri, located in Maiduguri Metropolis, Borno State, Nigeria. The experimental design followed a Completely Randomized Design (CRD) with three treatment groups and five replicates each: Fresh, Shade-Dried, and Sun-Dried C. *gariepinus* samples.

A total of 15 fresh C. *gariepinus* were procured from a local fish market. For processing, the fish were degutted and dried on a wire mesh. The sun-dried samples were prepared by drying for 7 days at an average temperature of 40°C. The shade-dried samples were dried for 9 days at an average temperature of 31°C. All samples were then transported to the Microbiology Laboratory for bacterial analysis.

A 4g portion of tissue was aseptically excised from each fish sample. For fresh samples, the tissue was smeared directly onto the culture medium. For dried samples, the tissue was first homogenized in 90 mL of normal saline to ensure a uniform distribution of bacteria. The streak plate method was employed for plating the samples on Plate Count Agar (PCA). The plates were incubated at 37°C for 24 hours in an incubator, for mesophilic bacteria. Following incubation, discrete bacterial colonies were counted to determine the total viable bacterial load (CFU/g).

Data were subjected to one-way analysis of variance (ANOVA) and a significance test for difference among sample variance using the least significance difference (LSD) in the mean comparison of means at $p<0.05$ level of significance using Statistics 10.0 software version.

## RESULTS AND DISCUSSION

The study demonstrated that both sun-drying and shade-drying significantly reduce the total bacterial load of *Clarias gariepinus*. As detailed in **Table 1**, the fresh samples exhibited the highest mean bacterial count at $4.0\times10^3$ CFU/g. This high count is a common characteristic of fresh fish due to high moisture content and ambient temperatures. The drying processes were effective in reducing this load, with the sun-dried samples showing a mean count of $3.0\times10^3$ CFU/g, and the shade-dried samples yielding the lowest count at $2.8\times10^3$ CFU/g.

**Table 1:** Mean Bacteria Population (CFU/gX10) in *Clarias gariepinus*

| Treatment | Bacterial Viable Count |
|---|---|
| FCG | $4.0 \pm 0.32^a$ |
| CSD | $2.8 \pm 0.20^c$ |
| SCG | $3.0 \pm 0.32^b$ |

**Key:** FCG = Fresh C. *gariepinus*, CSG = Shade-dried C. *gariepinus*, SCG = Sun-dried C. *gariepinus*

These findings are consistent with the general principle that fish preservation methods relying on moisture removal effectively inhibit microbial growth. However, when comparing these values to previous studies, some notable differences emerge. The bacterial load of fresh C. *gariepinus* in this study is considerably lower than the findings of Afolabi *et al*. (2020) and Andy *et al*. (2018), while being higher than those reported by Odozie *et al*. (2025). The lower microbial counts in this study may indicate relatively better hygienic practices during handling and processing, or variations in the natural microbial flora of the sampled fish. A total of ten bacterial species were identified across all treatments, with their prevalence varying based on the preservation method. As shown in Table 2, fresh samples contained the highest species diversity. The drying process caused a significant decrease in moisture-dependent bacteria like *E. coli*, which was the most prevalent species in fresh samples but was greatly reduced in the dried ones.

**Table 2:** Total Viable Bacteria (TVB) within each treatment of C*larias gariepinus*

| Treatment | Species of Bacterial | Count | Percentage |
|---|---|---|---|
| FCG | *Escherichia coli* | 5 | 25 |
| | *Bacillus subtilis* | 4 | 20 |
| | *Enterobacter sp.* | 3 | 15 |
| | *Staphylococcus aureus* | 2 | 10 |
| | *Corynebacterial sp.* | 2 | 10 |
| | *Streptococcus faecalis* | 2 | 10 |
| | *Aeromonas sp.* | 1 | 5 |
| | *Proteus mirabilis* | 1 | 5 |
| CSD | *Bacillus subtilis* | 4 | 28.57 |
| | *Corynebacterial sp.* | 4 | 28.57 |
| | *Staphylococcus epidermidis* | 3 | 21.43 |
| | *Staphylococcus aureus* | 2 | 14.28 |
| | *Micrococcus sp.* | 1 | 7.14 |
| SCG | *Corynebacterial sp.* | 4 | 26.66 |
| | *Bacillus subtilis* | 3 | 20 |
| | *Staphylococcus epidermidis* | 3 | 20 |
| | *Staphylococcus aureus* | 2 | 13.33 |
| | *Escherichia coli* | 1 | 6.67 |
| | *Micrococcus sp.* | 1 | 6.67 |
| | *Proteus mirabilis* | 1 | 6.67 |

**Key:** FCG = Fresh C. *gariepinus*, CSG = Shade-dried C. *gariepinus*, SCG = Sun-dried C. *gariepinus*

The most prevalent and resilient species across all treatments were *B. subtilis* and C*orynebacterium* sp., suggesting their high tolerance for low moisture conditions. *B. subtilis* was the most frequently isolated species, with a prevalence ranging from 20% to 28.57%. C*orynebacterium* sp. was the second most prevalent species, appearing with high frequency in both dried samples. In contrast, *Aeromonas* sp. was the least common isolate. Biochemical tests, as presented in **Table 3**, confirmed the identity of the isolates and their respective metabolic profiles.

**Table 3:** Biochemical Tests of Different Bacteria

| Bacteria | Gram Stain | Catalase | Oxidase | Indole | MR | VP | Citrate | Urease | Sugar Fermentation | Coagulase |
|---|---|---|---|---|---|---|---|---|---|---|
| *B. subtilis* | + | + | + | – | + | + | + | – | – | – |
| *Coryn. spp.* | + | + | – | – | – | + | + | + | + | – |
| *E. coli* | – | + | – | + | + | – | – | – | + | – |
| *Staph. aureus* | + | + | – | – | – | + | – | – | + | + |
| *Staph. epidermidis* | + | + | – | – | – | + | – | – | + | + |
| *Enterobacter sp.* | – | + | – | – | – | + | + | – | + | – |
| *Strep. faecalis* | + | – | – | – | + | – | + | – | – | – |
| *Micrococcus sp.* | + | + | + | – | – | – | – | – | + | – |
| *P. mirabilis* | – | + | – | – | + | – | + | + | – | – |
| *Aeromonas sp.* | – | + | + | + | + | + | + | – | + | – |

**Key:** MR = Methyl red, VP = Voges-Proskauer, + = present and - = absent.

## CONCLUSION

In conclusion, this study demonstrated that both sun-drying and shade-drying are effective in reducing the total bacterial load of C*larias gariepinus*, with the shade-dried method yielding the lowest bacterial count. The prevalence of certain bacteria, particularly *B. subtilis* and C*orynebacterium* sp., across all preservation methods highlights their resilience to these drying techniques. The findings underscore the importance of proper hygiene during fish processing to minimize microbial contamination from environmental and handling sources.

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# EFFECTS OF DIETARY PREBIOTIC *Musa accumulata* SUPPLEMENTATION ON HAEMATOLOGICAL INDICES OF AFRICAN CATFISH (*Clarias gariepinus* BURCHELL 1822)

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**ABSTRACT**
*This study evaluated the effects of locally formulated diets with dietary Musa acumulata peel powder (MAPP) as prebiotic at different inclusion levels on Haematological indices of Clarias gariepinus. One hundred and fifty fingerlings were purchased, divided into five experimental groups and fed the locally formulated diets with 0, 1, 3, 5, and 7% MAPP inclusion level respectively for a period of 120 days. Proximate composition of the experimental diets was determined at the beginning of the experiment. Haematological indices: Packed cell volume, Haemoglobin concentration, Red blood cell, mean corpuscular volume, mean corpuscular haemoglobin, mean corpuscular haemoglobin concentration, Platelet count, White blood cell counts and Differential Leucocyte Counts: Neutrophil, Lymphocyte, Monocyte, Eosinophil and Basophil were determined at the end of experimental period. The results showed significant difference (P< 0.05) between the treatment groups. The fish fed locally formulated diet with 3% MAPP have better Haemoglobin concentration, mean corpuscular volume, mean corpuscular haemoglobin, mean corpuscular haemoglobin concentration, Platelet counts and White blood cell counts. Better PCV result was obtained from fish fed diet with 7% MAPP while the RBC counts were better at 0 and 7% MAPP. From the findings of this study, it can be concluded that dietary Musa acumulata peel powder (MAPP) at 3% inclusion level showed clear improvement and could be used as prebiotic in Clarias gariepinus diets to increase WBC and Hb and hence, enhanced immune response. Further study on the effects of MAPP inclusion on Serum chemistry of the African catfish is recommended.*

**Keywords**; Aquaculture, Banana Peel Powder, Haematology.

## INTRODUCTION

African catfish (*Clarias gariepinus* Burchell 1822) is an important aquaculture species that is cultured in various regions in the world. The top producing country is Nigeria followed by the Netherlands, Brazil, Hungary, Kenya, Syrian Arab Republic, South African, Cameroon, and Mali (FAO 2022). The total production of African catfish officially reported by FAO is 246,476 tonnes in 2015 (FAO 2020). C. *gariepinus* is hardy; it grows tremendously at warm temperatures and as a facultative air breather, it survives in low oxygen content and can be farmed at high densities of up to 400 kg/m$^3$ (Ozigbo *et al*., 2014). It can be harvested within 6–9 months of age at a market size of between 1 and 3 kg (Adewumi, 2015).

Prebiotics are essential dietary supplement which, can be define as a substrate that is selectively utilized by host microorganisms conferring a health benefit (Gibson *et al*., 2017). The use of prebiotics in aquaculture have been reported to have resulted in enhanced growth performance, immunomodulation, eco-friendly and healthy fish while limiting disease outbreaks (InêsGuerreiro *et al*., 2017).

*Musa accumulate* peel powder (MAPP) is an example of common fruit waste that is discarded instead of eaten or used due to its unpleasant taste. The MAPP has rich nutritional contents and bioactive compounds that provide many benefits to one health even though its nutritional content and bioactive compound vary depending on the cultivar, environmental circumstances, methods for extraction, and

evaluation methods. It also contains antifungal and antibiotic properties, which benefit human health (Puraikalan *et al.*, 2018). Bioactive compounds like flavonoids, tannins, phlobatannins, alkaloids, glycosides, etc. were found in MAP and these compounds have been reported to exert various biological and pharmacological effects (Pereira and Maraschin 2015). Studies evaluating the effectiveness of prebiotics in fish culture have received very little attention and available data are still insufficient. This study therefore, evaluated the effects of prebiotics particularly *Musa accumulata* peel powder on haematological indices of *Claria gariepinus*.

## MATERIALS AND METHODS

### Study Area

The study was conducted at Research and Teaching Farm. Laboratories analyses were carried out at the Fish Nutrition Laboratory, of the Department of Fisheries, and Haematology Laboratory of the Department of Veterinary Physiology and Biochemistry, University of Maiduguri.

### Experimental Fish

One hundred and fifty (150) *Clarias gariepinus* fingerlings weighing 63.22g was purchased from Badamsy fish farm, Maiduguri and divided into five (5) treatment groups.

### Experimental Diet Formulation and Compounding

The basal feed for this study was locally formulated from the commercial ingredients (fish meal, Soya bean meal, maize, Vitamin, Minerals, Palm oil, premix, lysine, dicalcium phosphate, methionine, salt, and starch). Five experimental diets were formulated with the same basal feed ingredients and MAPP at 0, 1, 3, 5, and 7% inclusion levels was added respectively. The dry ingredients were milled with grinding machine to very fine particle size and sieved. The ingredients were weighed according to the formulation and mixed to homogeneity and was pelleted with small scale extruder pellet machine 160 Model with 2mm diameter size. The pellets were air dried at room temperature and stored in a polyethylene bag until used.

**Table1:** Gross composition of the experimental diets (%)

| Percentage of ingredients of Experimental diets | Treatment Groups $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
|---|---|---|---|---|---|
| FM | 37.13 | 37.13 | 37.13 | 37.13 | 37.13 |
| SBM | 37.12 | 37.12 | 37.12 | 37.12 | 37.12 |
| M | 7.87 | 7.87 | 7.87 | 7.87 | 7.87 |
| WB | 7.88 | 7.88 | 7.88 | 7.88 | 7.88 |
| MAPP | 0.00 | 1.00 | 3.00 | 5.00 | 7.00 |
| Premix | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Lysine | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Methionine | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Calcium | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Salt | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Starch | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Oil | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |

Keys: FM = Fish Meal, SBM = Soya Bean Meal, M = Maize, WB = Wheat Bran, MAPP = *Musa accumulate* peel powder

### Experimental Procedure

The setup comprised of five experimental diets with three replicates each. A total of 15 collapsible polythene pond of 1m×1m×1m dimension each were used for the study. The experimental fish were placed in plastic ponds and allowed to acclimatise for seven (7) days. They were fed basal feed twice daily

to satiation during acclimatisation. The fish in all the treatment groups were starved for 24 hours before the commencement of feeding the experimental diets. The experimental diets were fed twice daily (9.00am and 5.00pm) for four months and the quantity of feed fed daily was recorded. At the end of the experiment, one fish from each replicate was randomly selected and blood collected into heparinized bottle for haematological analysis at the Department of Veterinary Physiology and Biochemistry, University of Maiduguri.

**Proximate Analysis of Experimental Feed**

The proximate composition analysis of the experimental diet was carried out at the Fish Nutrition Laboratory of the Fisheries Department, University of Maiduguri. It was carried out according to the Standard methods described by the Association of Official Analytical Chemist (AOAC 2005).

**Haematological Analysis of Experimental Fish**

Manual haematological analysis was performed immediately after blood collection. Red blood cell count, Haemoglobin concentration, Packed cell volume, Platelets, mean corpuscular volume, mean corpuscular haemoglobin and Mean corpuscular haemoglobin concentration, White blood cell count and also differential leukocyte counts were determined according to procedures described by Faggio *et al*., (2012). The RBC counts was performed manually using a haemocytometer. RBC was expressed as $10^6 mm^{-3}$. The Packed cell volume was determined by microhaematocrit centrifugation. The PCV was calculated as follows: Packed red cells/packed red cells plus supernatant x 100%. MCV, MCH and MCHC were calculated indirectly from the above values using standard formulas as follows: MCV = PCV x 10/RBC; MCH = Hb/RBC and MCHC = Hb x100/PCV.

XLSTAT version 2023 was employed to analyse the data generated from this study. One-way Analysis of variance (ANOVA) was used to determine the effects of different treatment groups on proximate composition and haematological indices. Duncan's multiple range test at 95% ($P \leq 0.05$) confidence level was used to rank treatment means.

## RESULTS AND DISCUSSIONS

**Proximate Composition of Experimental Diets**

The proximate composition of the diets revealed that crude protein (CP), ether extract (EE), crude fibre (CF), and ash increased with higher banana peel powder (BPP) inclusion levels, while nitrogen free extract (NFE) decreased with increased level of banana peel. This is consistent with the findings of Romelle *et al*., (2016), who reported that banana peel is naturally rich in protein, lipid fractions, minerals, and dietary fibre, but contains relatively low carbohydrates. Similarly, Tsado *et al*., (2021) observed that incorporation of banana peel meal raises crude fibre and mineral content of feed while lowering available carbohydrate fractions.

**Haematological Indices of *Clarias gariepinus* Fed Diets with Different Inclusion Level of *Musa accumulata* Peel Powder**

Haematological indices serve as important indicators of fish health. In this study, packed cell volume (PCV) values remained within the normal range for C. *gariepinus* (Adeyemo, 2007), in all the treatment groups, suggesting no anaemia or severe physiological stress. The haemoglobin concentration, MCV, mean corpuscular haemoglobin (MCH), MCHC, PLA and white blood cell (WBC) counts showed clear improvements at 3% BPP inclusion. The increased WBC count at 3% inclusion may enhance the immune function of the fish and is consistent with findings of Ye *et al*. (2011), who reported that prebiotic supplementation in aquafeeds can stimulate immune responses and improve disease resistance. The higher leukocyte counts reflect improved immune response, this finding is consistent with Fasakin *et al*., (2020), who found that plant-based feed additives containing polyphenols and tannins stimulate

haematopoiesis and improve immunity in catfish. Likewise, Pereira and Maraschin, (2015) reported that banana peel bioactive such as flavonoids and alkaloids function as immunostimulants. However, the variability in red blood cell (RBC) counts among treatment groups suggests that higher inclusions may induce mild physiological stress, requiring cautious application.

**Table 2:** Proximate Composition of Experimental Diets of *Clarias Gariepinus* with MAPPat Different Inclusion Level

| | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| Moisture Content | 5.30±0.05$^{bc}$ | 5.40±0.05$^{b}$ | 5.20±0.05$^{c}$ | 5.20±0.05$^{c}$ | 5.80±0.05$^{a}$ |
| Crude Protein | 41.01±0.02$^{d}$ | 41.19±0.02$^{c}$ | 41.20±0.02$^{c}$ | 41.22±0.02$^{b}$ | 41.35±0.02$^{a}$ |
| Ether Extract | 5.10±0.07$^{c}$ | 5.90±0.07$^{b}$ | 5.20±0.07$^{c}$ | 5.30±0.07$^{b}$ | 5.40±0.0$^{a}$ |
| Crude Fibre | 5.10±0.02$^{c}$ | 5.50±0.02$^{c}$ | 6.50±0.02$^{b}$ | 6.50±0.02$^{b}$ | 7.00±0.02$^{a}$ |
| Ash Content | 7.52±0.01$^{d}$ | 7.54±0.01$^{d}$ | 8.12±0.01$^{c}$ | 8.90±0.01$^{b}$ | 9.30±0.01$^{a}$ |
| Nfe | 41.07±0.14$^{a}$ | 34.47±0.14$^{b}$ | 33.78±0.14$^{c}$ | 32.88±0.14$^{c}$ | 31.15±0.14$^{d}$ |

Means within the same row with different superscripts differ significantly ($p<0.05$).
Key: ± = Standard error of means, NFE=Nitrogen free extract

**Table 3:** Haematological Indices of *Clarias gariepinus* Fed Diets with Different Inclusion Level of *Musa accumulata* Peel Powder

| Parameter | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| PCV% | 34.00±0.73$^{ab}$ | 34.00±0.73$^{ab}$ | 34.00±0.73$^{ab}$ | 34.00±0.73$^{ab}$ | 35.00±0.73$^{a}$ |
| Hb g/dl | 11.40±0.05$^{c}$ | 11.10±0.05$^{d}$ | 11.90±0.05$^{a}$ | 11.60±0.05$^{b}$ | 11.30±0.05$^{c}$ |
| RBC $10^6$/mm$^3$ | 1.90±0.09$^{a}$ | 1.50±0.09$^{b}$ | 1.30±0.09$^{b}$ | 1.60±0.09$^{ab}$ | 1.60±0.09$^{a}$ |
| MCV | 180.45±15.08$^{b}$ | 220.06±15.08$^{ab}$ | 266.57±15.08$^{a}$ | 212.79±15.08$^{b}$ | 220.54±15.08$^{ab}$ |
| MCH | 6.04±0.48$^{b}$ | 7.42±0.48$^{b}$ | 9.29±0.48$^{a}$ | 7.27±0.48$^{b}$ | 7.14±0.48$^{b}$ |
| MCHC | 33.55± 0.77$^{ab}$ | 33.71±0.77$^{ab}$ | 35.02±0.77$^{a}$ | 34.14±0.77$^{ab}$ | 32.30±0.77$^{b}$ |
| PLA x $10^3$/mm$^3$ | 3.80±0.14$^{c}$ | 4.80± 0.14$^{ab}$ | 5.07± 0.14$^{a}$ | 5.00±0.14$^{ab}$ | 4.60±0.14$^{b}$ |
| WBC $10^6$/mm$^3$ | 13.90±0.07$^{b}$ | 14.00±0.07$^{b}$ | 15.80±0.07$^{a}$ | 13.10±0.07$^{d}$ | 13.40±0.07$^{c}$ |
| N% | 49.00±0.58$^{c}$ | 57.00±0.58$^{a}$ | 48.00±0.58$^{c}$ | 52.00±0.58$^{b}$ | 48.00±0.58$^{c}$ |
| L% | 43.00±0.58$^{a}$ | 35.00±0.58$^{d}$ | 41.00±0.58$^{b}$ | 37.00±0.58$^{c}$ | 43.00±0.58$^{a}$ |
| M% | 7.00±0.58$^{a}$ | 7.00±0.58$^{a}$ | 8.00±0.58$^{a}$ | 8.00±0.58$^{a}$ | 8.00±0.58$^{a}$ |
| E% | 1.00±0.32$^{b}$ | 1.00±0.32$^{b}$ | 3.00±0.32$^{a}$ | 3.00±0.32$^{a}$ | 1.00±0.32$^{b}$ |

Means within the same row with different superscripts differ significantly ($p<0.05$).
Keys; PCV= Packed cell volume, Hb= Haemoglobin concentration, PLA= Platelets, MCV= Mean corpuscular volume, MCH=Mean corpuscular haemoglobin, MCHC= Mean corpuscular haemoglobin concentration, WBC= White blood cell, N= neutrophils, L= lymphocyte, M= monocyte E= eosinophil

## CONCLUSION

From the findings of this study, it can be concluded that dietary *Musa acumulata* peel powder (MAPP) at 3% inclusion level can be used as prebiotic in *Clarias gariepinus* diets to increased WBC and Hb and hence, enhanced immune response. Further study on the effects of MAPP inclusion on Serum chemistry of the African catfish is recommended.

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# RESISTANCE PATTERN OF GRAM-NEGATIVE BACTERIA ISOLATED FROM SMOKED CATFISH SOLD IN SOME MARKETS IN ZARIA, KADUNA STATE, NIGERIA

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**ABSTRACT**
*The bacteriological quality of smoked catfish sold in three major markets within Zaria metropolis were determined; identification of Gram-negative bacterial contaminants and antimicrobial resistance to some antibiotics was conducted. A total of sixty smoked catfish samples were procured, precisely 20 samples from each market location (Sabo, Samaru and Zaria city). These were analysed for proximate composition, enumeration and isolation of microorganism were determined by standard procedures and Gram-negative isolates confirmed by Microgen GnA+ B; and antibiogram of isolates were determined by disk diffusion method. Mean values of proximate composition varied across the locations as follows: moisture content: 6.25 ± 1.01 (Zaria city), ash content: 11.45 ± 1.90 (Sabo), lipid content: 18.14 ± 5.96 (Samaru), crude protein: 61.26 ± 6.68 (Sabo), fibre: was not detected, and carbohydrate: 10.16 ± 5.68 (Sabo). Microbial population were determined and expressed as colony forming units per gram of sample (cfu/g) for total coliform counts. Mean values of the counts varied across the locations as follows: TCC: $1.27 \times 10^6 \pm 7.18 \times 10^5$ (Sabo). The differences in mean values of the bacterial counts were statistically significant ($P < 0.05$) using ANOVA with P value 0.0124. The following Gram-negative bacterial species were identified in the study: Proteus mirabilis, Cronobacter sakazakii, Pantoea agglomerans, Klebsiella oxytoca, Proteus vulgaris and Morganella morganii. The Multiple Antibiotic Resistance (MAR) indices of the bacterial isolates ranged from (0.5 to 0.6)*

**Keywords**: *Smoked, Catfish, Market and Resistance*

## INTRODUCTION

Foods are complex mixtures of chemicals and often contain compounds that are potentially harmful as well as those that are beneficial. It is a source of nutrients, central to good health, prosperity, social well-being of individuals and societies. Foods may also act as the vehicle by which an exogenous harmful agent may be ingested. This may be a pesticide, some other chemical contaminant added by design or accident, a microorganism or its toxin. When foods are not handled hygienically, it could be a medium for disease transmission.

Smoked catfish products are sold in the markets in different parts of the Nigeria for human consumption. Fish and fishery products constitute an important food item that most Nigerians cherish. Most fishes are low fat with few exceptions, high in protein and contains beneficial fatty acids such as omega-3 fatty acids (Odu and Imaku, 2013). In spite of these valuable nutrients derivable from fish, it is a perishable food as it loses its freshness in short time due to the microbial spoilage and autolysis (FSA, 2004; Dehghani *et al*. 2018).

The traditional methods of fish preservation which comprises of smoking, drying, salting, frying, fermenting and various combinations of these are employed to preserve and process fish for consumption and storage (Eyo, 2001). Smoking of foodstuffs have great importance on the improvement of food organoleptic characteristics, induces water loss, and reduces the microbial load. (Chakraborty and

Chakraborty 2017; Legese 2021). During smoking, the fish is preserved by drying, cooking and depositing natural wood–smoke chemicals like tars, phenols and aldehydes all of which have powerful bactericidal action and prevent the growth of other microorganisms on the flesh of the fish (Garrow and James, 2000). The smoke produced by the process of incomplete combustion of the wood then impacts a characteristic flavour and colour to the fish. The smoke determines the colour which ranges from black, dark brown, golden brown or light brown to dirty white (Clucas, 1981; Aremu *et al.*, 2013; Akinwumi *et al.*, 2015). In some instances that smoking is done for the enhancement of flavour and texture to the fish, this form of processing sometimes provides little or no protection against microbiological, enzymatic and chemical deteriorative factors, leading to the smoked food spoiling as readily as non-smoked foods (Jeyasanta *et al.*, 2015).

The usual practice of post smoking handling of smoked fish for consumption and trade is associated with handling with bare hands; drying on mat, or baskets and display in open bowls at points of sale. The microbial density of the dried fish is a reflection of the processing methods and hygienic level of processors and sellers. The consumption of smoked fish the way in which they are handled and the sanitary conditions in the smokehouse may contribute to the microflora present on the final product and to the growth of foodborne pathogens (Adedeji *et al.*, 2012).
Food quality varies from locations, time and seasons, it is evident that lack of stiff standardization and monitoring system towards smoked fish had invariably permitted poor handling practice.

Antimicrobial resistance has become increasingly evident, it threatens the effective prevention and treatment of wide range of infections caused by bacteria, parasites, viruses and fungi which are no longer susceptible to the commonly used medicines to treat them (Prestinaci *et al.*, 2016). There are concerns about the relationship of drug-resistant bacteria in human to antibiotic use in food animals (Marshall and Levy, 2011). Many have delved into this question, producing volumes of direct and indirect evidence linking animal use to antibiotic resistance confronting people. Among these are a number of studies which unequivocally support the concern that use of antibiotics in food animals (particularly nontherapeutic use) impacts the health of people on farms and, more distantly, via the food chain (Marshall and Levy, 2011). The aim of study is to determine the antimicrobial resistance pattern of some Gram-negative bacteria isolated from smoked catfish.

## MATERIALS AND METHODS

A total of 60 samples each weighing (100g) of smoked catfish were procured, comprised of 20 samples from each market (Sabo, Samaru and Zaria city) that were randomly selected and transported in sterile polythene bag to the laboratory for analyses. The fish samples were homogenized in a sterile mortar and pestle and ground into fine powder. The ground sample was used to determine parameters of proximate composition using Association of Analytical Chemist method (AOAC, 2005) and microbiological analyses using standard procedures.

For the microbiological analyses 25g of homogenized samples was mixed with 225ml of sterile peptone water to form a stock suspension. The suspension was subjected to ten- fold serial dilution in 9ml of sterile peptone water as diluent using 1ml sterile pipette. From the appropriate dilutions, 0.1ml was plated out on MaCconky agar using the spread plate method to determine viable plate counts. Plates containing 30 - 300 colonies were selected and counted at the expiration of the incubation period using the colony counter. Bacterial counts were expressed as colony - forming units per gram of smoked catfish sample (cfu/g). This was further confirmed by streaking the colonies on Levine's Eosin Methylene Blue (EMB) Agar and incubate at 37°C for 24 h. Pure cultures of all discrete colonies exhibiting typical dark to purple red colonies with metallic sheen which is characteristic of *E. coli* on EMB were recorded. The characterization and identification of bacterial isolates was carried out using standard conventional

methods. The colonial and morphological characterization of isolated colonies was done by observing and recording their colour and appearances. Isolates were subjected to Gram reaction as well as other biochemical tests. The Gram-negative bacterial isolates were confirmed by Microgen GnA+ B. Antimicrobial susceptibility test of identified bacterial isolates from sample was performed by the disk diffusion method using antibiotic discs on Mueller-Hinton agar. The antibiotics that were used in the disc susceptibility test include Ampicillin, Sulfamethoxazole/Trimethoprim, Azithromycin, Amoxicillin Clavulanate, Chloramphenicol, Ampicillin, Nitrofuratoin, Tetracycline, and Nalidixic acid. Zones of inhibition were measured in millimeter (mm) using a ruler and interpreted according to Clinical Laboratory Standard Institute (CLSI 2022) guidelines.

## RESULTS AND DISCUSSION

**Table 1:** Proximate Composition of Smoked Catfish Samples from Market Locations

| Market location | Moisture (%) | Ash (%) | Lipid (%) | Protein (%) | Fibre (%) | Carbohydrate (%) |
|---|---|---|---|---|---|---|
| Sabo | 5.97 ± 0.92 | 11.45 ±1.90 | 11.16 ± 4.82 | 61.26 ± 6.68 | 0 | 10.16 ± 5.68 |
| Samaru | 4.46 ± 1.29 | 9.08 ± 1.38 | 22.08 ± 6.44 | 58.12 ± 4.31 | 0 | 6.37 ± 4.49 |
| Zaria city | 6.25 ± 1.01 | 9.76 ± 2.62 | 18.14 ± 5.96 | 61.02 ± 6.16 | 0 | 2.60 ± 1.23 |

**Table 2** Means of Total Coliform Counts and Salmonella-Shigella Counts of bacteria on Smoked Catfish Samples from Different Market Locations

| Market Location | TCC (cfu/g) | P value |
|---|---|---|
| Sabo | $1.27 \times 10^6 \pm 7.18 \times 10^5$ | 0.0124 |
| Samaru | $8.66 \times 10^5 \pm 4.42 \times 10^5$ | 0.0124 |
| Zaria city | $3.35 \times 10^5 \pm 4.72 \times 10^5$ | 0.0124 |

**KEY**: MEAN±SD, P= ANOVA, TCC = Total Coliform Counts

Proximate composition of smoked catfish from different market locations is shown in Table 1. Total coliform count is shown in Table 2. Samples from Sabo had the highest TCC mean values ($1.27 \times 10^6 \pm 7.18 \times 10^5$) while the least mean value ($3.35 \times 10^5 \pm 4.72 \times 10^5$) were samples from Zaria city. Microgen GnA+B-ID System was used for the confirmation of some of the presumptive Gram-negative isolates. The following Gram negative bacteria were identified: *Klebsiella oxytoca* , *Pantoea agglomerans*, , *Proteus mirabilis*, *Cronobacter sakazakii*, *Proteus bulgaris*, and *Morganella morganii*.

The result of the antibiotic resistance pattern is shown in Table 3 the number of antibiotics resisted ranged from 3 to 5. Some of the isolates can be described as being multi-drug resistant (that is antibiotic resistance of at least one antibiotic from three or more classes (Magiorakos *et al*., 2012). The Multiple Antibiotic Resistance (MAR) index (ratio of number of antibiotics resisted to number of antibiotics tested) ranged from 0.4 to 0.6. *klebsiella oxytoca*, *Proteus vulgaris* and *Cronobacter sakazakii* had a MAR index of 0.6, *Proteus mirabilis*, and *Pantoea agglomerans*, had a MAR index of 0.5.

## DISCUSSION

Coliforms are among the indicator organisms whose presence especially in high numbers indicate a possibility of pathogenic organisms being present (FAO, 1992). Accordingly, coliform bacteria were recorded in all the market locations with these range of values recorded Sabo: $4.8 \times 10^5 – 3.0 \times 10^6$ cfu/g, Samaru: $1.8 \times 10^5 – 1.5 \times 10^6$ cfu/g and Zaria city: $8.0 \times 10^4 – 2.2 \times 10^6$ cfu/g. These values are within the acceptable limits (230 cfu/100g) by ICMSF, (1996) but higher than SON limit (NIS 2018). Essentially, the presence of high coliform load on smoked catfish, will be an indication of environmental contamination or pollution (ICMSF, 1996)

The population density from this study was comparable to other studies on smoked fish in Nigeria. Adegunwa *et al*., (2013) studied the microbial quality of smoked herring (*Sardinella eba*) at Odeda local government, Ogun state, Nigeria and reported Salmonella- Shigella (0.00, that is not detected). Ineyougha *et al*., (2015) reported that Salmonella-Shigella counts ranged from 0.201 –1.745

| Isolate | No of Antibiotics Tested | No of Antibiotics Resisted | No of Antibiotics Classes Resisted | Resistance Pattern | MAR Index |
|---|---|---|---|---|---|
| *Klebsiella oxytoca* | 8 | 5 | 4 | SXT, C, TE, AMC, AMP | 0.6 |
| *Pantoea agglomerans* | 8 | 5 | 4 | SXT, C, TE, AMC, AMP | 0.5 |
| *Proteus mirabilis* | 8 | 4 | 3 | NA, TE, AMC, AMP | 0.5 |
| *Proteus vulgaris* | 8 | 5 | 4 | SXT, NA, TE, AMC, AMP | 0.6 |
| *Cronobacter sakazakii* | 8 | 5 | 4 | SXT,C, TE, AMC, AMP | 0.6 |

KEY: AMC= Amoxicillin Clavulanate, AZM= Azithromycin, SXT= Sulfamethoxazole/Trimethoprim, NA= Nalidixic acid, AMP= Ampicillin, TE= Tetracycline, F= Nitrofuratoin, C= Chloramphenicol, MAR= Multiple Antibiotic Resistance

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# EVALUATION OF MICROBIAL LOAD OF AFRICAN CATFISH (*Clarias gariepinus*) SOURCED FROM SELECTED MARKETS IN RIVERS STATE, NIGERIA

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**ABSTRACT**

*As a result of the poor handling and the unhygienic environment in open markets where African catfish (Clarias gariepinus) is being sold, necessitated this study in order to ensure food safety, nutritional value and overall quality for consumers. The microbiological quality of parts of catfish samples, purchased from open markets in Rumuokoro, Mile 1 and Oil Mill, Rivers State, Nigeria, was analyzed using standard analytical methods. The bacterial and fungal isolates from the fish parts includes Bacillus spp, Entrococcus spp, Escherichia spp, Micrococcus spp, Salmonella spp, Pseudomanas spp, Shigalla spp, Entrobcater spp and Staphylococcus spp, while the fungal isolates include, Aspergillus spp, Penicillium spp, Mucor spp and Rhizopus spp. The bacterial counts in the fish parts across the market locations ranged from ($1.1\times10^2$ – $6.1\times10^4$ cfu/g) while the fungal counts ranged from ($1.0\times10^3$ – $5.0\times10^2$ cfu/g). The bacterial isolated from the catfish parts across the market locations showed that Escherichia spp. (16.7%) was the most predominant organism, followed by Enterococcus spp. (14.1%), Bacillus spp. (11.5%), Salmonella spp. (11.5%), Entrobacter spp. (10.3 %), Shigalla spp. (8.9 %), Pseudomonas spp. (7.7%) and Staphylococcus spp. (7.7%). Majority of the bacterial isolates were found in the skin of the fish samples. The fungal isolates were majorly found in the intestine of the fish parts. Results obtained from this study proved that, African catfish (Clarias gariepinus) purchased from these various markets contains pathogenic microorganisms. Hence, catfish purchased from these markets, should be thoroughly washed and cooked before consumption can take place.*

**Keywords:**
Microbiological; Catfish (*Clarias gariepinus*); Markets

## INTRODUCTION

Fish and fishery products are widely considered high-risk foods due to their susceptibility to contamination by pathogens, natural toxins, and other harmful substances. Globally, foodborne illnesses remain a leading cause of disease and mortality (Yousuf *et al*., 2008). These illnesses are frequently caused by the ingestion of bacterial toxins or microorganisms present in contaminated food. According to Wafaa *et al*. (2011), fish and seafood are vital dietary components for a significant portion of the global population, serving as a key source of animal protein after meat and poultry, largely due to their affordability. In recent years, public awareness of the nutritional value and health benefits of consuming fish has grown considerably (Amusan *et al*., 2010). As a result, more individuals are substituting red meat with fish in their diets. It is estimated that microbial activity alone is responsible for the spoilage of approximately 30% of all fish caught (Ghaly *et al*., 2010). Bacteria commonly found in aquatic environments include *Pseudomonas fluorescens*, *Aeromonas hydrophila*, *Edwardsiella tarda*, and various *Vibrio* species (Gilmour *et al*., 2016). Pathogens such as *E. coli*, *Salmonella*, and *Shigella* often enter water systems through fecal contamination from humans or animals, posing health risks when fish from such waters are consumed. During the harvesting of catfish (*Clarias gariepinus*), contamination can also occur through the equipment used, leading to spoilage. Being highly perishable, catfish often suffer post-

harvest losses and face market rejections. Freshness is typically the most critical quality attribute for determining the market value and acceptability of catfish. Additionally, storage and handling conditions play a significant role in determining microbial activity (Doyle, 2007). Under aerobic refrigeration, Pseudomonas and Shewanella are commonly found on fresh fish (Fitzgerald *et al.*, 2003; Hozbor *et al.*, 2006; Doyle, 2007). Therefore, this research was conducted to isolate, characterize, and identify microorganisms associated with fresh catfish (C*larias gariepinus*) obtained from selected open markets (Rumuokoro, Mile 1, and Oil Mill Market) within Port Harcourt Metropolis, Rivers State, Nigeria.

## MATERIALS AND METHODS

### Materials

Samples of live Catfish (C*larias gariepinus*)

### Methods

#### Sample Collection and Preservation

From each market, 6 catfish samples were randomly collected from different vendors. The fish were immediately packaged in separate labeled clean polythene bags, kept in an ice chest to maintain freshness and conveyed to the laboratory for analysis.

#### Sample Preparation

The fish samples were first measured for standard length using a measuring board, which were between 28–40 cm, while their weights were recorded using a digital weighing balance (Model C830), which weighed between 500-100 g. Dissection was carried out with a sterile knife to extract the intestine, gills, and skin individually. These organs were then oven-dried at 40°C. Once dried, each organ was blended separately to ensure uniformity and then weighed in preparation for microbiological analysis.

#### Microbiological Analysis of Fish Organs

The bacterial counts on the skin, intestine and gills were estimated as follows;

#### Skin Surface

To estimate the bacterial load on the fish skin, a sterile wire swab guide measuring 5 cm by 2 cm was placed along the lateral surface of each fish specimen. A sterile cotton swab, previously moistened with 0.10% sterile peptone water, was used to thoroughly swab the designated area. The swab was then transferred into a sterile container holding 100 mL of 0.10% (w/v) peptone water. The mixture was agitated vigorously for 10 minutes and subsequently left undisturbed for 20 minutes. A series of tenfold serial dilutions was then prepared in duplicate. This procedure was performed independently for each fish sample as described by Slaby *et al*. (2001).

#### Intestines and Gills

Ten grams of each organ (intestines and gills) were aseptically excised, homogenized, and placed into a sterile bottle containing 90 mL of 0.1% peptone water. The mixture was vigorously shaken for 10 minutes and allowed to settle for 20 minutes. Tenfold serial dilutions were then prepared in duplicates, and viable aerobic bacteria were counted using standard plate count agar after incubation at 37°C for 48 hours, as per the protocol of Slaby *et al.* (2001).

## RESULTS

### Microbiological Analysis

#### Total Coliform and Fungal Counts of Catfish Samples

Table 1 presents the total coliform and fungal count of the catfish samples (C*larias gariepinus*) samples

from three market locations. The range of the coliform count recorded for the fish parts across the various markets was from ($1.1\times10^2$ – $6.2\times10^3$ cfu/g), while the fungal counts ranged from ($1.0\times10^3$ – $5.0\times10^2$cfu/g). From the results, the highest coliform count was found in the intestine of the fish sample from Mile 1 market ($6.2\times10^3$ cfu/g) while the lowest coliform count was equally seen in the skin sample from Mile 1 market ($1.1\times10^2$ cfu/g). The highest fungal count was recorded in the intestine of the fish sample from Mile 1 market ($5.0\times10^2$ cfu/g), while the lowest fungal count was equally recorded in the skin of the fish sample from Mile 1 market ($1.0\times10^3$ cfu/g).

**Table 1:** Total Coliform and Fungal Counts (cfu/g) of Catfish (*Clarias gariepinus*) Samples

| Location | Isolated Fish Parts | TCC (cfu/g) | TFC (cfu/g | SON Acceptable Limit (NCP – 2018) |
|---|---|---|---|---|
| Rumuokoro | Gills | $5.3\times10^6$ | $2.5\times10^5$ | Unsatisfactory |
| Mkt | Intestine | $4.5\times10^5$ | $1.8\times10^5$ | Unsatisfactory |
| | Skin | $2.8\times10^6$ | $1.5\times10^6$ | Unsatisfactory |
| Mile 1 Mkt | Gills | $1.5\times10^3$ | $2.5\times10^3$ | Satisfactory |
| | Intestine | $6.2\times10^3$ | $5.0\times10^2$ | Satisfactory |
| | Skin | $1.1\times10^2$ | $1.0\times10^2$ | Satisfactory |
| Oil Mill Mkt | Gills | $5.0\times10^4$ | $1.9\times10^4$ | Marginal |
| | Intestine | $6.1\times10^4$ | $1.8\times10^2$ | Marginal |
| | Skin | $4.5\times10^4$ | $2.6\times10^3$ | Marginal |

Key: Data are Mean of Triplicate Determination, Mkt = Market, Satisfactory $<10^3$, Marginal $< 10^4$, Unsatisfactory $>10^5$, SON = Standard Organization of Nigeria (NCP-Nigerian Code for Practice for Fish)

Table 2 shows that the identified bacterial isolates were Bacillus spp, Enterococcus spp, Escherichia spp, Micrococcus spp, Salmonella spp, Pseudomonas spp, Shigalla spp, Entrobacter spp. and Staphylococcus spp.

**Table 2:** Characterization and Identification of Bacterial Isolates from Catfish (*Clarias gariepinus*) Samples.

| Location | Isolated Fish Part | Microscopic Appearance MCA | Shape | Form | Morphological Identity Gram Reaction | Motility | MR = VP | Imdole | Citrate | Catalasr | Coagulance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rumuokoro | Gills | Pink Cocci | Convex circular | - | - | - | + | - | + | - | Bacillus spp. |
| Mkt | Intestine | Green Rod | Convex spindle | + | + | - | + | + | - | + | Enterococcus spp. |
| | Skin | White Rod | Convex spindle | + | + | + | - | + | + | + | Escherichia coli |
| Mile 1 Mkt | Gills | White Rod | Spherical | - | + | + | - | + | + | + | Micrococcus spp. |
| | Intestine | Green Cocci | Convex spindle | + | - | - | + | - | + | + | Pseudomonas spp. |
| | Skin | Pink Cocci | Convex spindle | + | + | - | + | - | - | + | Salmonella spp. |
| Oil Mill Mkt | Gills | White Rod | Convex irregular | - | - | + | - | + | - | + | Shigella spp. |
| | Intestine | Green Rod | Convex irregular | + | + | + | - | + | + | + | Entrobacter spp. |
| | Skin | Pink Rod | Convex irregular | - | - | + | - | - | - | - | Staphylococcus spp. |

Key: MR-VP = Methyl Red- Vogues Proskauertest, MCA = MacConkey Agar.

**Table 3:** Frequency Occurrence of Bacterial Isolates from Catfish (*Clarias gariepinus*) Samples

| Location | Isolates | No. of Isolates Gills | Intestine | Skin | Fish Parts | % Rate |
|---|---|---|---|---|---|---|
| Rumuokoro | *Bacillus spp.* | 9 | 2 | 3 | 4 | 11.5 |
| Mkt | Enterococcus spp. | 11 | 2 | 4 | 5 | 14.1 |
| | *Escherichia spp.* | 1 | 6 | 2 | 5 | 16.7 |
| Mile 1 Mkt | *Micrococcus spp.* | 9 | 3 | 2 | 4 | 11.5 |
| | *Salmonella spp.* | 9 | 2 | 5 | 2 | 11.5 |
| | *Pseudomonas spp.* | 6 | 1 | 2 | 3 | 7.7 |
| | *Shigalla spp.* | 7 | 1 | 3 | 3 | 8.9 |
| Oil Mill Mkt | *Entrobacter spp.* | 8 | 1 | 3 | 4 | 10.3 |
| | *Staphylococcus spp.* | 6 | 1 | 3 | 2 | 7.7 |
| **Total** | | **78** | **19** | **27** | **32** | **100.0** |

**Frequency Occurrence of Fungal Isolates from Catfish Samples**

Table 4 shows the frequency occurrence of fungal isolates. A total of 23 fungal isolates were obtained in this study.

**Table 4:** Frequency Occurrence of Fungal Isolates from Catfish (*Clarias gariepinus*)

| Location | Isolates Gills | No. of Isolates | Fish Parts | Intestine | Skin | % Rate |
|---|---|---|---|---|---|---|
| Rumuokoro Mkt | Aspergillus spp. | 5 | 2 | 1 | 2 | 21.7 |
| Mile 1 Mkt | Penicillium spp. | 6 | 1 | 3 | 2 | 26.1 |
| Oil Mill Mkt | Mucor spp. | 5 | 1 | 3 | 1 | 21.7 |
| | Rhizopus spp. | 7 | 2 | 4 | 1 | 30.4 |
| Total | | 23 | 6 | 11 | 6 | 100.0 |

## DISCUSSION

**Microbial Load of Catfish (*Clarias gariepinus*) Parts**

The findings from the microbial analysis indicate that the catfish samples obtained from Rumuokoro, Mile 1, and Oil Mill markets were contaminated with a range of bacterial and fungal species. Identified bacterial isolates included Bacillus spp., Enterococcus spp., Escherichia spp., Micrococcus spp., Salmonella spp., Pseudomonas spp., Shigella spp., Enterobacter spp., and Staphylococcus spp. Fungal contaminants observed were Aspergillus sp., Penicillium sp., Mucor sp., and Rhizopus sp. The detection of these microorganisms is likely linked to the poor hygiene practices prevalent in the market environments, as well as contamination from fish handlers, containers, or other related sources. These results are consistent with the study by Adebayo *et al.* (2016), who reported similar microbial species in catfish sold in open markets in Ado-Ekiti, Ekiti State, Nigeria. Notably, the total coliform count was highest in the intestines of fish from Mile 1 market, followed by the gills and skin, with lower counts observed in samples from Rumuokoro and Oil Mill markets. This elevated intestinal contamination could be attributed to the particularly unhygienic conditions at Mile 1 market, facilitating microbial ingestion and accumulation in the gastrointestinal tract. Among the bacterial isolates, Escherichia coli emerged as the most frequently encountered species across the three market locations. Regarding fungal isolates, Rhizopus spp. was the most prevalent across different parts of the fish. This prevalence may result from inadequate hygiene practices by fish vendors and handlers. Spore-forming bacteria are often associated with the spoilage of heat-treated food products due to their ability to survive high temperatures (Doyle, 2007). Species of Pseudomonas such as P. fluorescens, P. fragi, P. lundensis, and P. viridiflava are among the primary spoilage agents in food (Doyle, 2007). The presence of Aspergillus spp. in the catfish samples is particularly concerning, as this genus is known to produce harmful mycotoxins. Aspergillus species are notable for their rapid growth, tolerance to high temperatures, and ability to survive in low-moisture environments, outcompeting Penicillium spp. under temperate conditions (Doyle, 2007). Penicillium and related fungi are commonly found in soils and decaying plant matter in both tropical and polar climates.

## CONCLUSION

This study was aimed to provide vital information on microbiological quality of parts/organs of catfish (*Clarias gariepinus)*, sourced from open markets in Rumuokoro, Mile 1 and Oil Mill, in Port Harcourt Metropolis, Rivers State. Results revealed that samples from Rumuokoro market had coliform and fungal loads exceeding acceptable safety limits, indicating potential health risks. Notably, the skin of the catfish samples harbored the majority of bacterial isolates, while the intestine showed the highest concentration

of fungal organisms. These findings highlight the varying microbial contamination levels across different fish organs and market sources, underscoring the importance of hygienic handling and proper market conditions in ensuring food safety.

## RECOMMENDATIONS

This study suggests that:

(i) Catfish vendors, especially at Rumuokoro market, should be sensitized and trained on proper hygiene practices during handling, processing and storage of fish to reduce microbial contamination

(ii) Routine monitoring and inspection by regulatory agencies should be carried out regularly on microbiological assessments of fish and other perishable products sold in open markets, in order to enforce food safety standards.

(iii) Consumers should be educated on proper washing, cooking and handling of catfish to minimize the risks of food borne illness.

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# SKIN HISTOLOGY OF *Clarias gariepinus* JUVENILES EXPOSED TO ACUTE TREATMENT OF HERBICIDES FORCE UP (GLYPHOSATE)

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**ABSTRACT**
*The research assessed the possibility of glyphosate bioaccumulation and its morphological effects in various freshwater fish organs, specifically Clarias gariepinus, following a single acute intraperitoneal exposure of 0, 20, 22, 24, 26 and 28 mg/l (with a limit of tolerance of 23.03 mg/l) and over gradually extended exposure durations (24 h, 48 h, 72 h, and 96 h). The target organ (skin) had varying and time-dependent glyphosate accumulation. Only at the 96-hour exposure point did the skin display the highest levels of herbicide glyphosate accumulation and accumulation. Within 24 hours of glyphosate exposure, histopathological changes were seen in the skin; these changes grew more pronounced and extensive after 96 hours. Based on the observation of initial damage from glyphosate exposure, histopathology is a sensitive technique to observe it. These results demonstrated a correlation between glyphosate accumulation and the induced morphological damages in different organs along the time in a tropical fish species, Clarias gariepinus*

**Keywords**: Skin, Histology, Juvenile, Herbicide, *Clarias gariepinus*

## INTRODUCTION

With aquaculture offering a consistent supply of fish for human consumption and revenue generation, the industry is growing quickly on a global scale (Bala et al 2014). However, the industry faces a number of difficulties that could jeopardize its sustainability and productivity, such as parasites, diseases, pests, and environmental pollution (Agbon *et al.* 2017). Herbicides are a major source of environmental pollution in aquaculture because they are frequently used to control weeds and unwanted vegetation in ponds, lakes, and rivers. In both terrestrial and aquatic settings, herbicides like glyphosate are frequently used. Their residues can linger in water and sediments, which may have an impact on the survival and well-being of aquatic life. It is known that herbicides are used in agricultural practices all over the world to control weeds (Nwani et al. 2020), through extensive and improper use of these herbicides can infiltrate aquatic ecosystems, resulting in detrimental impacts on fish populations, cellular processes, growth, and behavior (Rani and Deepak, 2020). The non-selective herbicide glyphosate is well-known for its ability to effectively suppress weeds and other undesirable plants. But according to recent research, there may be a toxicity issue for fish and other aquatic life (Akinrotimi and Amachree, 2016).

Numerous pathways, such as runoff from industrial sites, cities, and agricultural fields, can allow glyphosate to get into waterways. Glyphosate can be absorbed by aquatic organisms, such as fish, through their gills or by coming into direct contact with their skin. This can result in both acute and long-term toxicity. Histopathological changes have been widely used as biomarkers in the evaluation of the health of fish exposed to toxins (Thophon et al., 2003). Toxicological evaluation in aquatics can also be carried out by using biomarkers C*larias gariepinus* is found throughout much of Africa, from Algeria to South Africa and from the Nile to West Africa. It is widely cultivated and very profitable in the majority of Nigeria's fish farms. In Nigeria, it is also the most popular freshwater fish that is frequently eaten (Olaifa, et al. 2004), it breathes quickly and it can withstand a wide variety of foods and thrive in water with low oxygen levels. The aim of the paper is to determine skin histology of Clarias gariepinus juveniles exposed to acute treatment of herbicides force up.

## MATERIALS AND METHODS

### Experimental Site and fish

The experiment was conducted at the Zoology Laboratory Mau Yola One hundred and eighty (180) C. *gariepinus* juveniles (mean weight 18.53 ± 0.7 g and mean length 12.22 ± 0.3 cm) were used for the study. The fish were purchased from a reputed fish farm in Kano, Kano State.

### Experimental Design and Source of glyphosate

A completely randomized design was used for the experiment. A total of eighteen (18) plastic tanks with a capacity of (60cm x 40cm x 40cm) were used. The plastic tanks were thoroughly washed and then filled with 20 liters of water. All plastic tanks were marked. The fish were weighed and distributed into 10 fish per tank. A total of one hundred and eighty (180) C. *gariepinus* juveniles were randomly placed into the tanks in triplicate at a stocking rate of 10 fish per tank. Glyphoste with the trade name "Force Up" was purchased as a commercial herbicide from an agribusiness store at Jimeta Modern Market Adamawa State, Nigeria.

### Definitive Test

The concentration level to be used in the final test was guided by the scoping test results. The last test involved the filling of eighteen (18) plastic tanks, each holding twenty liters of water. Glyphosate concentrations that had been previously established by a removal test were used for the test. The glyphosate concentrations that were utilized were 0 mg, 20 mg, 22 mg, 24 mg, 26 mg, and 28 mg mg/L per liter of water. A sensitive balance was used to prepare the various concentrations. Fish non-reaction to glyphosate was lethal to 50% of the test organism after 96 hours of exposure, and fish response to mild stimuli was used as an indicator of toxicity.

### Histological studies

Histological analysis was carried out in the Department of Veterinary Nursing, Ahmadu Bello University, Zaria, Kadu,na State. At the end of the experiment, after 96 hours of exposure, one fish per treatment, i.e. three fish per concentration, was sampled. The organs were fixed in 10% formalin for three days, after which the tissue was dehydrated in periodic Schiff's reagent (PAS) according to the methods of (Hughes and Perry, 1976) at graded concentrations of 50, 70, 90 and 100% alcohol three Days for the paraffin to penetrate. Fish intestines were collected and fixed in Bouin's fluid for 24 h, dehydrated in graded ethanol concentrations, and embedded in paraffin wax. Sagittal sections (5 µm thick) were cut and mounted on glass slides. Sections were deparaffinized in xylene, hydrated in ethanol, and stained with hematoxylin-eosin (H&E). The skin was quickly dissected, cut into 3 mm thick slices and immersed in Bouin's fixative for 24 hours, dehydrated and embedded in paraffin; At least 5 pieces were created. Histological sections (5 µm thick) were cut and stained with H&E. Changes in the intestine and skin tissue caused by the treatment were photographed and analyzed using light microscopy.

### Statistical Analysis

Data were analyzed using Minitab 17 to obtain a summary of water quality parameter statistics. The mean lethal concentration ($LC_{50}$) for 96 hours was calculated using probit analysis (Finney, 1971).

## RESULTS AND DISCUSSION

The degree of histopathological alterations of C*larias gariepinus* skin was scored, and the changes were compared with the level of herbicides found in the vital organs of caught specimens. Fish are exposed to herbicides both directly from water and sediment and indirectly through the food chain, especially glyphosate. Pesticides bioaccumulate affects the structure and function of fish vital organs. Section of the skin of C. *gariepinus* juveniles exposed to acute concentrations of glyphosate revealed continuous and

gradual striking histological alterations such as enlarged alarm cell, numerous mucous cells, stratified squamous cells, inflammatory epithermal cells, focal necrotic epidermis, oedematous dermis, e.t.c. These changes are concentration and duration dependent. The observation was similar to the report by Heimroth et al. (2018) and Isiyaku et al. (2015) who reported a progressive moderate to severe histo-architectural changes observed in the gills of C. *gariepinus* exposed to concentrated grades of *V. amydalina* and mercury chloride which depicted a dose- dependent distortion especially with marked severity in those given the high concentration of the extract. The skin is recognized as a secondary respiratory tissue in several species (Urbina and Meredith 2014), and in catfish, epidermal mucus is directly related to respiratory physiology (Heimroth et al. 2018).

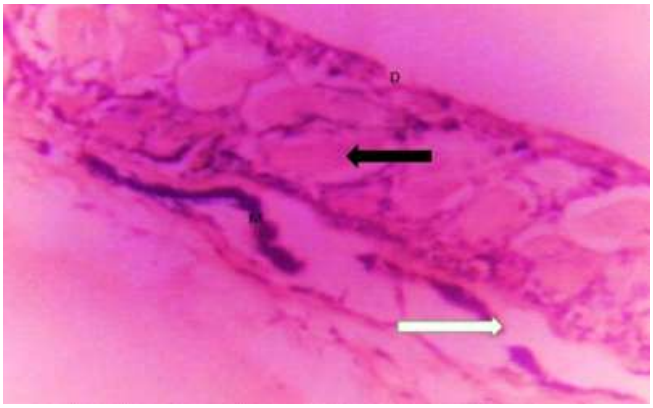



**Figure 1:** Skin of C. *gariepinus* expose to 0ml force-up shows normal architecture, the dermis, epidermal layer, mucous cell and epithelia surface, lymphocytes, goblet

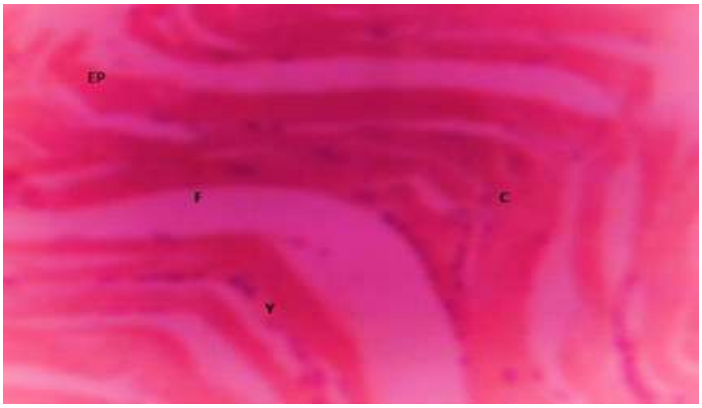



**Figure 2:** Skin of C. *gariepinus* expose to 20ml force-up shows showed thick epidermis of stratified squamo epithelium tissue, fibroblast and melanophores anus d hyperplasia of mucoid producing cells

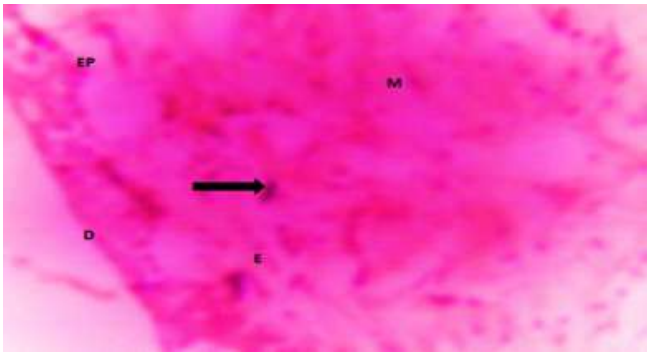



**Figure 3:** Skin of C. *gariepinus* expose to 22ml force-up shows a large goblet oblet cells of large size, spherical, oval shape and connective tissue, Melanocytes and dermis

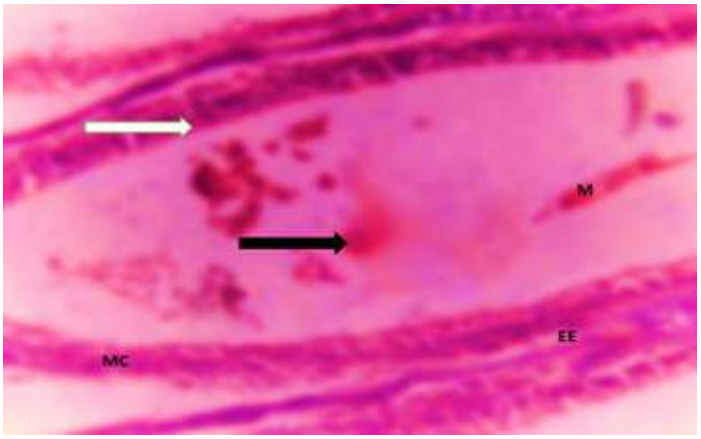



**Figure 4:** Skin of C. *gariepinus* expose to 24ml force-up shows thick epidermis of stratified squamous epithelium tissue composed of epidermis, goblet cell, Some epidermal mucous cells contain proteins, melanophores, and Club cell.

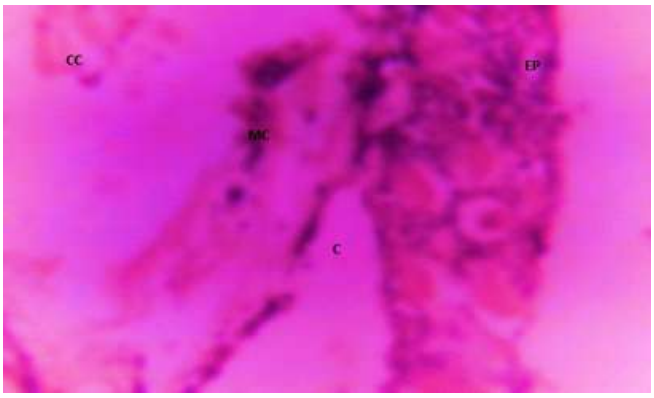



**Figure 5:** Skin of C. *gariepinus* expose to 26ml force-up shows the dermis, proliferated and hypertrophied mucous cells, eroded epithelia surface and elaborated mucous and Sulphated glycoproteins in mucous cells.

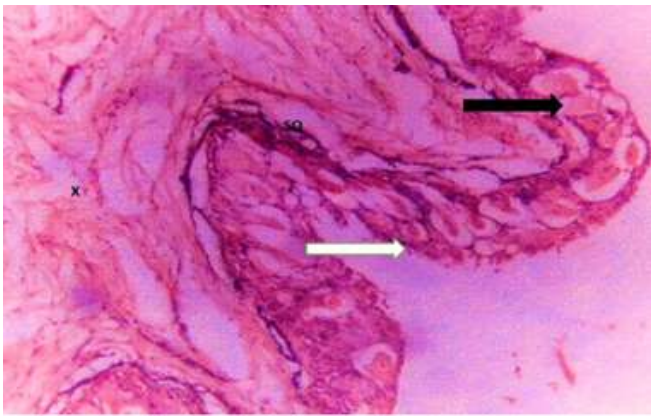



**Figure 6:** Skin of C. *gariepinus* expose to 28ml force-up shows thickened epidermal layer (white arrow) with proliferated and hypertrophied mucous cell, squamous cell and eroded epithelia surface.

The current study's observations of skin modifications were limited to the epidermis; the dermis and hypodermis did not exhibit any deeper alterations. According to Isiyaku *et al.* (2022), picnosis in the epidermal matrix denotes toxic circumstances that are irreversibly damaged. One initial line of defense is an increase in mucus production. It is frequently followed by a lack of production, which is shown by empty, worn-out mucous cells, and ultimately by an entirely absentee population of this type of cell, indicating a persistent deterioration of the environmental factors that cause long-term alterations. Depending on the sampling method, the epidermis may be excoriated in considerable sections or entirely

## CONCLUSION

Long term exposure of organisms to pesticides means a continuous health hazard for the population. So, human population is at high risk by consuming these toxic fishes. This implies that one should take the necessary precaution in the application of pesticides to protect the life of fish and other aquatic fauna. It is likely that approaches using molecular biology techniques will revolutionize toxicological applications that are cheaper and do not require the use of animals to detect environmental stressors. Pesticide toxicity in fish has been studied by several workers who have shown that at chronic level, it causes diverse effects including oxidative damage, inhibition of AchE activity, histopathological changes as well as developmental changes, mutagenesis and carcinogenicity. With reports of toxicants usage and its adverse effects on non-target organisms like fish, it has become essential to formulate stringent rules against indiscriminate use of this pesticide.

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# ISOLATION AND CHARACTERIZATION OF *Bacillus subtilis* FROM *Silurus Auritus* (LONG-EARED CATFISH) OYAN DAM, OGUN STATE

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**ABSTRACT**

*Fish are a significant source of dietary protein worldwide, especially in Nigeria. However, the increasing prevalence of antimicrobial-resistant bacteria in fish poses serious public health risks. This study aimed to isolate, characterize, and determine the antimicrobial resistance profiles of bacteria obtained from the. Bacterial samples were cultured from the gill, liver, and gut of freshly obtained fish using standard microbiological procedures. Isolates were subjected to morphological and biochemical characterization, including tests for sulphur, Indole, motility, urease, citrate utilization, glucose, and lactose fermentation. Gram staining was performed to determine cell wall characteristics. The total microbial load was determined by colony forming unit (CFU) count. Antimicrobial susceptibility testing was carried out using the disc diffusion method on ten commonly used antibiotics, following* Clinical and Laboratory Standards Institute (CLSI) *guidelines. A total of nine bacterial isolates were obtained, exhibiting varied colony morphology and biochemical features. Identified genera included* Staphylococcus, Klebsiella, Proteus, Escherichia, Enterococcus, *and* Enterobacter *spp. The total microbial load ranged from* $2.0 \times 10^5$ *to* $6.0 \times 10^6$ *CFU/ml, with liver isolates recording the highest counts. Antibiotic susceptibility testing revealed high levels of resistance to cotrimoxazole, amoxicillin, erythromycin, and cephalosporin. Some isolates retained partial sensitivity to fluoroquinolones and tetracycline. The results demonstrate a high level of bacterial diversity and multidrug resistance in fish tissues, particularly in the liver and gut. The results revealed a novel strain of Bacillus subtilis CUAB-GUA with 99.13 purity with accession number PX055651.*

**Keyword:** Fisheries, Molecular, River, Dam, Gut, Catfish

## INTRODUCTION

Fish are vital for global food security, particularly in developing countries like Nigeria, where they serve as a primary source of animal protein. The health and productivity of fish are significantly influenced by their gut microbiota, which comprises a complex community of microorganisms that perform essential biological functions, including nutrient digestion, immune modulation, and pathogen protection (Wang et al., 2021; Ringø et al., 2020).

Silurus auritus, commonly known as the Long-eared Catfish, is widely distributed in Nigerian inland water bodies, including Oyan Dam. Despite its ecological and economic significance, limited scientific information exists regarding its gut microbial composition (Adedire, 2022). This study aims to isolate and characterize the bacteria present in the gut of S. auritus, providing baseline data for developing probiotics and optimizing aquaculture strategies.

## MATERIALS AND METHODS

### Sample Collection

Fresh specimens of *Silurus auritus* were collected from Oyan Dam. The fish were dissected under aseptic conditions to obtain gut, liver, and gill samples for microbiological analysis.

### Isolation of Bacteria

The gut, liver, and gill samples were homogenized and subjected to serial dilutions. Aliquots from the

diluted samples were inoculated onto nutrient agar and incubated at 37°C for 24 hours to promote microbial growth. Isolates were subcultured for further identification.

**Biochemical Characterization**
Biochemical tests, including Gram staining, urease, citrate utilization, and sulfur-indole-motility (SIM) tests, were conducted to classify the bacterial isolates. The presence of specific metabolic activities was used to identify the bacterial genera.

**Molecular Characterization**
Molecular characterization was performed using 16S rRNA gene sequencing. Phylogenetic analysis was conducted to assess the evolutionary relationships among the identified bacterial species.

**RESULTS**
A total of nine bacterial isolates were obtained, exhibiting diverse colony morphologies, including irregular, circular, and filamentous forms. The isolates displayed varying colours, elevations, and surface textures, indicating the presence of multiple bacterial species. The biochemical tests revealed that all isolates tested negative for sulphur and indole production, while most were positive for urease and citrate utilization. Gram staining indicated both Gram-positive and Gram-negative cocci. Suspected genera included Staphylococcus, Klebsiella, and Enterobacter. The antibiotic susceptibility tests demonstrated extensive resistance among the isolates to commonly used antibiotics, such as Cotrimoxazole and Amoxicillin, with some isolates showing susceptibility to fluoroquinolones and tetracycline.

Phylogenetic analysis based on 16S rRNA gene sequences indicated that the isolates were closely related to Bacillus species, confirming their classification within the Bacillus genus. The evolutionary relationships among the identified strains were established, highlighting their genetic diversity.

**Table 1:** Molecular characterization of Bacteria isolate (Blasting)

| Sample ID | Organism | Sequence length (bp) | Identity (%) | GenBank |
|---|---|---|---|---|
| CUAB-GUA | *Bacillus subtilis* | 835 | 99.13 | PX055651 |

**DNA Sequence**
CAGTGTTAGGGGGTTCCGCCCTTAGTGCTGCAGCTAACGCATTAAGCACTCCGCCTGG
GGAGTACGGTCGCAAGACTGAAACTCAAAGGAATTGACGGGGGCCCGCACAAGCGGT
GGAGCATGTGGTTTAATTCGAAGCAACGCGAAGAACCTTACCAGGTCTTGACATCCTCT
GACAATCCTAGAGATAGGACGTCCCCTTCGGGGGCAGAGTGACAGGTGGTGCATGGTT
GTCGTCAGCTCGTGTCGTGAGATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTGA
TCTTAGTTGCCAGCATTCAGTTGGGCACTCTAAGGTGACTGCCGGTGACAAACCGGAG
GAAGGTGGGGATGACGTCAAATCATCATGCCCCTTATGACCTGGGCTACACACGTGCTA
CAATGGACAGAACAAAGGGCAGCGAATCCGCGAGGTTAAGCCAATCCCATAAATCGGTT
CTCAGTTCGGATCGCAGTCTGCAACTCGACTGCGTGAAGCTGGAATCGCTAGTAATCGC
GGATCAGCATGCCGCGGTGAATACGTTCCCGGGCCTTGTACACACCGCCCGTCACACC
ACGAGAGTTTGTAACACCCGAAGTCGGTGAGGTAACCTTTTAGGAGCCAGCCGCCGAA
GGTGGGACAGATGATTGGGGTGAAGTCGTAACAAGGTAACCCGTAAA

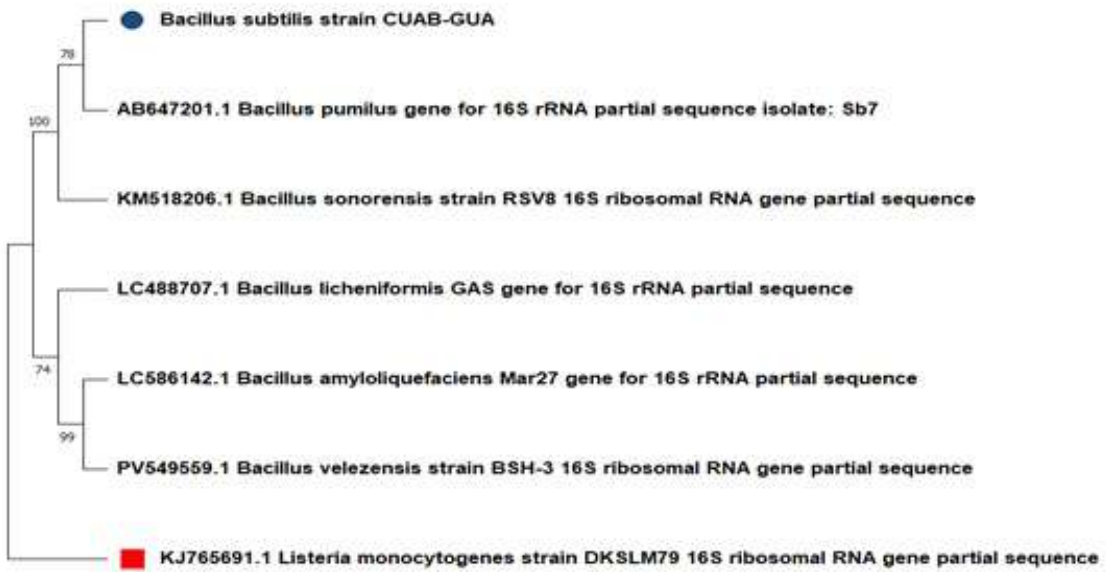



**Figure 1:** Evolutionary relationship of *B. Subtilis* GUA-CUAB (PX055651) WITH *Bacillus Strains* and outgroup acquired from NCBI

## DISCUSSION

The study revealed a diverse array of bacterial species inhabiting the gut of *Silurus auritus*, with significant implications for fish health and aquaculture practices. The presence of opportunistic pathogens and the high levels of antimicrobial resistance observed are concerning, given the potential for these bacteria to enter the human food chain through fish consumption.

The findings align with previous studies that have reported similar bacterial profiles in fish from aquatic environments (Aliyu, 2016; Awe et al., 2022). The diverse colony morphologies and biochemical characteristics suggest that the gut microbiota of *S. auritus* is influenced by various factors, including environmental conditions and dietary inputs.

The results of the antibiotic susceptibility tests underscore the need for strict regulation of antibiotic use in aquaculture. The detection of multidrug-resistant bacteria emphasizes the importance of monitoring microbial populations in fish to mitigate public health risks associated with antibiotic-resistant infections.

The phylogenetic analysis based on 16S rRNA gene sequences revealed that the bacterial isolates are closely related to Bacillus species, confirming their classification within this genus. This molecular approach is crucial for accurately identifying bacterial species, as traditional morphological methods may not provide sufficient resolution (Liu et al., 2019). The high identity percentage of 99.13% with *B. subtilis* (GenBank accession PX055651) demonstrates the reliability of molecular techniques in microbial identification. Such precision is essential for understanding the ecological roles of these bacteria, particularly in the gut microbiome of fish (Zhou et al., 2021).

## CONCLUSION

This study highlights the significance of understanding the gut microbiota of *Silurus auritus* as a crucial component of fish health management and aquaculture sustainability. The isolation and molecular characterization of bacteria from the gut provide valuable insights into the microbial diversity present in this species. Further research is needed to explore the functional roles of these bacteria and their potential applications in aquaculture practices.

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# COMPARATIVE STUDY OF THE DIVERSITY AND PARASITIC PREVALENCE OF FISHES IN LOWER RIVER BENUE AND RIVER DONGA, NIGERIA

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**ABSTRACT**

*This study investigated the diversity and prevalence of parasites in Bagrus bajad and Sarotherodon galilaeus from the River Donga (RD) and Lower River Benue (LRB), Taraba State, Nigeria. Fish samples were collected monthly for 12 months from three landing sites in each of the two rivers. A total of 720 fish were examined for ectoparasites and endoparasites from the skin, gills, intestine, and stomach. Twenty-two parasite species were identified in RD and twenty-one in LRB covering protozoans, nematodes, trematodes, cestodes, and crustaceans. In RD, Capillaria spp. (mean = 36 ± 4.8 isolates) and Eimeria spp. (62 ± 5.2) were dominant, followed by Ichthyobodo spp. (29 ± 2.1). In LRB, Ichthyobodo spp. (189 isolates in B. bajad) and Capillaria spp. (51 isolates in S. galilaeus) recorded the highest intensities, while nematodes such as Camallanus spp., Contracaecum spp., and Ascaris lumbricoides occurred frequently. Protozoans represented the largest group (45 – 50 % of total isolates), followed by nematodes (30 %). Parasitic richness was higher in LRB than in RD. The infection pattern reflected host ecology: demersal B. bajad harbored more protozoans, whereas omnivorous S. galilaeus carried more nematodes. However, presence of Contracaecum spp, Diphyllobothrium latum and Ascaris lumbricoides highlights potential public-health concerns.*

**Keywords:** *Bagrus bajad*, *Sarotherodon galilaeus*, Fish parasites, River Donga, Lower River Benue, Taraba State, Zoonotic risk

## INTRODUCTION

Fish play a vital role in human nutrition, trade, and economic development, serving as a primary source of animal protein and essential nutrients for millions worldwide, especially in tropical and subtropical regions where malnutrition persists (Vianna et al., 2020). However, freshwater fish populations are increasingly threatened by a range of biotic and abiotic stressors, with parasitic infections posing a significant risk to both wild and farmed species. Freshwater fish host diverse parasites, including protozoans, helminths, crustaceans, and nematodes, which can impair physiological functions, reduce growth rates, lower reproductive success, and, in severe cases, cause mortality. These impacts contribute to substantial economic losses in capture fisheries and aquaculture industries (Lymbery et al., 2014; Ferguson et al., 2016). Furthermore, fish parasites raise important public health concerns, as some are zoonotic and can infect humans through the consumption of raw, undercooked, or contaminated fish. These risks underscore the necessity for continuous monitoring and a thorough understanding of fish-parasite interactions in freshwater systems to ensure food safety and sustainable fish production (Williams and Eberhard, 2014).

## MATERIALS AND METHODS

### Experimental Sites

The study was conducted in two locations within Taraba State, Nigeria: the Lower River Benue (Ibi Local Government Area) and River Donga (Donga Local Government Area). Ibi Local Government Area covers approximately 2,672 km$^2$, situated between latitude 8°19'N and longitude 9°51'E (Taraba State Government, 2015). The area receives an annual rainfall of 1,058–1,300 mm and has a temperature range of 28°C to 39°C. Fishing is the predominant occupation, and the area is renowned for the annual *Nwonyo Fishing Festival*. The council area comprises Ibi, Dampar, Nwonyo, Rimiuku, and Sarkin Kudu. River Donga is located in the southern part of Taraba State, at latitude 7°42'59.99"N and longitude 10°02'60.00"E. Most inhabitants are engaged in farming, while a smaller proportion participate in fishing. The river receives effluents from rice mills, fertilizers, pesticides, herbicides, diesel, and domestic waste via surface runoff and drainage, particularly during the rainy season. River Donga serves as a vital source of water for both fishing and domestic purposes.

### Experimental Sites and Fish Sampling

Fish and water samples were collected randomly over a twelve-month period, from September 2024 to August 2025, at three sampling locations (landing sites) in each of the two rivers. The sampling sites on River Donga were Bakin Kogin Sarki, Gindin Doruwa, and Sogbanka, while those on Lower River Benue (Ibi) included Ibi Major Landing Site, Dampar, and Chinke. Two fish species, Bagrus bajad and Sarotherodon galilaeus, were procured from fisherfolk at both rivers. Five samples of each species were collected at each sampling site, resulting in a total of 720 fish examined for parasitic infections throughout the study. The collected fish were placed in clean, labeled, airtight jerry cans and transported to the Biology Laboratory, Faculty of Biosciences, Federal University Wukari, for analysis. The Formol-Ether concentration technique was employed for examination, following the methods described by Cheesbrough (2009) and Gracia (2017).

### Examination of Fish Samples for Ectoparasites and Endoparasites

Approximately 1 g each of the oesophagus, intestine, and stomach (for endoparasite detection), as well as the gills, skin, and fins (for ectoparasite detection), were homogenized in 10% formol saline and filtered through gauze into test tubes. The mixtures were then centrifuged at 4,000 revolutions per minute (rpm) for ten minutes, after which the supernatant was decanted. Subsequently, three milliliters of formol saline and one milliliter of ether were added to each tube, mixed thoroughly, and centrifuged again at 4,000 rpm for ten minutes. The debris adhering to the tube walls was loosened, the supernatant was discarded, and the sediment was resuspended. A drop of the resuspended sediment was placed on a grease-free glass slide, covered with a cover slip, and examined microscopically under ×10 and ×40 objective lenses. Lugol's iodine solution was used to enhance the visibility of parasitic structures.

### Sexing and Measurement of Fish

Sex identification was conducted by physically examining the urogenital papilla, which is elongated in males and rounded or reddish in mature females. This was further confirmed through gonadal inspection during dissection, as described by Imam and Dewu (2010). Total length (cm) of each fish was measured using a meter rule, and body weight (g) was determined with a top-loading sensitive weighing balance (Model: Mettler Toledo), following the method of Sogbesan et al. (2020).

### Data Analysis

Data were analysed using both descriptive and inferential statistical approaches. Simple percentages were calculated to determine the prevalence rates of parasitic infections. The Chi-square ($\chi^2$) test was used to assess significant differences in prevalence between species and sampling sites, while the t-test

was employed to compare the level of parasitic infestation between the two water bodies.

## RESULTS AND DISCUSSION

**Identification and Classification of Parasitic Species Infesting *Bagrus bajad* and *Sarotherodon galilaeus* from River Donga and Lower River Benue at Ibi, Taraba State, Nigeria**.

The study found a high diversity and prevalence of parasites in *Bagrus bajad* and *Sarotherodon galilaeus* from River Donga and Lower River Benue at Ibi, Taraba State as shown in Table 1 and 2 below.

**Table 1:** Identification and Classification of Parasitic Species Infesting *Bagrus bajad* and *Sarotherodon galilaeus* from River Donga, Taraba State, Nigeria.

| Phylum / Classes | Names of Parastes species Isolated | *Bagrus bajad* | | *Sarotherodon galilaeus* | | Total No. of fish infected (%) | Total No of Parasite Isolated (%) |
|---|---|---|---|---|---|---|---|
| | | No. of Fish Infected | No of Parasite Isolated (%) | No. of fish infected | No. of Parasite Isolated (%) | | |
| Acanthocephala | | | | | | | |
| ***Palaeacanthocephala*** | *Acanthogyrus spp* | 0 | 0 (0.0) | 8 | 8 (2.0) | 8 (2.0) | 8 (1.0) |
| Arthropoda | | | | | | | |
| **Copepoda** | *Argulus* | 0 | 0 (0.0) | 6 | 6 (1.2) | 6 (2.0) | 6 (0.5) |
| | *Ergasilus* | 0 | 0 (0.0) | 6 | 8 (2.0) | 6 (2.0) | 8 (1.0) |
| | *Lernea* | 0 | 0 (0.0) | 7 | 7 (1.4) | 7 (2.0) | 7 (0.6) |
| Myxozoa(Cnidaria) | | | | | | | |
| **Myxosporea** | *Myxobolus spp* | 3 | 5 (0.6) | 27 | 78 (16.0) | 30 (7.6) | 83 (6.6) |
| Nematoda | | | | | | | |
| **Chromadorea** | *Contracaecum* | 0 | 0 (0.0) | 23 | 45 (9.0) | 23 (5.8) | 45 (3.5) |
| | *Ascaris lumbricoides* | 16 | 70 (9.0) | 0 | 0 (0.0) | 16 (4.0) | 70 (5.5) |
| | *Camallanus spp* | 16 | 33 (4.2) | 22 | 32 (6.4) | 38 (9.6) | 65 (5.0) |
| **Enoplea** | *Capillaria spp* | 30 | 52 (6.7) | 33 | 64 (13.0) | 63 (16.0) | 116 (9.0) |
| | *Trichuris spp* | 6 | 9 (1.2) | 0 | 0 (0.0) | 6 (1.5) | 9 (0.7) |
| Platyhelminthes | | | | | | | |
| **Cestoda** | *Bothriocephalus* | 0 | 0 (0.0) | 18 | 30 (6.0) | 18 (4.5) | 30 (2.4) |
| | *Diphyllobothrium latum* | *12* | 12 (1.5) | 0 | 0 (0.0) | *12 (3.0)* | 12 (1.0) |
| **Trematoda** | *Dactylogyrus spp* | 1 | 2 (0.3) | 0 | 0 (0.0) | 1 (0.0) | 2 (0.1) |
| | *Gyrodactylus spp* | 0 | 0 (0.0) | 7 | 12 (2.4) | 7 (2.0) | 12 (1.0) |
| | *Opisthorchis spp* | 4 | 4 (0.5) | 0 | 0 (0.0) | 4 (1.0) | 4 (0.3) |
| Protozoa | | | | | | | |
| **Cilliates** | *Ichthyophthirius multifiliis* | 24 | 140 (18.0) | 19 | 108 (22.0) | 43(10.8) | 248 (19.6) |
| | *Tetrahymena spp* | 18 | 39 (5.0) | 0 | 0 (0.0) | 18 (4.5) | 39 (3.0) |
| | *Trichodina spp* | 0 | 0 (0.0) | 26 | 95 (19.2) | 26 (6.5) | 95 (7.5) |
| | *Ichthyobodo spp* | 33 | 267 (35.0) | 0 | 0 (0.0) | 33 (8.0) | 267 (21.0) |
| | *Piscinoodinium* | 14 | 40 (5.0) | 0 | 0 (0.0) | 14 (3.5) | 40 (3.0) |
| | *Spirinucleus vortens* | 15 | 95 (12.3) | 0 | 0 (0.0) | 15 (3.7) | 95 (7.5) |
| **Flagellates** | *Microsporidians spp* | 1 | 2 (0.3) | 0 | 0 (0.0) | 1 (0) | 2 (0.1 |
| **TOTAL** | | **193** | **770** | **202** | **493** | **395** | **1,263** |

In River Donga, 1,263 parasites were found in 395 infected fish, while 1,067 parasites were isolated from 222 infected fish in Lower River Benue. Protozoan parasites were most common, with *Ichthyobodo spp.* (21.0%) and *Ichthyophthirius multifiliis* (19.6%) being the most prevalent in River Donga. In Lower River Benue, *Eimeria* accounted for 24.6% of isolates. Nematodes such as C*apillaria spp*. and C*amallanus spp.* were also identified. These findings are consistent with Abd-Elrahman et al. (2023) and Omeji et al. (2024), who reported high protozoan prevalence in similar studies. Differences in parasite types were linked to the feeding habits of the fish, as supported by Obande and Jackson (2024). The detection of zoonotic helminths, including C*ontracaecum spp*. and *Diphyllobothrium latum*, underscores public health concerns, echoing findings by Davidovich et al. (2025) regarding the presence of zoonotic parasites in Nigerian freshwater fish

**Table 2:** Identification and Classification of Parasitic Species Infesting *Bagrus bajad* and *Sarotherodon galilaeus* from Lower River Benue at Ibi, Taraba State, Nigeria.

| Phylum / Classes | Names of Parasite species Isolated | *Bagrus bajad* | | *Sarotherodon galilaeus* | | Total No. of fish infected (%) | Total No. of Parasites Isolated (%) |
|---|---|---|---|---|---|---|---|
| | | No. of Fish Infected | No of Parasite Isolated (%) | No. of fish infected | No of Parasite Isolated (%) | | |
| Acanthocephala | | | | | | | |
| ***Palaeacanthocephala*** | *Acanthogyrus* | 0 | 0 (0.0) | 1 | 1 (0.2) | 1 | 1 (0.1) |
| Arthropoda | | | | | | | |
| **Copepoda** | *Lernea* | 1 | 1 (0.2) | 0 | 0 (0.0) | 1 | 1 (0.1) |
| Myxozoa | | | | | | | |
| **Myxosporea** | *Myxobolus spp* | 3 | 11 (1.7) | 4 | 13 (3.0) | 7 | 24 (2.2) |
| Nematoda | | | | | | | |
| **Chromadorea** | *Contracaecum* | 5 | 10 (1.5) | 6 | 17 (4.0) | 11 | 27 (2.5) |
| | *Ascaris lumbricoides* | 6 | 9 (1.4) | 7 | 16 (3.7) | 13 | 25 (2.3) |
| | *Camallanus spp* | 8 | 26 (4.0) | 9 | 28 (6.5) | 17 | 54 (5.0) |
| **Enoplea** | *Capillaria spp* | 20 | 133 (21.0) | 28 | 148 (35.0) | 48 | 281 (26.3) |
| | *Trichuris spp* | 1 | 1 (0.2) | 1 | 1 (0.2) | 1 | 1 (0.1) |
| Platyhelminthes | | | | | | | |
| **Cestoda** | *Bothriocephalus* | 4 | 13 (2.0) | 3 | 11 (2.5) | 7 | 24 (2.2) |
| | *Diphyllobothrum latum* | 4 | 6 (0.9) | 5 | 7 (1.6) | 9 | 13 (1.2) |
| | *Ligula intestnals* | 3 | 3 (0.4) | 0 | 0 (0.0) | 3 | 3 (0.3) |
| **Trematoda** | *Dactylogyrus spp* | 8 | 21 (3.3) | 11 | 31 (7.2) | 19 | 52 (4.9) |
| | *Gyrodactylus spp* | 0 | 0 (0.0) | 3 | 7 (1.6) | 3 | 7 (0.7) |
| | *Opisthorchis spp* | 3 | 7 (1.1) | 3 | 7(1.6) | 6 | 14 (1.3) |
| | *Clinostomum spp* | 2 | 4 (0.6) | 0 | 0 (0.00 | 2 | 4 (0.4) |
| Protozoa | | | | | | | |
| ***Conoidasida*** | *Eimeria* | 9 | 206 (32.7) | 7 | 57 (13.3) | 16 | 263 (24.6) |
| | *Goussia* | 6 | 82 (13.0) | 5 | 18 (4.2) | 11 | 100 (9.4) |
| **Cilliates** | *Ichthyophthirius multifiliis* | 0 | 0 (0.00 | 5 | 8 (1.8) | 5 | 8 (0.7) |
| | *Tetrahymena spp* | 3 | 6 (0.9) | 0 | 0 (0.0) | **3** | **6 (0.5)** |
| | *Trichodina spp* | 4 | 10 (1.5) | 4 | 8 (1.8) | 8 | 18 (1.6) |
| **Flagellates** | *Ichthyobodo spp* | 9 | 47 (7.4) | 6 | 44 (10.2) | **15** | **91 (8.5)** |
| | *Piscinoodinium* | 4 | 12 (1.9) | 4 | 6 (1.4) | **8** | **18 (1.6)** |
| | *Spirinucleus vortens* | 3 | 8 (1.2) | 0 | 0 (0.0) | 3 | 8 (0.7) |
| **Microsporideans** | *Microsporidians spp* | 4 | 13 (2.0) | 0 | 0 (0.0) | 4 | 13 (1.2) |
| TOTAL | | **110** | **629** | **112** | **428** | **222** | **1,067** |

**Frequency of Parasites and Sites of *Bagrus bajad* and *Sarotherodon galilaeus Sampled* from River Donga and Lower River Benue at Ibi, Taraba State, Nigeria**

The study recorded 22 parasite species in River Donga and 21 in Lower River Benue (Ibi), infecting *Bagrus bajad* and *Sarotherodon galilaeus* across all anatomical sites examined (skin, gills, intestine, and stomach) as shown in Figure 1 and 2 below. Infection prevalence and intensity varied by site and host species. In River Donga, both *B. bajad* and *S. galilaeus* were predominantly infected by protozoans, which accounted for over 45% of all isolates (Abd-Elrahman et al., 2023), including *Ichthyobodo spp.*, *Eimeria spp.*, *Goussia spp.*, and C*apillaria spp.* Nematodes, specifically C*apillaria Spp*. and C*amallanus spp.*, contributed 30–35% of total infections (Ahmed et al., 2022), while cestodes such as *Diphyllobothrium latum* and *Bothriocephalus* spp. were also present (El-Tantawy and Abdallah, 2023). The detection of C*ontracaecum spp*. and Ascaris lumbricoides suggests contamination from domestic waste, consistent with findings by Davidovich et al. (2025). In Lower River Benue (Ibi), overall parasite abundance was higher than in Donga. B. bajad showed heavy infections with *Ichthyobodo spp.*, *Spironucleus vortens*, and *Ichthyophthirius multifiliis*, while *S. galilaeus* was dominated by nematodes such as C*apillaria spp.*, C*amallanus spp.*, and Contracaecum *spp*. Protozoan intensity exceeded values

reported by Omeji et al. (2024), likely due to warmer temperatures and organic pollution that favour parasite proliferation (Okoye et al., 2023). Nematodes made up 28–33% of total parasites, aligning with the 30% reported by Obande and Jackson (2024). The occurrence of zoonotic parasites, including *Contracaecum spp*., Diphyllobothrium spp., and Ascaris lumbricoides, in both rivers highlights potential public health risks associated with the consumption of inadequately cooked freshwater fish (Davidovich et al., 2025).

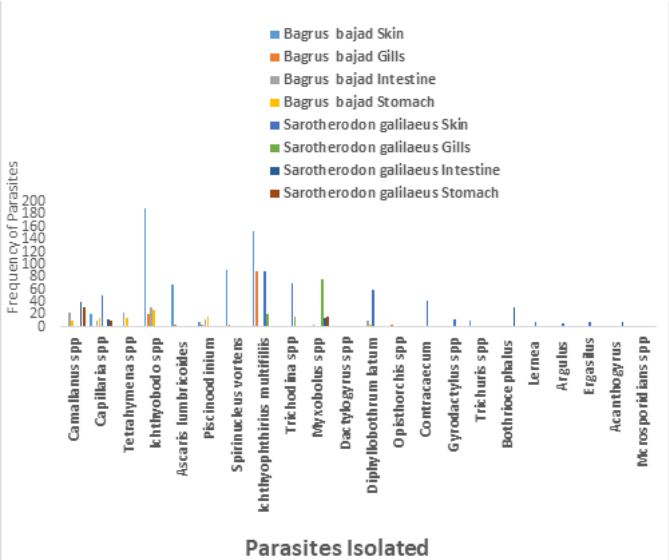



Figure 1: Frequency of Parasites and Sites of Two fish sampled from River Donga

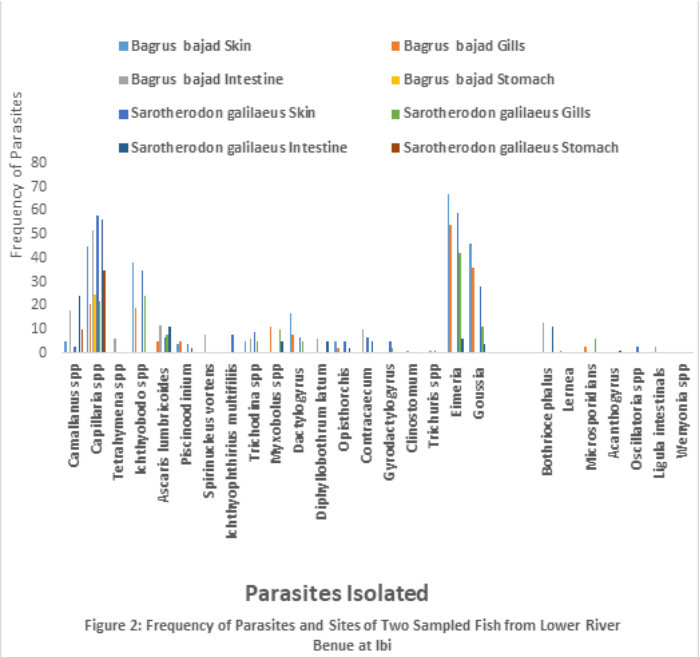



Figure 2: Frequency of Parasites and Sites of Two Sampled Fish from Lower River Benue at Ibi

## CONCLUSION

The study found significant differences **($p < 0.05$)** in parasite prevalence between fish species and rivers, with *Sarotherodon galilaeus* and fish from Lower River Benue (Ibi) showing higher parasite loads. These differences are likely due to ecological conditions, pollution, and feeding habits.

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# FISHERIES EXTENSION, CONFLICT MANAGEMENT AND COMMUNITY DEVELOPMENT - FECC

# FISHERIES STUDENTS' KNOWLEDGE AND PERCEPTION OF RESEARCH METHODOLOGY: A CASE STUDY OF FEDERAL COLLEGE OF FRESHWATER FISHERIES TECHNOLOGY (FCFFT), BAGA

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**ABSTRACT**

*Research methodology forms the backbone of scientific inquiry, equipping students with essential skills for evidence-based decision-making. This study assessed the knowledge and perception of research methodology among final-year fisheries students at the Federal College of Freshwater Fisheries Technology (FCFFT), Baga. A descriptive survey design was adopted, and data were collected from 25 HND students using a structured questionnaire. Results showed that 64% of respondents were male, 60% fell within the age range of 23–27 years, and 100% had completed a course in research methodology, while 88% had either conducted or were currently conducting a research project. In terms of knowledge, students reported strong understanding in basic research concepts (Mean = 4.28), and differentiation between research methods (Mean = 4.12), but relatively lower competence in using statistical tools like Statistical Package for the Social Sciences. and Excel (Mean = 3.20). Perceptions were generally positive: the course was seen as important (Mean = 4.60), relevant to future careers (Mean = 4.68), and in need of more practical applications (Mean = 4.56), although ease of understanding was moderate (Mean = 3.08). Key challenges faced included inadequate practical sessions (84%), lack of research materials (72%), and poor access to statistical software (68%). The study concludes that while students recognize the value of research methodology, gaps remain in technical and practical competencies. Enhanced hands-on training and access to research tools are recommended to improve student outcomes.*

**Keywords:** Fisheries students, Research methodology, Perception, Knowledge assessment, FCFFT Baga

## INTRODUCTION

Research methodology is an essential component of academic inquiry, playing a crucial role in knowledge production and scientific discovery (Creswell and Creswell, 2018). It provides students with the necessary skills to design, conduct, and analyse research effectively, forming the foundation for evidence-based decision-making in various disciplines, including fisheries and aquatic sciences. In the fisheries sector, research methodology is particularly important for addressing key challenges such as declining fish populations, aquaculture sustainability, climate change effects, and marine biodiversity conservation (Gómez *et al.*, 2021).

The Federal College of Freshwater Fisheries Technology (FCFFT), Baga, is a specialized institution focused on training professionals in fisheries and aquaculture. As part of its curriculum, research methodology is taught to equip students with the analytical skills needed to contribute meaningfully to the field. However, despite the significance of this course, many students struggle with its concepts, leading to poor engagement and understanding. Studies have shown that students often perceive research methodology as complex and abstract, resulting in anxiety and disinterest (Bryman, 2016; Saunders *et al.*, 2019).

In Nigeria, the importance of fisheries research cannot be overstated, given the country's reliance on aquatic resources for food security, employment, and economic development (Elliott *et al.*, 2020). Research in fisheries is essential for developing improved fish farming techniques, sustainable harvesting methods, and conservation policies. However, without a strong foundation in research methodology, fisheries students may find it challenging to conduct independent research, analyse scientific data, or contribute to policy formulation.

This study aims to assess the knowledge and perception of research methodology among fisheries students at FCFFT, Baga. By understanding students' attitudes toward research, as well as the challenges they face, this study will provide insights into how fisheries education can be enhanced to improve research competence among students.

## METHODOLOGY

### Research Design

The study adopts a "descriptive survey research design" to systematically assess students' knowledge and perception of research methodology. This design is appropriate because it allows the collection of data from a specific population, enabling the researcher to describe and interpret trends, opinions, and knowledge levels (Creswell and Creswell, 2018). A quantitative approach was employed, using a structured questionnaire as the sole data collection instrument. The structured questionnaire ensures uniformity in responses, making data analysis more objective and statistically measurable (Saunders *et al.*, 2019).

### Study Area

The research was conducted at the fisheries extension unit of the Federal College of Freshwater Fisheries Technology, Baga at their temporary site in Lake Cahad Research Institute kilometer 6, Gamboru Ngala Road, Jere local government, Borno State (Latitudes 11$^0$51'43" N and Longitudes 13$^0$13'36" E), between June and July 2025. FCFFT, Baga, offers diploma and higher national diploma programs in Fisheries Technology, providing students with theoretical knowledge and hands-on experience in fisheries management, aquaculture production, and marine resource conservation. The institution was chosen for this study because it provides a well-structured research methodology course as part of its curriculum, making it an ideal setting to evaluate students' understanding and perception of the subject.

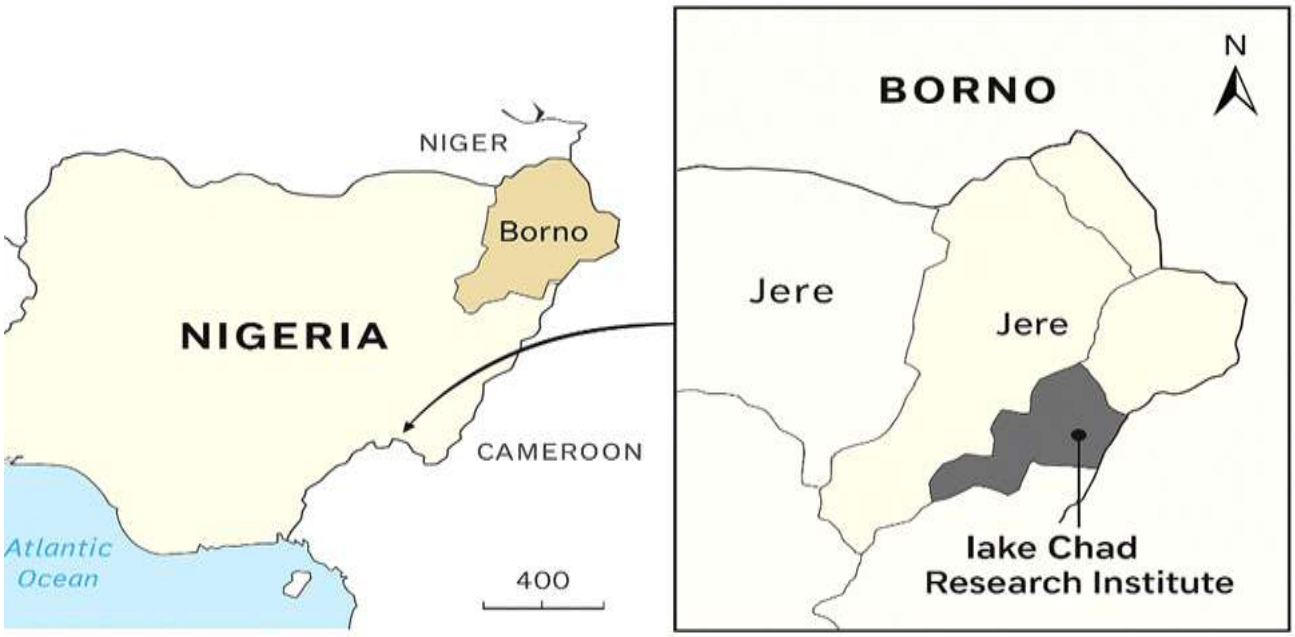



**Figure 1:** Map of Nigeria showing the study Area

**Population of the Study, Sampling Technique and Sample Size**

The target population consists of final-year fisheries students at FCFFT, Baga. These students were selected because they have completed coursework in research methodology and are expected to apply their knowledge in conducting research projects. According to records from the Academic Planning Unit (Exam Office) of FCFFT, Baga, the total number of final-year students (HND) in fisheries Technology programs is approximately 25. These students form the study population since they have direct experience with research methodology as a course and can provide meaningful insights into their knowledge and perception of it. A simple random sampling technique was used to select participants. This method ensures that every student in the final-year fisheries class has an equal chance of being included in the study, eliminating bias and improving the generalizability of findings (Sekaran and Bougie, 2020).

**Data Collection Instrument**

Data was collected using a structured questionnaire, which was distributed to final-year students during class sessions. The questionnaire was designed to gather information on: Demographic Characteristics (e.g., age, gender, program of study), Knowledge of Research Methodology (e.g., understanding of research concepts, statistical methods, research ethics), Perception of Research Methodology (e.g., ease of learning, relevance to career, confidence in conducting research) and Challenges Faced (e.g., difficulty in understanding research methods, lack of access to resources). The questionnaire used Likert-scale questions (ranging from "Strongly Agree" to "Strongly Disagree") and multiple-choice questions to capture quantitative data.

**Data Collection Procedure**

The researcher administered the questionnaire in person during scheduled class hours to maximize response rates. The questionnaire was distributed, explained, and collected immediately to prevent loss or incomplete responses.

**Data Analysis**

Data collected was analyzed using descriptive statistics, which include: Frequency and Percentage Distributions – To summarize students' knowledge levels and perceptions, mean Scores and Standard Deviations – To measure trends in students' responses and Chi-Square Tests – To examine associations between demographic factors and students' knowledge or perceptions. The data was processed and analyzed using SPSS (Statistical Package for the Social Sciences) version 26 (Pallant, 2020) and the results were presented in tables for better visualization.

## RESULTS AND DISCUSSION

The table 1 below describes the basic background of the respondents where male appear to be (64%), while females made up 36%. Most respondents (60%) were between 23–27 years, a typical age for final-year HND students. All respondents had completed a research methodology course (100%), which validates their eligibility for the study. 88% of students were either conducting or had conducted a research project, meaning they had practical exposure to applying research methodology.

**Table 1:** Demographic Characteristics of Respondents (N = 25)

| Variable | Category | Frequency | Percentage (%) |
|---|---|---|---|
| Gender | Male | 16 | 64 |
| | Female | 9 | 36 |
| Age Group | 18–22 years | 7 | 28 |
| | 23–27 years | 15 | 60 |
| | 28 years and above | 3 | 12 |
| Completed Research Methodology | Yes | 25 | 100 |
| Conducted or Conducting Project | Yes | 22 | 88 |
| | No | 3 | 12 |

Table 2 summarizes how knowledgeable the students perceive themselves to be in various areas of research methodology. High scores were seen in understanding basic concepts (4.28) and differentiating research types (4.12). Lower scores were reported in technical competencies like writing research reports (3.64) and especially using software for data analysis (3.20), indicating areas needing improvement.

**Table 2:** Knowledge of Research Methodology

| Statement | Mean Score | Std. Dev |
|---|---|---|
| I understand the basic concepts of research methodology | 4.28 | 0.79 |
| I can differentiate between qualitative and quantitative methods | 4.12 | 0.83 |
| I am familiar with sampling techniques used in research | 3.84 | 0.91 |
| I understand how to formulate a research hypothesis | 3.88 | 0.85 |
| I can effectively collect and analyze research data | 3.76 | 0.98 |
| I know how to write a proper research report | 3.64 | 1.03 |
| I can use statistical tools (e.g., SPSS, Excel) for data analysis | 3.20 | 1.12 |

Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), Strongly Disagree (1)

This table (table 3) reflects how students feel about the course. Very high agreement that the course is important (4.60), relevant to future careers (4.68), and should be more practical (4.56). Moderate scores in feeling confident to conduct research (3.72) and in finding the course easy to understand (3.08) suggest students find it valuable but difficult.

**Table 3:** Perception of Research Methodology

| Statement | Mean Score | Std. Dev |
|---|---|---|
| Research methodology is important in my field | 4.60 | 0.50 |
| Research methodology is easy to understand | 3.08 | 1.14 |
| The course helped develop analytical/problem-solving skills | 4.24 | 0.69 |
| I feel confident conducting research in fisheries | 3.72 | 0.92 |
| The course should be more practical than theoretical | 4.56 | 0.71 |
| Research methodology is useful for my future career | 4.68 | 0.48 |

Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), Strongly Disagree (1)

The table 4 outlines the major barriers students face when learning research methodology. The top challenge was inadequate practical sessions (84%), showing a gap between theory and application. Lack of materials (72%) and poor access to software tools (68%) also significantly hinder student learning. Over half of the students also noted difficulty in understanding research concepts (56%), reinforcing earlier findings in Table 3. Limited supervision (48%) suggests students may not be receiving enough guidance from lecturers during their research projects.

**Table 4:** Challenges Faced by Students in Learning Research Methodology

| Challenge | Frequency | Percentage (%) |
|---|---|---|
| Lack of research materials | 18 | 72 |
| Difficulty in understanding research concepts | 14 | 56 |
| Inadequate practical sessions | 21 | 84 |
| Poor access to statistical software/tools | 17 | 68 |
| Limited supervision from lecturers | 12 | 48 |

The findings show that a significant proportion of final-year fisheries students at FCFFT, Baga, possess a moderate to high level of understanding of research methodology, particularly in basic concepts (Mean = 4.28) and differentiating between research types (Mean = 4.12). These values are consistent with Gómez *et al*. (2021), who emphasized the growing competence in research literacy in science-oriented institutions. However, the relatively low mean score in using statistical tools (3.20) indicates a technical skill gap contrary to Pallant (2020), who found that students trained in SPSS exhibited stronger data interpretation skills.

Regarding perception, most students agreed that research methodology is important (Mean = 4.60) and relevant for their careers (Mean = 4.68), aligning with Elliott *et al*. (2020) who highlighted the critical role of research in fisheries development. However, the relatively lower confidence in conducting research (Mean = 3.72) and ease of understanding (Mean = 3.08) mirrors findings by Bryman (2016) that students often find research abstract and anxiety-inducing. This may be attributed to inadequate practical sessions reported by 84% of students in this study supporting Saunders *et al*. (2019), who advocated for experiential learning in research education. While previous works like those by Sekaran and Bougie (2020) focused on business students' methodology perceptions, our findings resonate similarly in the technical sciences. This study reveals that students perceive methodology as less interactive and too theoretical (Mean = 4.56 for making it more practical), suggesting a disconnect between learning and application (particularly in abstract concepts like hypothesis formulation and software use).

## CONCLUSION

The study reveals that while final-year fisheries students at FCFFT, Baga, recognize the importance of research methodology and show moderate knowledge of its concepts, there are notable deficiencies in technical application, especially in statistical analysis and practical engagement. Perception of the course is generally positive, yet students express a strong desire for a more hands-on, applied approach. Major challenges include lack of materials, insufficient practical sessions, and limited access to tools, which collectively hinder students' confidence and competence in conducting research.

## RECOMMENDATION

To enhance students' research capacity, the college should revamp the delivery of the research methodology course by incorporating more interactive and practical sessions, such as field-based research simulations, workshops on SPSS/Excel, and mentorship from active researchers. Providing

access to modern software tools, improving the availability of research materials, and organizing periodic training on scientific writing and data analysis will further bridge the gap between theoretical knowledge and research practice. Equally, institutional support through dedicated research hubs and improved lecturer-student engagement can significantly bolster students' confidence and performance in independent research projects.

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# ASSESSMENT OF FRESH AND SMOKED FISH MARKETING IN KEFFI LOCAL GOVERNMENT AREA, NASARAWA STATE, NIGERIA

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**ABSTRACT**
*The study was conducted to assess the demand of fresh and smoked fish in Keffi Local Government Area, Nasarawa State. Multi-stage sampling technique was used to select 120 respondents for the study. Data generated were analysed using descriptive statistics. Results showed that males (92.0%) exhibit a strong preference for fresh fish, while only a small percentage (3.0%) opt for smoked fish. A substantial majority of females (97.0%) expressed a preference for smoked fish, while only 8.0% favoured fresh fish. Single individuals showed a higher preference for both smoked (68.0%) and fresh fish (63.0%), making up most of the overall demand (66.0%). Households with 1-5 members had the highest demand for both fresh and smoked fish, with 26 and 43 percent, respectively. Specifically, 52.0% of respondents with non-formal education prefer smoked fish, while 45.0% prefer fresh fish. Among those who are members of the association, 65.0% prefer smoked fish, while 63.0% prefer fresh fish. On the other hand, among those who are not members of the association, 35.0% opt for smoked fish, and 37.0% prefer fresh fish. When considering the combined frequencies, 64.0% of respondents prefer smoked fish, and 36.0% prefer fresh fish. A significant proportion of respondents with 1-5 years of marketing experience prefer smoked fish (52.0%) compared to fresh fish (43.0%). For smoked fish, processor to local consumers (51.7%) was the most preferred marketing channel. Most dominant channel for fresh fish was the direct sale from fishermen to processors, constituting 50% of the responses. The most prominent constraint to fresh marketing was lack of capital (56.7%) and season (46.7%). Furthermore, the most prominent constraints to smoked fish marketing were lack of capital (61.7%) and cost of transportation (58.3%).*

**Keywords:** Fresh fish, Smoked fish, Marketing and Respondents

## INTRODUCTION

Fish is a major source of food for humans, providing significant portion of the protein intake in the diet of large proportion of the people, particularly so in developing countries. Fish is less tough and more digestible compared to beef, chicken and mutton. Moreover, it has little or no religious rejection that gives it an advantage over pork and beef (Kumolu-Johnson and Ndimele, 2011). Fish demand in Nigeria is put at about 1.2 million metric tons per annum, and the total domestic fish production is only 511,700 metric tons (Akinneye *et al*., 2007). Since aquatic resources are finite, although renewable, every effort should be geared towards increased fish production through improved resource management, resource conservation and intensive aquaculture practices. This should be matched with fish post-harvest losses through handling, preservation and processing to prevent and subsequent loss (Akinneye *et al*., 2007).

Fish smoking is one of the traditional methods of preservation of fish in Africa. It is mostly done at the artisanal level by women in riverine communities whose main economic activity is fish processing and marketing. Smoke curing, as applied to fish, is a method of preservation effected by combination of drying and the deposition of naturally produced chemicals, resulting from the thermal breakdown of

wood (Ahmed *et al*., 2010). The reasons for fish smoking are varied but in Nigeria, the process has proven relevant to prolonging shelf life, enhancing flavour, storing for lean season and increasing protein availability of people throughout the year (Kumolu-Johnson and Ndimele, 2011). The study aimed at assessing the demand of fresh and smoked fish marketing in Keffi Local Government Area, Nasarawa State.

## MATERIALS AND METHODS

### Research Area

The study was conducted in Keffi Local Government Area of Nasarawa State. Keffi is a historic town located in Nasarawa State, North central Nigeria between latitude 8°511 and 8° 531 North of the equator and longitude 7° 501 and 7° 511 East of the Greenwich meridian. Keffi is located about 128km away from Lafia Nasarawa State capital and about 57km away from Abuja. Keffi has a population of 92,664 persons with distribution of 47,801 males and 44,863 females (NPC, 2006).

### Population Size and Sampling Techniques

Multi-stage sampling technique was employed in this study. The first stage involved the selection of the existing three (3) districts which are Jiwada, Angwan-Lambu and the Angwan Jaba districts.
In the second stage, two (2) communities known for high demand of fresh and smoked dried fish were purposively selected from each of the three (3) districts giving a total of six (6) communities for the study.

Third stage was the random selection of twenty (20) fish monger and consumers from each of the six (6) communities giving the total of 120 respondents for the study.

### Sources of Data

The primary data were collected using both structured questionnaire and personal interview with the fish sellers and consumers.

### Data Analysis

The data collected were analyzed using both descriptive and inferential statistic. The descriptive analysis was mainly in terms of percentage and frequency of distribution to show the socio-economic profile of respondents in the study area. The inferential statistical analysis involved chi-square to find out the relationship that exist between the demand of fresh and smoke dried in Keffi Local Government Area of Nasarawa State.

## RESULTS

**Table 1.** Socio-Economic Characteristics of Fresh and Smoked Fish Marketers

| | Smokes Fish | | Fresh Fish | | Combined | |
|---|---|---|---|---|---|---|
| Variables | Frequency | Percentage | Frequency | Percentage | Frequency | Percentage |
| Age | | | | | | |
| 15-20 | 7 | 12.0 | 8 | 13.0 | 15 | 13.0 |
| 21-30 | 12 | 20.0 | 19 | 32.0 | 31 | 26.0 |
| 31-40 | 17 | 28.0 | 11 | 18.0 | 28 | 23.0 |
| 41-50 | 13 | 22.0 | 19 | 32.0 | 32 | 27.0 |
| 50 and above | 11 | 18.0 | 3 | 5.0 | 14 | 12.0 |
| Total | 60 | 100.0 | 60 | 100.0 | 120 | 100.0 |

| Variables | Smokes Fish Frequency | Percentage | Fresh Fish Frequency | Percentage | Combined Frequency | Percentage |
|---|---|---|---|---|---|---|
| **Gender** | | | | | | |
| Male | 2 | 3.0 | 55 | 92.0 | 57 | 47.0 |
| Female | 58 | 97.0 | 5 | 8.0 | 63 | 53.0 |
| Total | 60 | 100 | 60 | 100 | 120 | 100 |
| **Marital status** | | | | | | |
| Single | 41 | 68.0 | 38 | 63.0 | 79 | 66.0 |
| Married | 15 | 25.0 | 21 | 35.0 | 36 | 30.0 |
| Widowed | 4 | 7.0 | 1 | 2.0 | 05 | 4.0 |
| Total | 60 | 100 | 60 | 100 | 120 | 100 |
| **Household size** | | | | | | |
| 1-5 | 26 | 43.0 | 24 | 40.0 | 50 | 42.0 |
| 6-10 | 11 | 18.0 | 17 | 28.0 | 28 | 23.0 |
| 11-15 | 20 | 33.0 | 10 | 17.0 | 30 | 25.0 |
| 16-20 | 3 | 5.0 | 09 | 15.0 | 12 | 10.0 |
| Total | 60 | 100 | 60 | 100 | 120 | 100 |
| **Educational level** | | | | | | |
| Primary | 7 | 12.0 | 13 | 22.0 | 20 | 17.0 |
| Secondary | 13 | 22.0 | 8 | 13.0 | 21 | 18.0 |
| Tertiary | 9 | 15.0 | 12 | 20.0 | 21 | 18.0 |
| Non formal education | 31 | 52.0 | 27 | 45.0 | 58 | 48.0 |
| Total | 60 | 100 | 60 | 100 | 120 | 100 |
| **Membership of association** | | | | | | |
| Yes | 39 | 65.0 | 38 | 63.0 | 77 | 64.0 |
| No | 21 | 35.0 | 22 | 37.0 | 43 | 36.0 |
| Total | 60 | 100 | 60 | 100 | 120 | 100 |
| **Marketing experience** | | | | | | |
| 1-5 | 31 | 52.0 | 26 | 43.0 | 57 | 48.0 |
| 6-10 | 12 | 20.0 | 15 | 25.0 | 27 | 23.0 |
| 11-15 | 5 | 8.0 | 5 | 8.0 | 10 | 8.0 |
| 16-20 | 4 | 7.0 | 9 | 15.0 | 13 | 11.0 |
| 21 and above | 8 | 13.0 | 5 | 8.0 | 13 | 11.0 |
| Total | 60 | 100 | 60 | 100 | 120 | 100 |

**Table 2:** Marketing Channel for Smoked Fish

| Marketing Channels | Frequency | Percentage |
|---|---|---|
| Processor to local consumers | 31 | 51.7 |
| Processor to retailer | 18 | 30 |
| Processor to wholesaler | 10 | 16.7 |
| Processor to hotel/restaurants/shops | 01 | 1.7 |
| **Total** | **60** | **100** |

**Table 3:** Marketing channels for Fresh Fish

| Marketing Channels | Frequency | Percentage |
|---|---|---|
| Fishermen-local fishermen | 10 | 16.7 |
| Fishermen-local consumer | 07 | 11.7 |
| Fishermen-retailer | 13 | 21.7 |
| Fishermen-processor | 30 | 50 |
| **Total** | **60** | **100** |

**Table 4:** Constraints to Fresh Fish Marketing in Keffi LGA of Nasarawa State

| Constraints | Frequency | Percentage | Rank |
|---|---|---|---|
| Lack of capital | 34 | 56.7 | 1st |
| Season | 28 | 46.7 | 2nd |
| Low selling price of fish | 26 | 43.3 | 3rd |
| Government policy | 20 | 33.3 | 4th |
| Cost of transportation | 11 | 18.3 | 5th |
| Lack of storage facilities | 08 | 13.3 | 6th |
| Cost of gears | 05 | 8.3 | 7th |

**Table 5:** Constraints to smoked fish marketing in Keffi LGA of Nasarawa State

| Constraints | Frequency | Percentage | Rank |
|---|---|---|---|
| Lack of capital | 37 | 61.7 | 1st |
| Cost of transportation | 35 | 58.3 | 2nd |
| Lack of preservation | 31 | 51.7 | 3rd |
| Price instability | 31 | 51.7 | 3rd |
| Fish spoilage | 23 | 38.3 | 4th |
| Season | 20 | 33.3 | 5th |
| Proximity of market | 10 | 16.7 | 6th |
| Cost of processing materials | 10 | 16.7 | 6th |

## DISCUSSION

### Socio-Economic Characteristics of Fresh and Smoked Fish Marketers

There is a relatively balanced demand for both smoked and fresh fish. However, the slightly higher percentage favoring fresh fish (32.0%) indicates a preference for the natural and unprocessed quality of fresh fish within this demographic area. This finding could be attributed to health-conscious choices or a desire for more traditional culinary options. Businesses operating in this market may find it beneficial to emphasize the freshness and nutritional aspects of their products when targeting this age group. In contrast, the 21-30 age range demonstrates a notable disparity in demand between smoked and fresh fish. The higher percentage favouring fresh fish (32.0%) over smoked fish (20.0%) could be indicative of a preference for less processed or traditional food choices among younger consumers. Marketers may explore promoting the freshness and versatility of fresh fish to cater to the preferences of this age group, tapping into potential opportunities for market growth (Adewole and Ojo, 2022). Moving on to the 31-40 age group, the shift in demand towards smoked fish (28.0%) compared to fresh fish (18.0%) suggests a unique preference within this demographic area. This trend may be influenced by factors such as convenience, taste preferences, or cultural considerations. Businesses may consider tailoring their marketing strategies to highlight the convenience and flavour profiles associated with smoked fish to better resonate with this age group. Examining the 15-20 age group, where there is a slightly higher demand for fresh fish (13.0%) compared to smoked fish (12.0%), it implies that younger individuals may lean towards unprocessed and natural food options. This could be attributed to a growing awareness of health benefits associated with fresh fish or a cultural inclination towards less processed (Adewole and Ojo, 2022).

**Gender of the Respondents**

Table 1 reveals a notable gender-based disparity in fish demand. Firstly, it is evident that the majority of males (92.0%) exhibit a strong preference for fresh fish, while only a small percentage (3.0%) opt for smoked fish. This marked difference suggests that fresh fish is significantly more popular among males. The preference for fresh fish might be influenced by factors such as taste, texture, or cultural preferences (Okon and Ibrahim, 2021). This finding has significant implications for suppliers and marketers in the fish industry who should consider tailoring their products and marketing strategies to cater to the distinct preferences of male consumers. On the other hand, the data reveals a contrasting pattern among females. A substantial majority of females (97.0%) express a preference for smoked fish, while only 8.0% favor fresh fish. This preference may be attributed to various factors such as convenience, longer shelf life, or even health considerations.

**Marital Status of Respondents**

Table 1 presents a breakdown of fresh and smoked fish demand based on marital status, revealing noteworthy patterns. Single individuals show a higher preference for both smoked (68.0%) and fresh fish (63.0%), making up the majority of the overall demand (66.0%). In contrast, married respondents exhibit a lower inclination towards fish consumption, with only 25.0% and 35.0% opting for smoked and fresh fish, respectively, contributing to a combined demand of 30.0%. Widowed individuals, while forming a smaller portion of the sample, express a minimal preference for smoked fish (7.0%) and a negligible one for fresh fish (2.0%), resulting in a combined demand of 4.0%. These findings suggest that marketing strategies targeting single individuals may yield more significant returns, necessitating a nuanced approach for the married and widowed segments (Abdullahi and Adeleke, 2013).

**Household Size of the Respondents**

Table 1 presents results of fresh and smoked fish demand based on household size categories. It shows that households with 1-5 members have the highest demand for both fresh and smoked fish, with 26 and 43 percent, respectively. On the other hand, larger households of 6-10 members and 11-15 members show a decrease in demand for both types of fish, with 18 and 28 percent for fresh fish, and 33 and 17 percent for smoked fish, respectively. The smallest demand is observed in households with 16-20 members, accounting for 5 percent for fresh fish and 15 percent for smoked fish. The implications of these results are multifaceted. Firstly, it suggests that smaller households tend to have a higher demand for fish, which could be attributed to easier meal preparation and less storage requirements. This information is valuable for fish suppliers and marketers who can tailor their marketing strategies to target smaller households. Additionally, the decline in demand with increasing household size may indicate that larger families might be opting for alternative protein sources or have specific dietary preferences (Adebayo and Oladele, 2015).

**Educational Level of the Respondents**

Results on the educational level of the respondents as shown in table 1 reveals that individuals with non-formal education exhibit a significantly higher demand for both smoked and fresh fish compared to those with primary, secondary, or tertiary education. Specifically, 52.0% of respondents with non-formal education prefer smoked fish, while 45.0% prefer fresh fish. This suggests that there might be a correlation between lower educational levels and a higher demand for both types of fish. This information is crucial for market analysis and targeting specific consumer segments. Businesses in the fish industry may need to adapt their marketing and distribution strategies to cater to the preferences of consumers with non-formal education, who constitute a significant portion of the market. This could involve packaging, pricing, or promotion strategies that align with the preferences and purchasing power of this demographic. Understanding the relationship between educational levels and fish preference is essential for sustainable development in the industry, as it enables targeted interventions to meet the

diverse needs of the market (Olatunji and Ogunleye, 2016).

**Membership of Association**

Fresh and smoked fish demand based on the membership status in an association as shown in table 1 revealed that among those who are members of the association, 65.0% prefer smoked fish, while 63.0% prefer fresh fish. On the other hand, among those who are not members of the association, 35.0% opt for smoked fish, and 37.0% prefer fresh fish. When considering the combined frequencies, 64.0% of respondents prefer smoked fish, and 36.0% prefer fresh fish. These results have implications for market strategies and supply chain management in the fish industry. The higher preference for smoked fish among association members suggests a potential market segment for smoked fish products. Tailoring marketing efforts and product availability to meet the demand for smoked fish within this group could be a strategic approach. Additionally, the result indicates a substantial overall demand for smoked fish, which could inform production planning and resource allocation for fish processing businesses. Understanding preferences within different customer segments can help businesses optimize their product offerings and distribution channels to meet consumer demand effectively (Ahmed and Bello, 2019).

**Marketing Experience**

The result in table 1 presents the information of fresh and smoked fish demand based on respondents' marketing experience. The result indicates that a significant proportion of respondents with 1-5 years of marketing experience prefer smoked fish (52.0%) compared to fresh fish (43.0%). This suggests a potential market trend where individuals with relatively less marketing experience show a higher inclination towards smoked fish. On the other hand, respondents with 6-10 years of experience exhibit a more balanced preference, with 20.0% opting for smoked fish and 25.0% for fresh fish. Interestingly, the percentage of those preferring fresh fish increases among individuals with 16-20 years of marketing experience (15.0%) compared to smoked fish (7.0%). These findings have important implications for businesses in the fish industry. Companies might consider tailoring their marketing strategies based on the target audience's marketing experience. For instance, for individuals with 1-5 years of experience, emphasizing the convenience and longer shelf life of smoked fish could be effective. Meanwhile, for those with 16-20 years of experience, highlighting the freshness and natural attributes of fresh fish might resonate better. According to Yusuf and Adeoye (2017), marketing experience can enable businesses to optimize their product offerings and marketing messages to better meet the varied demands of different market segments.

**Marketing Channels for Smoked Fish**

Table 2 provides valuable insights into the marketing channels for smoked fish, shedding light on the distribution patterns and consumer preferences. The highest frequency (51.7%) in the "Processor to local consumers" category suggests a significant direct-to-consumer trend. This may imply a growing demand for a more transparent and traceable supply chain, where consumers prefer to purchase directly from processors, possibly for perceived freshness, trust, or regional sourcing. Processors could leverage this information to enhance their local marketing strategies, focusing on building relationships with consumers, ensuring product quality, and communicating the benefits of buying directly from the source (Akande and Sule, 2022). On the other hand, the relatively lower percentages for "Processor to retailer" and "Processor to wholesaler" (30% and 16.7%, respectively) indicate that intermediary channels are less prevalent. Processors might reconsider the efficiency and effectiveness of these channels, potentially exploring ways to strengthen relationships with retailers and wholesalers to increase market reach. Additionally, the minimal presence in "Processor to hotel/restaurants/shops" (1.7%) suggests an untapped market potential for processors to collaborate with hospitality businesses, such as hotels and restaurants, to expand their market share. This could involve tailored marketing strategies, product

development, or partnerships to meet the unique demands of these segments and tap into new revenue streams (Akande and Sule, 2022).

**Marketing Channels for Fresh Fish**

Table 3 revealed the distribution of marketing channels for fresh fish. It was evident that the most dominant channel is the direct sale from fishermen to processors, constituting 50% of the responses. This suggests a substantial demand for fresh fish from processors, possibly driven by the desire for high-quality, directly sourced products. The second most prevalent channel is through local retailers, representing 21.7%. This highlights the significance of retail outlets in catering to consumer demand for fresh fish. However, it's worth noting that direct sales from fishermen to local consumers and local retailers are also noteworthy, with 16.7% and 11.7%, respectively. These findings imply a diverse market with demand spread across various channels, indicating the importance of understanding and catering to the preferences of different consumer segments. The implications of these results are crucial for stakeholders in the fresh fish industry. For fishermen, there is an opportunity to optimize their distribution strategies by aligning with the dominant channels, particularly emphasizing direct sales to processors. Processors should consider strengthening their relationships with local fishermen to ensure a consistent and reliable supply of fresh fish. Retailers can capitalize on their significant market share by focusing on marketing strategies that promote the freshness and quality of their products. According to Babatunde and Ojo (2019), a comprehensive understanding of the demand patterns across various marketing channels is essential for stakeholders to make informed decisions, enhance efficiency, and meet the diverse preferences of consumers in the fresh fish market.

**Constraints to Fresh Fish Marketing**

The results presented in Table 4 provide valuable insights into the constraints affecting the marketing of fresh fish in the study area. The most prominent constraint identified is the lack of capital (56.7%) ranking it as the primary constraint. This implies that financial constraints significantly impact the ability of fish marketers to operate effectively, potentially limiting their capacity to meet the demand for both fresh and smoked fish products. As a result, addressing financial barriers and promoting access to capital could have a substantial positive effect on the overall fish market. The second most frequently cited constraint was season (46.7%) recognizing its impact on fish marketing. This suggests that the seasonal variability in fish availability may affect both the supply and demand for fresh. The low selling price of fish emerges as the third significant constraint, with (43.3%) of the respondents identifying it as a challenge. This highlights the economic pressure faced by fish marketers, potentially leading to reduced profitability. Additionally, the influence of government policy (33.3%) on fish marketing cannot be ignored. Government interventions, regulations, and support mechanisms play a crucial role in shaping the market dynamics. The relatively lower frequencies for cost of transportation, lack of storage facilities, and cost of gears suggest that while these factors are recognized, they may have a comparatively lesser impact on the overall demand dynamics. Nonetheless, addressing these issues could contribute to a more efficient and robust fish marketing system (Adekunle and Ajayi, 2021).

**Constraints to Marketing of Smoked Fish**

Table 5 outlines the constraints to smoked fish marketing. Firstly, the high percentage of responses indicating a lack of capital (61.7%) as the primary constraint suggest that financial barriers significantly impact market participation. This implies that interventions aimed at providing financial support or access to credit for fishers and processors could stimulate increased production and supply, potentially meeting the demand for both fresh and smoked fish. Secondly, the cost of transportation (58.3%) emerges as the second most critical constraint. Addressing this issue is crucial for expanding market reach and ensuring efficient distribution. Investments in transportation infrastructure and the development of transportation networks could reduce costs, benefiting both producers and consumers.

Furthermore, improved transportation could contribute to the availability of fresh fish in distant markets, potentially affecting the demand for smoked fish as an alternative preservation method (Salau and Mohammed, 2019). The third and fourth constraints, lack of preservation (51.7%) and price instability (51.7%), are closely related and underscore the need for effective preservation techniques and market stabilization measures. If preservation challenges are mitigated, it could positively impact smoked fish demand. Similarly, addressing price instability through market interventions and policies may enhance consumer confidence and boost overall fish consumption. The lower-ranked constraints, including fish spoilage (38.3%), season (33.3%), proximity of market (16.6%), and cost of processing materials (16.7%), while individually less prevalent, collectively contribute to market inefficiencies. Fish spoilage and seasonality may influence the availability of fresh fish, potentially impacting consumer preferences for smoked fish as a reliable alternative. Improvements in processing technology and practices, coupled with addressing market proximity issues, could enhance the overall competitiveness of smoked fish in the market (Ojo and Yusuf, 2018).

## CONCLUSION

In conclusion, the study reveals intriguing patterns in fish consumption preferences across various demographic factors. Age plays a significant role, with the 21-30 and 31-40 age groups favouring smoked fish, aligning with the 41-50 age category, while those between 15-20 lean towards fresh fish. Gender differences are stark, with a vast majority of males preferring fresh fish, in contrast to females who overwhelmingly express a preference for smoked fish. Interestingly, single individuals constitute the majority of the overall demand, showcasing a higher preference for both smoked and fresh fish. Household size also influences preferences, with 1-5 member households exhibiting the highest demand for both types of fish. Education and association membership further shape choices, with respondents with non-formal education and association members showing distinct preferences. Marketing experience also plays a role, with those with 1-5 years favouring smoked fish.

## RECOMMENDATIONS

Government agencies responsible for economic development and fisheries can implement targeted interventions to address capital constraints. They can provide financial support in the form of low-interest loans or grants to individuals in the fish marketing sector. Businesses involved in processor-to-local consumer relationships and direct sales from fishermen to processors can explore and implement diversification of marketing channels. This may involve leveraging online platforms, partnering with specialty stores, or exploring new distribution channels. To effectively cater to diverse fish consumption preferences, targeted marketing strategies based on age and gender dynamics can be implemented. It is important to tailor campaigns for smoked fish to the 21-40 age groups, acknowledging their higher preference, and focus fresh fish promotions on the 15-20 age category to accommodate distinct taste preferences.

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# EVALUATION OF FISH FARMERS' AWARENESS AND ADOPTION OF MODERN AQUACULTURE TECHNIQUES IN DUTSIN-MA LOCAL GOVERNMENT, KATSINA STATE

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**ABSTRACT**
*Aquaculture is increasingly recognized as a sustainable strategy for enhancing food security, income generation, and poverty reduction in Nigeria. This study assessed the awareness and adoption of modern aquaculture practices among fish farmers in Dutsin-Ma Metropolis, Katsina State. Data was collected from 20 fish farmers using structured questionnaires and it was analysed using descriptive statistics such as frequencies and percentages with SPSS version 25. The results showed a high level of awareness of modern aquaculture practices, with 90% of respondents indicating familiarity with techniques such as pond management, artificial feed usage, and fish disease control. Adoption rates were also encouraging with 80% of farmers practicing at least one modern aquaculture method. Pond management (60%), use of artificial feed (70%), and disease control (50%) were the most widely adopted practices, while breeding and hatchery management recorded the lowest adoption (35%). The study concludes that while awareness and adoption of modern aquaculture practices are high, strengthening training, extension services, and access to resources are recommended to enhance adoption and ensure the sustainability of aquaculture in the study area.*

**Keywords:** Aquaculture, awareness, adoption, fish farmer

## INTRODUCTION

Aquaculture has emerged as one of the fastest-growing food production sectors in the world, contributing significantly to global food security, employment, and economic development. With capture fisheries increasingly constrained by overexploitation, pollution, and climate change, aquaculture provides a viable alternative for meeting the growing demand for fish and fishery products (Food and Agriculture Organization, 2022). Despite its potential, aquaculture in Nigeria is characterized by opportunities and challenges. On one hand, there has been remarkable progress in the awareness of modern aquaculture practices, driven by agricultural extension services, workshops, and peer-to-peer learning. Farmers are increasingly familiar with essential techniques such as pond management, water quality monitoring, fish disease control, and the use of artificial feed (Adeyemi et al., 2020). On the other hand, adoption rates of these practices remain uneven, with more advanced methods such as breeding and hatchery management being less widely embraced, often due to financial, technical, and infrastructural limitations (Ahmed and Ibrahim, 2019). Katsina State is located in North-western Nigeria, holds considerable potential for aquaculture development owing to its growing population and rising fish demand. Understanding both the level of awareness and the extent of adoption of modern aquaculture practices is therefore critical in identifying gaps and formulating strategies that can enhance productivity and sustainability of the sector.

## MATERIALS AND METHODS

### Study Area

The study was conducted in Dutsin-Ma Metropolis. Dutsin-Ma is lies in the north-eastern part of Katsina State, Nigeria, between latitude 12°27`N and longitude 7°29`E, covering about 527km$^2$. The soils are mainly sandy loam to loamy, ideal for earthen fish ponds, while vegetation is of the sudan savannah type with annual rainfall of 700-900mm, and temperatures ranging from 21°C to 30°C. The area is drained by Dutsin-Ma and Zobe reservoir which provide reliable water sources for aquaculture.

**Sample Size and Sampling Technique**
A purposive and simple random sampling technique was used to select respondents. A total of 20 fish farmers were surveyed, representing small, medium, and large-scale practitioners as indicated in the demographic results.

**Data Collection**
A structured questionnaire was developed and used to collect primary data. The questionnaire consisted of five sections. It was pre-tested with a small group of farmers outside the study area to ensure clarity and reliability before administration. Primary data were collected through face-to-face interviews and self-administered questionnaires, depending on the literacy level of the respondents.

**Data Analysis**
The collected data were analysed using descriptive statistics such as frequencies and percentages were used to summarize demographic characteristics, awareness levels and adoption rates. Data analyses were carried out using the Statistical Package for Social Sciences (SPSS) version 25, and results were presented in tables for easy interpretation.

**RESULTS**
Table 1 provides an overview of the demographic characteristics of the respondents. The study showed that most respondents are young (20–30 years), accounting for 40%. The Majority (70%) of respondents are male, suggesting that aquaculture practices in this study area may be male-dominated. However, 30% of respondents being female indicate a noticeable involvement of women in the industry. Most respondents (40%) have tertiary education, which may reflect a more educated and potentially more informed group of farmers. The majority (45%) of respondents have 1–5 years of experience in aquaculture. 50% of the respondents are involved in small-scale operations highlighting the emerging and subsistence-oriented nature of the industry.

**Table 1:** Section A – socio-economic characteristics of the farmers

| Demographic Variable | Response Option | Frequency | Percentage (%) |
|---|---|---|---|
| Age Group | 20 – 30 years | 8 | 40.0% |
| | 31 – 40 years | 6 | 30.0% |
| | 41 – 50 years | 4 | 20.0% |
| | Above 50 years | 2 | 10.0% |
| | | **20** | **100%** |
| Gender | Male | 17 | 85.0% |
| | Female | 3 | 15.0% |
| | | **20** | **100%** |
| Educational Background | Primary education | 4 | 20.0% |
| | Secondary education | 8 | 40.0% |
| | Tertiary education | 8 | 40.0% |
| | | **20** | **100%** |
| Years of Experience | Less than 1 year | 2 | 10.0% |
| | 1 – 5 years | 9 | 45.0% |
| | 6 – 10 years | 6 | 30.0% |
| | More than 10 years | 3 | 15.0% |
| | | **20** | **100%** |
| Scale of Operation | Small-scale | 10 | 50.0% |
| | Medium-scale | 6 | 30.0% |
| | Large-scale | 4 | 20.0% |
| TOTAL | | **20** | **100%** |

***SOURCE:*** *Field Survey Data 2025*

Table 2 shows the awareness of modern aquaculture practices. Majority (90%) of the fish farmers are aware of modern aquaculture methods. The main information channels are agricultural extension services (25%) and training/workshops (30%), both pointing to formal and structured education. The highest awareness is found in pond management (70%), water quality management (50%), and fish disease control (60%). The use of artificial feed is also highly recognized (75%). Awareness of breeding and hatchery management is lower (40%), indicating less exposure or interest in these areas.
Table 3 above indicates practice of modern aquaculture methods. A large proportion (80%) of respondents are adopting modern aquaculture methods, indicating a positive attitude towards new practices in the industry. Pond management, use of artificial feed, and fish disease control are the most adopted practices (60% to 75%). Breeding and hatchery management (35%) has the least adoption, which could be due to complexity or resource requirements. Adoption frequency is relatively high, with 35% of respondents adopting modern aquaculture techniques. Significant proportion (30%) often adopts, but there is still a small group that rarely or occasionally adopts these practices (15% and 20%, respectively).

**Table 2:** Section B – awareness of modern aquaculture practices

| Awareness Item | Response Option | Frequency | Percentage (%) |
|---|---|---|---|
| Awareness of modern aquaculture practices | Yes | 18 | 90.0% |
| | No | 2 | 10.0% |
| Source of first learning about modern aquaculture practices | Agricultural extension services | 5 | 25.0% |
| | Fellow farmers | 4 | 20.0% |
| | Media (Radio/TV/Newspaper) | 3 | 15.0% |
| | Online sources | 2 | 10.0% |
| | Training/workshops | 6 | 30.0% |
| Modern aquaculture practices respondents are aware of | Pond management | 14 | 70.0% |
| | Water quality management | 10 | 50.0% |
| | Fish disease control | 12 | 60.0% |
| | Use of artificial feed | 15 | 75.0% |
| | Breeding and hatchery management | 8 | 40.0% |

***SOURCE:*** *Field Survey Data 2025*

**Table 3:** Section C – adoption of modern aquaculture practices

| Adoption Item | Response Option | Frequency | Percentage (%) |
|---|---|---|---|
| Practice of modern aquaculture methods | Yes | 16 | 80.0% |
| | No | 4 | 20.0% |
| Practices adopted (if Yes) | Pond management | 12 | 60.0% |
| | Water quality management | 9 | 45.0% |
| | Fish disease control | 10 | 50.0% |
| | Use of artificial feed | 14 | 70.0% |
| | Breeding and hatchery management | 7 | 35.0% |
| Frequency of adopting modern aquaculture techniques | Always | 7 | 35.0% |
| | Often | 6 | 30.0% |
| | Occasionally | 4 | 20.0% |
| | Rarely | 3 | 15.0% |

***SOURCE:*** *Field Survey Data 2025*

## DISCUSSION

The respondents were predominantly young (20–30 years). This is similar to findings by Olaoye et al., (2021), who reported that aquaculture in Nigeria, is largely practiced by youthful and energetic individuals capable of handling the labor-intensive nature of fish farming. However, the presence of female farmers (15%) indicates a gradual inclusion of women, which has been highlighted as an important step toward achieving gender inclusivity in aquaculture (Erondu et al., 2021). Most respondents had at least secondary or tertiary education, which positively influences awareness and adoption of new technologies. This is in line with the work of (Effiong and Edet, 2022) who reported that educated farmers are more likely to understand and implement technical recommendations. The moderate experience level (1–5 years) reported by nearly half of the respondents suggests that aquaculture is a growing sector in the area, attracting new entrants. The study revealed that while awareness was highest for pond management (70%), artificial feed usage (75%), and fish disease control (60%), awareness of breeding and hatchery management was relatively low (40%). This aligns with Ahmed and Ibrahim (2019), who reported that while farmers are often knowledgeable about basic management practices, more complex activities like hatchery operations remain underutilized due to their technical demands. Adoption rates were encouraging, with 80% of respondents practicing modern aquaculture methods. The most adopted practices included pond management, use of artificial feeds, and fish disease control. Conversely, breeding and hatchery management were the least adopted, corroborating findings by Adeyemi et al. (2020), who identified high costs and technical difficulties as major barriers to hatchery operations in Nigeria.

## CONCLUSION

This study showed that most fish farmers in Dutsin-Ma are aware of modern aquaculture practices and have adopted them. However practices like breeding and hatchery management are still less common. The results also revealed that most of the farmers are young and educated.

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Olaoye, O. J., Adeoye, S. A., and Salau, E. S. (2021). Socioeconomic impacts of fish farming in rural Nigeria. *Nigerian Agricultural Journal, 12*(4), 56–69.

# ASSESSMENT OF SOCIO-ECONOMIC CHARACTERISTICS AND ECONOMIC IMPACT OF POSTHARVEST FISH LOSSES AMONG SMALL SCALE FISHERMEN IN FEFERUWA LAKE, LAFIA LOCAL GOVERNMENT AREA, NASARAWA STATE.

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**ABSTRACT**
*The study was conducted to assess the socio-economic characteristics and economic impact of Postharvest fish losses among small scale fishermen in Feferuwa in Lafia, Nasarawa State. Data obtained were subjected to descriptive statistics such as means, frequency and percentages. The result of the study showed that most (44.0%) of the respondents' age ranged between 21-30 years. The mean age was approximately 27 years. Also, 86.0% of the respondents were male, with most (56.0%) of the respondents being married. Majority (60.0%) had between 6-10 persons per household, and in all, 86% of all the respondents had attended one form of education. The mean years of fishing experience was 7 years, and most (62.0%) of the respondents do not have access to credit facilities. Majority of respondents (60.0%) employ drift nets for their fishing activities, while a substantial number (90.0%) utilize planked boats. Interestingly, these planked boats were predominantly 9 meters in lengths, as reported by 56.0% of respondents within the study area. The absence of electricity (66.0%) and the lack of ice provisions (34.0%) pose considerable challenges in the preservation of fresh fish in the study area. 86.0% used sacks or nylon materials to cover fresh fish during transportation from the fishing grounds to the respondents sold through kilogram. Inadequate storage facilities (78.0%) and high temperature (62.0%), contributed to a reduction in the market value of fish.*

**Keywords:** *Economic Impact, Feferuwa, Postharvest Losses, Small-scale Fishermen.*

## INTRODUCTION

Worldwide, around 14 percent of food produced is lost from the postharvest stage, but excluding, the retail stage. Highly nutritious material is lost or nutritionally compromised, affecting the diets of millions of people, including in regions where under nutrition and micronutrient deficiencies are endemic FAO (2011). Fish is a perishable food that has a high potential for waste and loss, but robust assessments from low- and middle-income Akande and Diei-Ouadi (2010).

The fisheries sector has acquired a unique status in economy contributing to the socio-cultural setting, rural employment and food and nutritional security. Because of its vast span, and immense potential for development, the sector continues to provide direct and indirect livelihood opportunities to over 12 million people. Freshwater aquaculture has been expanding very fast, contributing from less than 20% to nearly 50% to the total fish production over a decade Dof (2012). In spite of all positive measures taken towards increment of production, post-harvest loss of fish in Nigeria is enormous. The huge loss in fisheries exerts immense pressure on food security of the country.

Fish loss occurs throughout the value chain from catch or production to final consumption. Loss is influenced by several factors including the species of fish, the associated physical characteristics, the perceived value of the fish, volumes handled, the level of seasonality present, and geographical location.

Spoilage and quality downgrading of the product is more likely to occur in lower-income economies due to high ambient temperatures, lack of access to services, infrastructure, basic technology, a reliance on more traditional smoking and drying techniques for preservation, and lack of cooling (cold chain) facilities Geethalakshmi (2020).
The study aimed to assess thesocio-economic characteristics and economic impact of postharvest fish losses among small scale fishermen in Feferuwa Lake, Lafia local government area, Nasarawa state.

## MATERIALS AND METHODS

### Research area

The study was conducted in Feferuwalake in Lafia local government area in Nasarawa state, Nigeria with a population of 330,712 at the 2006 census. It coordinates: $8^0$38'56"N, $8^0$52' 44"E

### Data collection

Data for the study was collected using a well structure questionnaire, administered among fishermen in Feferuwa Lake in Lafia. 60 respondents were selected within the fishing area. The questionnaire consists of three sections; the first section capture the demographic characteristic of the respondents, the second section consist of the level of the fish storage facilities and assesses the challenges contributing to postharvest losses of fish among small scale fishermen, the third section consist of the economic impact of post harvest loss of fish, in Feferuwa, Lafia Nasarawa State.

### Statistical analysis

Data obtained was subjected to Descriptive statistics (such as means, frequency and percentages) using Statistical Package for Social Sciences (SPSS), Version 16.0.

## RESULTS

**Table 1:** Demographic Characteristics of the Respondents in the Lake Feferuwa

| Characteristics | Frequency | Percentage | Mean ($\bar{x}$) |
|---|---|---|---|
| **Age** | | | |
| 10-20 | 5 | 10.0 | |
| 21-30 | 22 | 44.0 | 26.6 |
| 31-40 | 18 | 36.0 | |
| 41-50 | 5 | 10.0 | |
| Total | 50 | 100.0 | |
| **Sex** | | | |
| Female | 7 | 14.0 | |
| Male | 43 | 86.0 | |
| Total | 50 | 100.0 | |
| **Marital status** | | | |
| Single | 22 | 44.0 | |
| Married | 28 | 56.0 | |
| Total | 50 | 100.0 | |
| **Household size** | | | |
| 1-5 | 16 | 32.0 | |
| 6-10 | 30 | 60.0 | 7.9 |
| 11-15 | 4 | 8.0 | |
| Total | 50 | 100.0 | |

| | | | |
|---|---|---|---|
| **Educational qualification** | | | |
| No formal education | 7 | 14.0 | |
| Primary education | 12 | 24.0 | |
| Secondary education | 20 | 40.0 | |
| Tertiary education | 11 | 22.0 | |
| Total | 50 | 100.0 | |
| **Years of fishing experience** | | | |
| 1-5 | 10 | 20.0 | |
| 6-10 | 22 | 44.0 | 7.2 |
| 11-15 | 15 | 30.0 | |
| 16-20 | 3 | 6.0 | |
| Total | 50 | 100.0 | |
| **Access to credit** | | | |
| No | 19 | 38.0 | |
| Yes | 31 | 62.0 | |
| Total | 50 | 100.0 | |

*Source: Field survey, 2023*

**Table 2:** Handling Practices, Storage Facilities and Transportation System Used at the Landing Site

| Variables | Frequency | Percentage |
|---|---|---|
| **Type of fishing gear used** | | |
| Drift net | 30 | 60.0 |
| Cast net | 14 | 28.0 |
| Hooks and lines | 6 | 12.0 |
| **Types of fishing boat used** | | |
| Plank boat | 45 | 90.0 |
| Metal boat | 3 | 6.0 |
| Aluminum boat | 2 | 4.0 |
| **Size of boat used (meter)** | | |
| Less than 7 | 5 | 10.0 |
| 8 meters | 17 | 34.0 |
| 9 meters | 28 | 56.0 |
| **Do you make use of ice to preserve fresh fish?** | | |
| Yes | 7 | 14.0 |
| No | 43 | 86.0 |
| **If no, state why** | | |
| No electricity | 33 | 66.0 |
| No ice | 17 | 34.0 |
| **Other forms of method used to preserve fresh fish from the fishing ground to landing site** | | |
| Ice method | 4 | 8.0 |
| Evaporative cooling method | 3 | 6.0 |
| Covering of fish with sack/nylon | 43 | 86.0 |

| | | |
|---|---|---|
| **Are fish landed and offloaded without delay** | | |
| Yes | 48 | 92.0 |
| No | 2 | 4.0 |
| **Where is fresh fish placed at the landing site** | | |
| On the ground | 10 | 20.0 |
| Plastic basin | 28 | 56.0 |
| Woven basket | 12 | 24.0 |
| **How do you sell your fresh fish at the landing site** | | |
| Basket | 4 | 8.0 |
| Per kilogram, hand and basket | 46 | 92.0 |

*Source: Field survey, 2023*

**Table 3:** Economic Impact of Post-Harvest Loss of Fish

| Impact statement | Frequency | Percentage |
|---|---|---|
| Insect infestation lead to loss in value, price and icome | 11 | 22.0 |
| Poor storage facilities reduces the market value for fish | 39 | 78.0 |
| Mechanical damage results to unattractiveness of fresh fish leads to reduced food security | 30 | 60.0 |
| High temperature causes discoloration and loss in value in financial burden | 31 | 62.0 |
| Poor packaging influence the freshness of fish | 25 | 50.0 |

Source: Field survey, 2023*multiple responses

## DISCUSSION

### Demographic characteristics of the respondents in the Lake Feferuwa

From Table 1, most (44.0%) of the respondents' age ranged between 21 – 30 years, while 36.0% were between the age ranges of 31-40 years. The mean age was approximately 27.0 years which indicates that the majority of the respondents are relatively young. This raises questions about the level of experience and expertise among the surveyed fishermen. Inexperienced fishermen may be more prone to postharvest fish losses due to factors like inadequate handling, storage, and processing techniques. According to Ashley-Dejo and Adelaja, (2022). The high percentage of male-headed households underscores the prevailing gender dynamics in the fishing industry. It suggests that, traditionally, fishing activities are often associated with men in the region. This observation reflects the existing gender roles and responsibilities within the fishing communities, with men typically taking on the role of fishermen. Also, men are likely to be the primary owners and controllers of fishing assets, such as boats, fishing gear, and the catch itself. Men often play a central role in the livelihoods of fishing communities, which can have implications for how postharvest practices are organized and the priorities placed on minimizing fish losses (Ashley-Dejo *et al.* 2017). It was further observed that most (56.0%) of the respondents were married individuals, while 44.0% were still single. The presence of married individuals in the sample may indicate that they have access to family labour, which can be an asset in fish handling and preservation. This can affect the ability to implement effective postharvest loss reduction strategies, as they may have more hands available to assist in handling and processing the catch.

The household size of the fishers indicates that majority (60.0%) had between 6-10 persons per household while 32.0% had between 1-5 persons per household. The average household size was approximately 8 persons per household.

A larger household size, with an average of around 8 persons per household, implies that these small-scale

fishermen are likely to have multiple dependents. With a considerable number of household members to support, the income generated from fishing becomes even more critical. Reducing postharvest losses can contribute to increased income for these households, which, in turn, can be invested in improving their overall quality of life (Apata, 2012).

The educational qualification of the respondents revealed that 86% of all the respondents had attended one form of education and hence can read and write. It suggests that educational interventions and capacity-building programs can be effectively implemented to address fish loss issues. According to Nguvava, (2013), literacy and basic education can enhance the ability of small-scale fishermen to adopt and adapt to new technologies and innovations that could help reduce postharvest losses. The mean years of fishing experience is 7 years, which indicates that the average level of fishing experience among the respondents is moderate. This implies that the respondents possess a reasonable level of knowledge and skills related to fishing practices. The varying years of fishing experience can significantly impact postharvest fish losses. Fishermen with more years of experience may have a better understanding of handling, processing, and preserving fish to minimize losses. On the other hand, those with less experience may be more prone to common postharvest losses due to lack of knowledge or access to proper postharvest technologies and practices.

Most (62.0%) of the respondents do not have access to credit facilities while only 38.0 had access to credit. This is a strong indication of financial constraints. This suggests that these fishermen may face challenges in investing in improved postharvest handling and storage facilities, which could help reduce fish losses.

**Handling practices, storage facilities and transportation system used at the landing site**

Table 2 illustrates that the majority of respondents (60.0%) employ drift nets for their fishing activities, while a substantial number (90.0%) utilize planked boats. Interestingly, these planked boats were predominantly 9 meters in length, as reported by 56.0% of the respondents within the study area. This data underscores the fact that small-scale fishers commonly opt for larger wooden canoes crafted from dugout logs for their fishing operations. This observation aligns with the findings of Nguvava (2013).
Furthermore, a significant portion of the respondents (86.0%) do not incorporate ice either on board or at the landing site to preserve their fresh catch. The absence of electricity (66.0%) and the lack of ice provisions (34.0%) pose considerable challenges in the preservation of fresh fish in the study area. The absence of ice preservation methods indicates that a substantial amount of fresh fish catch is subject to rapid spoilage. This could result in significant postharvest losses for the small-scale fishermen, leading to economic losses, reduced income, and food insecurity.. Consequently, the fish are promptly offloaded upon reaching the landing site (92.0%). The use of ice and refrigeration in the postharvest phase can also lead to reduced energy consumption and more sustainable practices, which are essential for conserving resources and minimizing environmental impact. Yohanna, *et al.*, (2011) have postulated that improper handling of fish could lead to deterioration within a mere 12 hours after harvest.

In an effort to mitigate this issue, many respondents resort to covering fresh fish with sacks or nylon materials (86.0%) during transportation from the fishing grounds to the landing site. While the quality of these covering materials may not be ideal, they effectively serve the primary purpose of shielding the fish from excessive sunlight, which can hasten spoilage. Tesfay and Teferi (2017) have noted that the use of sacks is a practical method to maintain the coolness of fish due to the absence of ice in the study area, offering an improvised solution for ensuring the quality of fish during transit.

With respect to where fish are placed at the landing site, 56.0% of respondents placed fish in the plastic basin, 24.0% placed inside woven basket while 16.0% placed fish on the ground. This implies that

majority of respondents make use of plastic basin to keep the fish in good quality and suitable for purchase. Majority (92.0%) of the respondents sold through kilogram.

Table 3 presents information concerning the economic consequences of post-harvest fish loss. Respondents overwhelmingly concurred that inadequate storage facilities contribute to a reduction in the market value of fish (78.0%). Additionally, high temperatures were identified as a factor leading to discoloration and loss in value (62.0%), while mechanical damage was associated with deformity and a decline in the visual appeal of fresh fish (60.0%). These factors collectively have a detrimental impact on the economic value of fish post-harvest. Furthermore, the study found that suboptimal packaging practices have a significant influence on the freshness of fish (50%). Bolonmduro (2013) further supported these findings by asserting that fish farmers experience substantial economic losses during transportation, storage, and due to the effects of high temperatures.

## CONCLUSION

Based on the findings of this study, several key observations can be drawn. First and foremost, the majority of the respondents were married. Additionally, it was noted that most of the participants had received some form of education, but they had limited access to credit. The primary method employed by these small-scale fishermen for their fishing activities was the use of drift nets, typically carried out using planked boats.

Furthermore, when it came to preserving their fresh catch from the fishing grounds to the landing site, respondents commonly employed the practice of covering the fish with sacks or nylon, and fish were typically sold by weight (kilogram).

However, it was evident that inadequate storage facilities posed a challenge, leading to a reduction in the market value of the fish. High temperatures were identified as a significant factor contributing to discoloration and value loss, negatively impacting the economic returns derived from the fish post-harvest. The respondents encountered significant fish losses, and the most prevalent challenge faced by these small-scale fish farmers was the exposure of their catch to high temperatures, which hindered their ability to preserve and market the fish effectively.

## RECOMMENDATIONS

a) Improvement of Postharvest Handling Practices
b) Diversification of Fishing Techniques
c) Introduction of Value-Adding Practices
d) Market and Price Negotiation Skills
e) Environmental Mitigation Measures

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# SOCIO-ECONOMIC STATUS AND CONSTRAINTS OF HOMESTEAD FISH FARMERS IN IMO STATE, NIGERIA

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**ABSTRACT**
*Aquaculture plays a vital role in enhancing food security and reducing fish imports in Nigeria, yet domestic production remains inadequate to meet demand. Homestead fish farming has emerged as a household-level strategy for income and food security, but its performance is shaped by socio-economic and infrastructural factors. This study examined the socio-economic status, production practices, and challenges of homestead fish farmers in Imo State, Nigeria. A total of 162 respondents were selected through stratified random sampling across the state's three agro-ecological zones. Data from structured questionnaires and interviews were analysed using descriptive statistics. Findings revealed that fish farming is predominantly practiced by males (75.93%), with most respondents being literate (62.96% tertiary education), married (72.22%), and within the productive age group of 30–49 years (57.41%). Farmers owned an average of 4–6 ponds and harvested three cycles annually, producing 2,000–3,000 kg per cycle, with average annual earnings between ₦800,000 and ₦1,000,000. However, only 11% belonged to associations, limiting access to training and credit. Major challenges included high feed and fingerling costs, poor storage and marketing facilities, theft, limited extension services, and unreliable electricity. Strengthening cooperatives, improving credit access, and upgrading infrastructure are recommended to enhance the profitability and sustainability of homestead aquaculture in Nigeria.*

**Keywords:** Aquaculture, food security, potential, challenges

## INTRODUCTION

Nigeria faces a significant fish supply deficit, consuming over 3.5 million tonnes annually but producing less than 1.2 million tonnes domestically (NIOMR, 2021). Aquaculture has been identified as a sustainable pathway to bridge this gap (FAO, 2022). It has strong potential to close the demand–supply gap through expansion of fish farming systems, intensive and semi-intensive systems - recirculatory aquaculture systems (RAS), integrated fish farming (rice–fish, poultry–fish) to increase yields per unit area, cage culture (Ozigbo et al., 2014). Lakes, reservoirs, and coastal waters also offer huge untapped space for cage aquaculture. Establishment of reliable hatcheries to ensure quality fingerlings, technology and innovation - digital tools for farm monitoring, disease control, and market access, improved breeds (e.g., fast-growing tilapia, catfish hybrids) need to be harnessed (Nwuba & Onuoha, 2021). Among various aquaculture systems, homestead fish farming, though small-scale, has gained traction and contributes significantly to household food security, income, and rural livelihoods (Nwachukwu & Onyenweaku, 2007).

Imo State, located in the south-eastern region of Nigeria, possesses significant potential for aquaculture development due to its favourable ecological conditions and water resources. However, the sector faces socio-economic and infrastructural challenges that limit its growth potential. These include limited access to credit, high input costs, scarcity of quality fingerlings and feed, inadequate extension services, poor power supply, and low market prices for fish (Eze *et al.*, 2010). In addition, lack of farmer

registration in cooperative or agricultural bodies further limits access to government interventions and capacity-building initiatives (Ugwumba & Okoh, 2010).

Evaluating the socio-economic status of homestead fish farmers is essential for understanding the constraints they face and identifying opportunities for policy interventions. Such analysis can inform stakeholders and policymakers in designing targeted support programs to enhance productivity, income levels, and food security in rural communities. This study examines the socio-economic characteristics and production challenges of homestead fish farmers in Imo State, with a view to providing policy recommendations for improving productivity and livelihoods.

## METHODOLOGY

### *Description of the study area*

The study was conducted in Imo State, south-eastern region of Nigeria having 27 Local government areas and 3 main agro-ecological zones, Owerri, Orlu zone and Okigwe. Owerri is the capital and largest city serving as the state's commercial and administrative centre. It lies between latitudes 4º′45′N and 7º15′N and longitudes 6º50′E and 7º25′E within an area of approximately 5,100 Sq Km, making it one of the smaller states in Nigeria by landmass. The state shares boundary with Anambra State to the north, Rivers State to the south, Abia State to the east, and Delta State to the west. (GIF, 2010).

### *Data collection and analysis*

Primary and secondary data were obtained using well-structured questionnaires and oral interviews where necessary with a stratified random sampling technique. Two-third (2/3) of the sample space was surveyed from each of the three (3) agro-ecological zones in Imo state which are Owerri, Okigwe and Orlu having nine (9), five (5), and twelve (12) local government areas respectively using ballot technique (randomization). Descriptive statistics including frequencies, percentages and tables were used for analysis.

## RESULTS

Socio-economic analysis shows in **(**Table I**)** that 75.93% of respondents were males. 62.96% had tertiary education. A majority were married (72.22%) and within the productive age bracket of 30–49 years (57.41%). Household sizes were moderate (4–6 persons), and most respondents had resided in their communities for over 20 years.

Farm ownership patterns revealed that 88.89% of farmers were landlords, while pond holdings averaged 4–6 ponds. Production was predominantly intensive (94.44%), with farmers harvesting three cycles per year and producing 2,000–3,000 kg per cycle. Average annual income from fish farming was between ₦800,000 and ₦1,000,000, although many farmers engaged in additional occupations to supplement income. Only 11% of farmers belonged to associations, which limited access to training, credit, and collective bargaining **(**Table II**).**

*Perceived constraint and challenges*

The major challenges identified included high cost of feed and fingerlings, poor access to credit facilities, theft, weak pricing systems, inadequate extension services, and irregular electricity supply. These constraints mirror national challenges reported in aquaculture development studies **(Table III).**

**Table I:** Socio-economic characteristics of espondents

| Characteristics | Categories | Frequency | Percentage |
|---|---|---|---|
| Sex | Male | 123 | 75.93 |
| | Female | 39 | 24.07 |
| | **Total** | **162** | **100.00** |
| Age | <30 | 30 | 18.52 |
| | 30-39 | 45 | 27.78 |
| | 40-49 | 48 | 29.63 |
| | 50-59 | 39 | 24.07 |
| | 60 and above | - | - |
| | **Total** | **162** | **100.00** |
| Marital status | Single | 39 | 24.07 |
| | Married | 117 | 72.22 |
| | Divorced | - | - |
| | Widow(er) | 6 | 3.70 |
| | **Total** | **162** | **100.00** |
| Educational level | Primary education | 3 | 1.85 |
| | Secondary education | 57 | 35.19 |
| | Tertiary education | 102 | 62.96 |
| | No formal education | - | - |
| | **Total** | **162** | **100.00** |
| Family size | 1-3 | 27 | 16.67 |
| including dependents | 4-6 | 111 | 68.52 |
| and house helps | 7-9 | 21 | 12.96 |
| | 10-12 | 3 | 1.85 |
| | **Total** | **162** | **100.00** |
| Religion | Christianity | 162 | 100.00 |
| | Islam | - | - |
| | Others | - | - |
| | **Total** | **162** | **100.00** |
| Tenancy status | Landlord | 144 | 88.89 |
| | Tenant | 18 | 11.11 |
| | **Total** | **162** | **100.00** |
| Years of residence | <5 | 21 | 12.96 |
| in community | 5-9 | 15 | 9.26 |
| | 10-19 | 12 | 7.41 |
| | 20 and above | 114 | 70.37 |
| | **Total** | **162** | **100.00** |

*Source: Field survey, 2021.*

**Table II:** Distribution of respondents based on agricultural organization

| Characteristics | Categories | Frequency | Percentage |
|---|---|---|---|
| Registered in any | Yes | 18 | 11.11 |
| agricultural organization | No | 144 | 88.89 |
| | **Total** | **162** | **100.00** |
| If yes to above do farmer | Yes | 15 | 83.33 |
| participate in the organization | No | 3 | 16.67 |
| | **Total** | **18** | **100.00** |
| Organization membership | <5 | 9 | 50.00 |
| experience (years) | 5-9 | 6 | 33.33 |
| | 10-14 | 3 | 16.67 |
| | 15-19 | - | - |
| | 20 and above | - | - |
| | **Total** | **18** | **100.00** |

*Source: Field survey, 2021*

**Table III:** Perceived constraint associated with homestead fish production

| Constraint | Categories | Frequency | Percentage |
|---|---|---|---|
| Difficulty | Yes | 99 | 61.11 |
| in assessing farm inputs | No | 63 | 38.89 |
| | **Total** | **162** | **100.00** |
| Lack of storage | Yes | 33 | 20.37 |
| facilities | No | 129 | 79.63 |
| | **Total** | **162** | **100.00** |
| Pest and disease | Yes | 21 | 12.96 |
| outbreak | No | 141 | 87.04 |
| | **Total** | **162** | **100.00** |
| Poor pricing | Yes | 99 | 61.11 |
| of harvested fish | No | 63 | 38.89 |
| | **Total** | **162** | **100.00** |
| Insufficient Capital for | Yes | 144 | 88.89 |
| production activities | No | 18 | 11.11 |
| | **Total** | **162** | **100.00** |
| Thieves from | Yes | 12 | 7.41 |
| neighborhood | No | 150 | 92.59 |
| | **Total** | **162** | **100.00** |
| Disturbance from L.G.A. | Yes | 3 | 1.85 |
| health Workers | No | 159 | 98.15 |
| | **Total** | **162** | **100.00** |
| Lack of government | Yes | 159 | 98.15 |
| support | No | 3 | 1.85 |
| | **Total** | **162** | **100.00** |
| Participation of farmers | Yes | 9 | 6.56 |
| in group | No | 153 | 94.44 |
| | **Total** | **162** | **100.00** |
| Difficulty from getting | Yes | 162 | 100.00 |
| loans for expansion | No | - | - |
| | **Total** | **162** | **100.00** |
| Poor power | Yes | 87 | 53.70 |
| supply | No | 75 | 46.30 |
| | **Total** | **162** | **100.00** |

Source: Field survey, 2021

## DISCUSSION

The study area indicate 62.96% of the fish farmers were engaged in fish farming activities and other businesses. Patronage for full-time however was low, only twenty seven respondents (16.67%). Civil servants and retired civil servants were 20.37%. This observation could be an indication that ad-hoc farmers use this to assist themselves financially as a leverage for family needs to support additional income. Gomma *et al.*, 2020 asserts fish farming as a means of generating additional income for many farmers who engage in it part time. This collaborates the findings of Odebode and Arimi (2011) that people take part in most agricultural production to help meet up with the food security of their household.

The respondents had male dominance (75.93%). The dominance of male in homestead fish production activities may be because such production process requires much time and energy which can mostly be met by the males as reported by Akinbile *et al.*, (2008) that males tend to have more physical energy than their female counterparts and this they use to carry out their activities. The dominance of male in fish farming in Nigeria has been reported by Ogunlade (2007), Adeoye *et. al.*, (2012) Wuyep and Rampedi (2018), George and Akinrotimi (2021) and Subasinghe *et. al.*, (2021). This is the case across Africa (de Graaf and Garibaldi, 2014 , as well as globally as the number of female homestead farmers in this study

(24.07%) is comparable to the 2024 FAO's report of about 25% female fish farmers.

Majority of the homestead farmer (88.89%) were not registered in any agricultural organization. A very low number (18 respondents) 11.11% were registered and has less than 5 years organization membership experience. 33.33% had 5-9 years and 16.67% had 10-14 years. This could be as a result of lack of awareness and interest (Oboh *et al.*, 2025) where they can get advice or gain knowledge on best practices. However, being a member of association/group could create peer pressure for farmers to adopt new technologies.

***Production cycle and generated income***

The production cycle of three times a year by majority of the respondents revealed that 114 out of 162 farmers representing 70.37%, may be an indication of efficient management practices due to the literacy level of farmers in the study area. The output per cycle (Kilogram harvest) realized from fish farmers indicated more than average (59.26%) of the respondents produced between 2001-3000 kg of fishes and 1.85% produced above 3000kg. This could be due to the size of the farm as an average of 4 – 6 fish ponds per farmer measuring about 5mx5m with production target of 600 – 800gm per fish are sold to fish processors engaged in smoke-drying.

Majority of the homestead fish farmers (94.44%) employed intensive management with the use of commercial feed as major input and this could be a reason for relatively good output of 2000-3000kg per cycle by individual farmers. However, 90.74% get their fish seed from other fish hatcheries while 9.26% produce their own fish seed. This indicated that fish seeds sourced from fish farms are more likely to be healthier with improved genes as education influences this action. The income realised per production cycle shows majority (46.30%) of the homestead fish farmers earned an income within the range of ₦800,000-₦996,000. 27.78% earned less than ₦600,000-₦796,000 while 18.52% earned between ₦400,000- ₦596,000. This implies that homestead fish production is a relatively profitable business and could be the reason why most (62.96%) of the respondents who were not core-fish farmers engaged in fish farming with other businesses.

Farmers were found to have an average on-the job experience ranging from 1 – 5years (51.85%), and 33.33% having 5-10years experience. This findings was supported by results of Oyekale *et al.* (2003). The more years acquired by farmers/, the more the know-how about activities carried out resulting in lowering costs, thus increasing income generated from production and sales. The results indicated that the profit generated by the homestead fish farmers covered their expenses on children school fees, hospital bills and electricity bills with a percentage of 22.22%, 59.26% and 83.33% respectively. In addition, the income generated did not cover the family expenses with a percentage of 77.78%, 40.74% and 16.67% respectively.

***Constraints, predation and theft***

Top constraints reported were lack of standard fish pricing and marketing information systems and network, access to low interest loans, high cost of feed and high quality fingerlings, these are factors limiting the expansion of aquaculture in Nigeria as outlined by (Subasinghe *et al.*, 2021, Adeoye, *et al.*, 2012). All the fish farmers pointed to difficulty from getting loans for expansion as the major constraint. Most of them claimed that assessing farm inputs, pricing of harvested fishes, capital for production activities, government support, loans and poor supply (61.11%, 61.11%, 88.89%, 98.15%, 100.00 and 53.70% respectively) were serious constraints. A high prevalence of theft (92.59%), disturbance from L.G.A health workers (98.15%) was also reported, pest and disease (87.04%), lack of storage facilities (79.63%), however, 7.41%, 1.85%, 12.96% and 20.37% respectively claimed that they were serious problems.

Power supply to run their farms is poor, 88.89% of the respondents uses (Enugu Electricity Distribution Company) EEDC and gasoline generators as their source of electricity supply while 11.11% uses gasoline generator only. 50.00% use gas as a cooking fuel, 31.48% use wood, and 18.52% use kerosene. 85.19% rely on borehole water, 5.56% relied on streams or rivers while 9.26% depends on stream or rivers and bore hole. All the fish farmers (100%) finance their farming activities from their personal savings, most (92.59%) had savings while 7.41% did not have savings.

Findings from this study, indicate fish farming in Imo State have reduced poverty this can be an implication on poverty eradication programme. Though most of the fish farmers' practice farming and other businesses, and these businesses joined with farming had a positive effect on their productivity as they have no support from the government.

Extension agents knowledgeable on fish farming should be deployed to the study area by the government as well as adequately funded as a strategy of strengthening eradication of poverty through homestead fish farming. Efforts to improve infrastructural amenities like road, electricity needs to be heightened by the government. This will further increase the income of farmers as cost of running gasoline generators will be reduced. Good roads will provide easy access for extension agents to reach the farmers as well as transportation of farm inputs and produce. Low interest accessible loans by the government will afford farmers to expand and increase their production and meet up the cost of inputs. To settle the issue of poor pricing, fish farmers should adopt price fixing according to weight of fishes and also ensure the use of scaling machine in the marketing process.

## CONCLUSION

Homestead aquaculture in Imo State is a profitable venture with significant potential to enhance food security and rural livelihoods. However, farmers face multiple socio-economic and infrastructural challenges that limit productivity. To address these issues, the following are recommended:

1. Strengthen farmer cooperatives and associations to improve access to credit, training, and collective bargaining.
2. Enhance input supply chains to reduce costs of feed and fingerlings.
3. Expand extension services to improve technical capacity of farmers.
4. Upgrade infrastructure, including power supply, storage, and market facilities.
5. Implement supportive policies to integrate homestead aquaculture into Nigeria's food security agenda.

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# TRAINING AND DEMONSTRATION OF CATFISH CULTURE AND PROCESSING: APPRAISAL, PROFITABILITY, AND CONSTRAINTS AMONG FARMERS IN SABON YALWA, IGABI LGA, KADUNA STATE

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**ABSTRACT**
*This study reports on training and demonstration of catfish culture and processing conducted with farmers in Sabon Yalwa, Igabi LGA, Kaduna State. We evaluated participants' appraisal of the training, analysed profitability, and identified major constraints. Twenty-five participants received hands-on training on pond construction, stocking, feeding, harvesting, and processing. Data were collected through field demonstrations and participant responses. Results show that 68% of participants rated the practices as very easy to adopt, 24% found them moderately easy, and 8% considered them difficult. Gross margin analysis indicated an average net return of ₦15,500 per production cycle per participant. Key constraints were the high cost of inputs, limited technical knowledge, and poor market access. The findings suggest that catfish culture and processing are viable income sources for rural farmers, provided constraints are addressed through targeted policy and extension support.*

**Keywords:** aquaculture, extension training, gross margin, constraints, Kaduna State, Nigeria

## INTRODUCTION

Aquaculture is increasingly recognized as an alternative source of income and employment for rural households in Nigeria. However, poor knowledge of fish culture techniques and processing has hindered adoption. Training and demonstration methods can enhance learning and promote adoption among farmers. This study assessed participants' appraisal of training on catfish culture and processing, determined enterprise profitability, and identified major constraints faced by participants in Sabon Yalwa, Igabi LGA, Kaduna State.

## MATERIALS AND METHODS

The study was conducted in Sabon Yalwa community of Igabi LGA, Kaduna State, in 2018. A total of 25 participants were trained using demonstration plots and hands-on practicals on catfish pond construction, stocking, feeding, harvesting, and processing. Data were collected on participants' appraisal of the training, profitability indicators, and perceived constraints. Descriptive statistics and gross margin analysis were employed. Gross margin (GM) was computed as Total Revenue (TR) minus Total Variable Cost (TVC).

## RESULTS AND DISCUSSION

Overall, the appraisal results affirm the effectiveness of the training approach. The positive gross margin confirms the short-term viability of the intervention, while the constraints highlight where extension and policy should focus (input cost reduction, continuous training, and market linkages).

**Table 1:** Participants' appraisal of the training is summarized

| Appraisal category | Frequency | Percentage (%) |
|---|---|---|
| Very easy | 17 | 68 |
| Moderately easy | 6 | 24 |
| Difficult | 2 | 8 |

**Table 2:** Profitability of fish culture and processing

| Item | Value (₦ per cycle) |
|---|---|
| Total Revenue (TR) | 45,500 |
| Total Variable Cost (TVC) | 30,000 |
| Gross Margin (GM = TR − TVC) | 15,500 |

**Table 3:** Ranking of Major constraints identified by participants

| Constraint | Ranking |
|---|---|
| High cost of inputs (feed, fingerlings) | 1 |
| Limited technical knowledge | 2 |
| Poor market access | 3 |
| Water management challenges | 4 |

## CONCLUSION

Training and demonstration improved participants' knowledge and willingness to adopt catfish culture and processing. The enterprise was profitable at the observed scale, but challenges such as high input costs and limited market access persist. We recommend targeted subsidies for feed and fingerlings, ongoing capacity building, and facilitation of market linkages to sustain adoption and impact.

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# ASSESSMENT OF YOUTH PARTICIPATION IN FISH FARMING IN IBADAN PERI-URBAN AREA OF OYO STATE, NIGERIA

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**ABSTRACT**
*This study examined youth participation in fish farming in peri-urban Ibadan, Oyo State. A three-stage sampling procedure was used to select 136 respondents. Data were collected with interview schedules and analysed using descriptive statistics and Pearson's correlation at 0.05 level. Respondents were mostly male (88.2%), with mean age of 29.6 years. Polyculture was practiced by 43.4%, with average farming experience of 5.4 years. Survival was the leading reason for participation (mean=2.95). Most respondents (92.6%) perceived fish farming as beneficial, though high feed cost (mean=2.65), lack of credit (mean=2.21), and scarcity of fish seed (mean=2.20) were key constraints. Overall, 67.6% had high participation. Farming experience (r=0.215, p=0.012) and perceived constraints (r=-0.341, p=0.000) significantly influenced participation. Fish farming presents prospects for youth employment; government provision of loans and inputs is recommended.*

**Keywords:** Fish farming, Peri-urban, Ibadan, Youth participation.

## INTRODUCTION

Nigeria's fish demand exceeds supply despite vast resources, with aquaculture contributing significantly but insufficiently to national needs. Fish farming has potential to reduce unemployment among youths who form about 60% of the Nigerian population. However, participation is limited due to high input costs and inadequate support. This study investigated youth participation in fish farming in peri-urban Ibadan, Oyo State, with objectives to:

a) describe socio-economic characteristics of respondents in the study area.
b) determine the perception of youths towards fish farming enterprise in the study area.
c) identify the constraints limiting youth's participation in fish farming enterprise.
d) ascertain the benefits derived by the respondents from participation in fish farming.
e) determine the level of youth's participation in fish farming enterprise in the study area.

## MATERIALS AND METHODS

The study was conducted in six peri-urban LGAs of Ibadan, Oyo State. Three LGAs (Ido, Lagelu, Egbeda) were purposively selected based on prominence in fish farming. A sample of 136 respondents was randomly drawn from fish farmer groups. Data were collected via structured questionnaire and analysed using descriptive statistics and Pearson's correlation.

**Table 1:** Sampling procedure and sample size

| Selected Local Governments | No of Fish farmer groups in each LGAs | No of fish farmers in each group | 45% of fish farmers from each group |
|---|---|---|---|
| Lagelu | 4 | | |
| | Showers of God | 15 | 7 |
| | Yawiri Powerline | 18 | 9 |
| | Olosun Alapo | 35 | 16 |
| | Association of Kotilo | 32 | 15 |

| | | | | |
|---|---|---|---|---|
| | Green leaf | 14 | 7 | |
| | Eni Osa | 12 | 6 | |
| | Ifesowapo | 12 | 6 | |
| | Ejalonibu | 15 | 7 | Total =73 |
| Ido | 7 | | | |
| | Agbejoba | 12 | 6 | |
| | Agbeloba | 10 | 5 | |
| | Araromi Ologunso | 13 | 6 | |
| | Olowolagba | 12 | 6 | |
| | Flourishers | 17 | 8 | |
| | Achievers | 17 | 8 | |
| | Abaniso | 10 | 5 | |
| | Alapo | 15 | 7 | Total=51 |
| Egbeda | 2 | | | |
| | Able | 15 | 7 | |
| | Peace | 10 | 5 | Total =12 |
| | | | | ***Grand Total =136*** |

## RESULTS AND DISCUSSION

### Socioeconomic characteristics

Respondents' mean age was 29.6 years, with average 5.4 years' farming experience. Most were male (88.2%), single (57.4%), and educated (75.6% tertiary level). Annual income averaged ₦397,134, above national minimum wage. Polyculture was practiced by 43.4%.

**Table 2:** Selected socioeconomic characteristics

| Variables | Categories | Frequency | % | Mean±SD |
|---|---|---|---|---|
| Age | 21-30 | 85 | 62.5 | 29.57±2.85 |
| | above 30 | 51 | 37.5 | |
| Sex | Male | 120 | 88.2 | |
| | Female | 16 | 11.8 | |
| Marital Status | Single | 78 | 57.4 | |
| | Married | 53 | 38.2 | |
| | Widowed | 3 | 2.2 | |
| | Divorced | 1 | 0.7 | |
| | Separated | 1 | 0.7 | |
| Level of Education | No formal education | 4 | 2.9 | |
| | Primary education | 5 | 3.7 | |
| | Secondary education | 24 | 17.6 | |
| | Tertiary | 103 | 75.6 | |
| Years of Farming Experience | 1-5 years | 83 | 61.0 | |
| | 6-10 years | 48 | 35.3 | 5.40±2.89 |
| | 11-15 years | 4 | 2.9 | |
| | Above 15 | 1 | .7 | |

| | | | | |
|---|---|---|---|---|
| Average Income per Year (#) | < 100,000 | 1 | 0.7 | |
| | 100,001 - 500,000 | 35 | 25.7 | 761235.29±397134.33 |
| | 500,001 - 1,000,000 | 81 | 59.6 | |
| | > 1,000,000 | 19 | 14.0 | |
| Cultured Species | Cat Fish | 54 | 39.7 | |
| | Tilapia | 23 | 16.9 | |
| | Both | 59 | 43.4 | |

## PERCEPTION TOWARDS FISH FARMING

Most respondents viewed fish farming as beneficial but capital-intensive. Over half (55.9%) had unfavourable perception, reflecting challenges like labour intensity and feed costs.

| Perception | Freq. | % | Minimum | Maximum | Mean | SD |
|---|---|---|---|---|---|---|
| Unfavourable Perception | 76 | 55.9 | 28.00 | 46.00 | 35.71 | 3.57 |
| Favourable Perception | 60 | 44.1 | | | | |

## CONSTRAINTS TO PARTICIPATION IN FISH FARMING

High feed costs (mean=2.65), lack of credit (2.21), and scarcity of fish seed (2.20) were top challenges. These constraints align with other aquaculture findings in Nigeria.

**Table 3:** Top-ranked constraints

| Constraint | Severe f (%) | Mild f (%) | Not a Constraint f (%) | Mean | Rank |
|---|---|---|---|---|---|
| Lack of credit facilities | 37(27.2) | 91(66.9) | 8(5.9) | 2.21 | 2nd |
| High cost of fish feed | 91(66.9) | 43(31.6) | 2(1.5) | 2.65 | 1st |
| No start-up capital | 23(16.9) | 96(70.6) | 17(12.5) | 2.04 | 6th |
| Unavailability of fish seed | 32(23.5) | 100(73.5) | 4(2.9) | 2.20 | 3rd |
| Absence of extension services | 20(14.7) | 88(64.7) | 28(20.6) | 1.94 | 8th |
| Poor processing and storage facilities | 36(26.5) | 89(65.4) | 11(8.1) | 2.18 | 4th |
| Shortage of farm labour | 29(21.3) | 99(72.8) | 8(5.9) | 2.15 | 5th |
| Erosion and flooding | 24(17.6) | 86(63.2) | 26(19.1) | 1.99 | 9th |
| Unavailability of fertilizers | 14(10.3) | 97(71.3) | 25(18.4) | 1.92 | 10th |
| Presence of predators (toads, birds etc.) | 16(11.8) | 110(80.9) | 10(7.4) | 2.04 | 6th |

## BENEFITS DERIVED FROM FISH FARMING

Major benefits included financial support to family (mean=1.83), meeting responsibilities (1.79), and savings opportunities (1.73). Nearly half (48.5%) reported high benefits.

**Table 4:** Top-ranked benefits

| Benefits derived | Major benefit f (%) | Minor benefit f (%) | No benefit f (%) | Mean | Rank |
|---|---|---|---|---|---|
| Ability to support family financially | 116 (85.3) | 17 (12.5) | 3 (2.2) | 1.83 | 1st |
| Increase availability of quality food | 100 (73.5) | 33 (24.3) | 3 (2.2) | 1.71 | 4th |
| Becoming financially independent | 98 (72.1) | 36 (26.5) | 2 (1.5) | 1.70 | 5th |
| Opportunity to join farmers association | 101 (74.3) | 29 (21,3) | 6 (4.4) | 1.69 | 6th |
| Opportunity of having saving | 102 (75.0) | 32 (23.5) | 2 (1.5) | 1.73 | 3rd |
| Ability to take care of responsibilities | 110 (80.9) | 24 (17.6) | 2 (1.5) | 1.79 | 2nd |
| Employment generation | 96(70.1) | 36(26.5) | 4(2.9) | 1.67 | 8th |
| Engagement to Reduce Youth Restiveness | 102(75.0) | 25(18.4) | 9(6.6) | 1.68 | 7th |

## LEVEL OF PARTICIPATION IN FISH FARMING

Most youths (67.6%) had high participation, especially in feeding (mean=1.85) and stocking (1.70). Physical tasks like pond construction had lower participation.

**Table 5:** Selected participation activities

| Level of participation in fish Farming | Always f (%) | Occasionally f (%) | Not at all f (%) | Mean | Rank |
|---|---|---|---|---|---|
| Construction of pond | 50(36.8) | 65(47.8) | 21(15.4) | 1.21 | 14th |
| Stocking of the fish pond | 97(71.3) | 37(27.2) | 2(1.5) | 1.70 | 2nd |
| Fish seed production | 78(57.4) | 48(35.3) | 10(7.4) | 1.50 | 7th |
| Formulation of feed | 96(70.6) | 32(23.5) | 8(5.9) | 1.65 | 3rd |
| Feeding of fish | 98(72.1) | 34(25.0) | 3(2.2) | 1.85 | 1st |
| Manage water and soil quality in your pond | 80(58.8) | 53(39.0) | 3(2.2) | 1.57 | 5th |
| Administering medication to fish | 58(42.6) | 70(51.5) | 8(5.9) | 1.37 | 11th |
| Fish breeding and storage | 89(65.4) | 38(27.9) | 9(6.6) | 1.59 | 4th |
| Fish processing | 69(50.7) | 58(42.6) | 9(6.6) | 1.44 | 9th |
| Harvesting of the fish | 76(55.9) | 54(39.7) | 6(4.4) | 1.51 | 6th |
| Smoking of fish | 71(52.2) | 56(41.2) | 9(6.6) | 1.46 | 8th |
| Marketing | 63(46.3) | 69(50.7) | 4(2.9) | 1.43 | 10th |

## CORRELATION ANALYSIS

There was a significant negative correlation between constraints and participation ($r=-0.341$, $p<0.05$), indicating constraints reduced youth involvement.

**Table 6:** Correlation between constraints and participation

| Variable | r-value | p-value | Decision |
|---|---|---|---|
| Constraints | -0.341 | 0.000 | Significant |

## CONCLUSION

Fish farming in peri-urban Ibadan is male-dominated, with youths engaging mainly for survival. Despite constraints, participation is high, showing the sector's potential for job creation.

## RECOMMENDATIONS

1. Organize training to boost technical knowledge.
2. Provide credit support and soft loans.
3. Encourage female participation through empowerment schemes.

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# FISHERIES GOVERNANCE, POLICY AND MARINE PROTECTED AREAS - FGPM

# CAUSES AND IMPLICATIONS OF PRODUCTION FLUCTUATIONS IN NIGERIA AQUACULTURE SECTOR

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**\ABSTRACT**
*The study examined causes and implications of production fluctuations in Nigeria aquaculture sector. The study was secondary research which involved the use of secondary data from Food and Agricultural Organization (FAO), information from reputable journals and reports from National Bureau of Statistics (NBS). From the documents examined, the study established that inflation rate, exchange rate, government policy on fuel subsidy removal and the Covid-19 pandemic were some of the causes of production fluctuations in Nigeria aquaculture sector. The implications of these fluctuations in production are labour shortage, brain drain, food insecurity among others. It is therefore recommended that government policy changes on these key causes should be holistic, involving all critical stakeholders that will be affected by the changes in government policy. Also, aquaculture firms should be encouraged to go into backward integration that will enable them to access their inputs from areas that are near their firms. This will reduce logistics burden in cases of pandemic such as the Covid-19.*

**Key words:** Aquaculture production, fluctuations, inflation, exchange rate, covid-19

## INTRODUCTION

The Nigeria's aquaculture sector is an important food sector in the economy contributing to household food security, livelihood, and economic development in many ways. The aquaculture sector since 2000, has been growing at 13.6% per year (Ogunji and Wuertz, 2023). In 2000, aquaculture production in Nigeria (Table 1) increased from 25,718 tonnes to 261,711 tonnes in 2020, making Nigeria the second highest producer in Africa (FAO, 2022).

**Table 1:** Aquaculture fish productions in Nigeria

| Year | Production | Year | Production | Year | Production | Year | Production |
|---|---|---|---|---|---|---|---|
| 1981 | 6283 | 1991 | 15365 | 2001 | 24297 | 2011 | 221128 |
| 1982 | 6559 | 1992 | 17088 | 2002 | 30663 | 2012 | 253898 |
| 1983 | 6842 | 1993 | 17090 | 2003 | 30677 | 2013 | 278706 |
| 1984 | 6519 | 1994 | 15030 | 2004 | 43950 | 2014 | 313231 |
| 1985 | 7892 | 1995 | 16619 | 2005 | 56355 | 2015 | 316727 |
| 1986 | 5456 | 1996 | 19491 | 2006 | 84578 | 2016 | 306767 |
| 1987 | 6002 | 1997 | 24297 | 2007 | 85087 | 2017 | 296191 |
| 1988 | 10631 | 1998 | 20485 | 2008 | 143207 | 2018 | 291323 |
| 1989 | 25840 | 1999 | 21737 | 2009 | 152796 | 2019 | 289543 |
| 1990 | 7347 | 2000 | 25718 | 2010 | 200535 | 2020 | 261711 |

*Source: Food and Agricultural Organization [FAO] (2022).*

Nigeria's aquaculture production declined from the record high 316,727 tonnes in 2015 to 261,711 tonnes in 2020. Given the base line of 9.12 kg for per capita fish and seafood consumption, Nigeria would

need an extra 2,397,748 tonnes of fish and seafood to meet the demand of an estimated population of 262.977million people by 2030 (FAO, 2022).

Given the above status of aquaculture production in Nigeria, fluctuations in productions would most likely lead to volatility in price of fish for consumers. This could cause detrimental effect on the nutritional well-being of consumers and general food security (Olajide *et al*., 2022). This is because, following the cob-web theory, prices tend to increase in periods of low production and decrease in periods of high production. This leads to economic uncertainty thereby making it difficult for actors within the value chain such as producers, processors, logistics providers, wholesalers, and retailers, to plan their activities and earn stable livelihoods (Rice *et al*., 2024).

Empirical results have shown that aquaculture production in Nigeria is profitable (Omeje *et al*., 2022), it is expected that a venture that is profitable should continue to witness massive investment which will result to a continues increase in production. However, such is not the case with Nigeria as evidence from FAO, (2022) have revealed fluctuations in aquaculture production in Nigeria. The information on the causes and implications of production fluctuations in Nigeria aquaculture sector is limited and it is based on this, the study specifically,

1. Examined the causes of production fluctuations in aquaculture production; and
2. Implications of production fluctuations in Nigeria aquaculture sector.

## MATERIALS AND METHODS

The study was a secondary research which employed secondary data from FAO, information from reputable journal articles, Nigerian Bureau of Statistics (NBS) and relevant documents with necessary information on the causes and implications of production fluctuations in Nigeria aquaculture sector.

## RESULTS AND DISCUSSION

### Causes of Production Fluctuations in Aquaculture Production in Nigeria Inflation

The consistent and general rise in the prices of goods and services is known as inflation (Idisi *et al*., 2023). This phenomenon has profound implications for food prices, as rising costs can diminish the purchasing power of consumers, making it difficult for households, especially low-income earners to afford adequate nutrition (Olufemi-Phillips *et al*., 2024). Persistent inflation in Nigeria affects the performance of aquaculture production. Based on available data from FAO (2022), aquaculture production started declining from 2015 while according to Statista (2022), the rate of inflation in Nigeria has maintained a double digit since 2016. Nigeria witnessed a high rate of prices in 2017 with an inflation rate of 16.5%. This rate decreased to 12.09% in 2018 and 11.4% in 2019 but increased back to 13.25% in 2020. The periods of inflation had detrimental effect on fish farmers especially the new entrants in the business who are small scale in nature. This is because the general rise in prices affects the prices of inputs. For instance, according to NBS (2024), the rise in food inflation on a year -on-year basis was caused by increases in prices of Guinea Corn, Rice, Maize Grains, Rice, Yam, Water Yam, Coco Yam, Palm Oil, Vegetable Oil, etc. These are critical ingredients for fish feed formulation. Small scale fish farmers who are beginners in the business may not be able to cope with the persistent increase in the prices of inputs; thus, prompting pre-mature sales of fish or poor management of fish farms which eventually results to a decline in general aquaculture production in Nigeria.

### Exchange rate volatility

Exchange rate volatility is another major set-back to increased aquaculture production in Nigeria. Volatility in exchange rate which is influenced by monetary policy, has a direct negative impact on aquaculture production in Nigeria. According to Olagunju *et al*., (2024), the growth in the aquaculture sector was consistent when the exchange rate (2004–2014) was relatively stable. The decline in aquaculture production began when a rapid depreciation of the value of Naira set in. The devaluation of

the naira significantly influenced the cost of production. The aquaculture sector like the agricultural sector also relies on the importation of major inputs such as starter feeds. The rising cost of such imported inputs makes it quite difficult for farmers to keep or expand their enterprises when the naira is devalued (Muhammed, 2024). The Nigerian aquaculture sector is mainly driven by the intensive farming of African Catfish (FAO, 2022), the cost of production is mainly influenced by the prices of fish feed which accounts for more than 70% of the cost of production (Omeje *et al*., 2022). Like imported feed brands, prices of commercial feeds produced in Nigeria are also influenced by the exchange rate because they rely on importation for their major ingredients, particularly the protein components. An increase in the exchange rate which is not accompanied by a corresponding increase in the prices of fish as observed in 2015, would have a negative impact in the aquaculture sector; thus, lowering farmers' profits (Olagunju *et al*., 2024). This means that the devaluation of the naira will reduce the investment capacity of fish farmers; larger firms will cut down on their scale of production thereby leading to a decrease in production with corresponding decrease in the contribution of aquaculture to GDP.

**Government policy on fuel subsidy removal**

Government policy on the removal of fuel subsidy played a major factor in production fluctuations in aquaculture. According to Bala (2023), the removal of fuel subsidy in Nigeria, will aggravate the existing poverty, cripple businesses and cause recession. This is because the policy dramatically increased transportation costs which resulted to increased prices of goods in the market (NBS, 2023). Fuel has limited substitute while the transportation segment of the aquaculture value chain relies on fuel for easy transportation of fish. The removal of fuel subsidy reduced the demand for high cost farmed Catfish thereby resulting to a decrease in fish production by fish farmers.

**Impact of Covid-19 pandemic**

The Covid-19 pandemic in Nigeria affected aquaculture production in many ways. According to Flourizel *et al*. (2023), the pandemic caused shortage of labour to fish farms because of the lockdown and restriction of movement. These restrictions also affected access to key inputs by fish farmers in Nigeria. The lockdowns affected the supply chains as well as fluctuations in prices of fish which led to a shift in demand. Fish farmers also struggled in planning and decision making which resulted in so many of them shutting down their business due the unfavourable economic conditions (Olagunju *et al*., 2024).

**Implications of Production Fluctuations in Aquaculture Production in Nigeria**

The implications of production fluctuations in Nigeria aquaculture sector is quite enormous. A fall in production will cause labour shortage in the aquaculture sector while unstable and unfavourable exchange rate will slow down investment in the sector especially by indigenous aquaculture firms. The teeming Nigerians youths will be forced to seek employment outside the shores of the country while those who can't afford to travel abroad will be forced to accept lower paying jobs that cannot meet their basic needs. The phenomenon of high rate of inflation and unstable exchange rate, if it remains unchecked will certainly lead to food insecurity in the country. This is because the World Bank's food security update identified Nigeria as one of the nations that will experience catastrophic levels of food insecurity (Eje *et al*., 2023).

## CONCLUSION AND RECOMMENDATIONS

The study established that inflation rate, exchange rate, government policy on fuel subsidy removal and the Covid-19 pandemic were some of the causes of production fluctuations in Nigeria aquaculture sector. The implications of these fluctuations in production are labour shortage, brain drain, food insecurity among others. It is therefore recommended that government policy changes on these key causes should be holistic, involving all critical stakeholders that will be affected by the changes in government policy. Also, aquaculture firms should be encouraged to go into backward integration that will enable them to

access their inputs from areas that are near their firms. This will reduce logistics burden in cases of pandemic such as the Covid-19.

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# FISH NUTRITION AND ALTERNATIVE FEED DEVELOPMENT - FNAFD

# DIETARY EFFECTS OF MICROALGA ON ZOO-TECHNICAL PERFORMANCE AND STRESS BIOMARKERS IN KOI CARP (*Cyprinus rubrofuscus,* Lacepede, 1803)

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**ABSTRACT**
*This study evaluated the dietary effects of freshwater microalga, Spirulina platensis on the growth performance, nutrient utilisation and stress biomarkers in Koi carp, Cyprinus rubrofuscus fingerlings raised in recirculatory aquaculture system. Five feeds were formulated with different inclusion levels of spirulina at 0, 25, 50, 75 and 100% each representing treatment 1 (control), 2, 3, 4 and 5 respectively. The result showed significant differences (P≤0.05) in the growth and nutrient utilization parameters in treatment 4 with 75% spirulina inclusion having the best protein efficiency ratio, feed conversion and feed efficiency ratios. The results from the stress biomarker analysis indicated that Spirulina platensis reduced liver stress and enhances liver function in Cyprinus rubrofuscus fingerlings, as evidenced by the decreasing ALT and AST levels in the liver of fish with spirulina diet.*

**Keywords**: Spirulina, Aquafeed, Ornamental, Physiology, Carp

## INTRODUCTION

Ornamental fish are aquatic animals kept in an aquarium for display, shows, studies, and aesthetics. According to (Ukaonu *et al.*, 2011), ornamental fish include fish, invertebrates, crustaceans, mollusk, and live rock. They are a significant component of the global ornamental fish trade, which is a multi-billion-dollar industry. It contributes to the livelihoods of many people, particularly in developing countries where ornamental fish breeding is a source of income for local communities. The state of ornamental fish trade in Nigeria is far from satisfactory. Nigeria being a tropical country has a very high potential for ornamental fish production and exportation. Fish and fishery products remain some of the most traded food commodities in the world (FAO, 2024).

Koi carp, *Cyprinus rubrofuscus*, is a valuable ornamental fish due to its coloration, patterning and scalation. Koi carp, often simply referred to as "koi," are a species of ornamental fish that are highly prized for their vibrant colours and distinctive patterns. They come in a wide range of colours and patterns, including red, white, yellow, black, and blue. The most popular varieties include Kohaku (white body with red markings), Taisho Sanke (white body with red and black markings), Showa Sanshoku (black body with red and white markings), and Bekko (solid colour with black markings) .Ekpo, (2013).
Microalgae are microscopic algae invisible to the naked eye. They are phytoplankton typically found in freshwater and marine systems, living in both the water column and sediment. They are unicellular species which exist individually, or in chains or groups. Spirulina (*Arthrospira platensis*) is a protein-rich source because it contains approximately 60% protein. Microalgae are essential in aquaculture feeding, where they are used extensively as live feed, particularly for molluscs and marine fish larvae. However, these can also be used in dried form within production diets (Hirano and Suyama, 1985), for example *Arthrospira platensis* also known as Spirulina (blue-green algae).

Stress biomarkers in fish are crucial indicators of their physiological response to various stressors, aiding in the assessment of their health and welfare. The enzyme aspartate aminotransferase (AST) is widely distributed in erythrocytes and tissues, principally heart, liver, muscles, and kidneys. Alanine

aminotransferase (AST), also known as glutamate-pyruvate transaminase (GPT) and ALT, formerly known as serum glutamic pyruvic transaminase (SGPT), is found mainly in the liver, but also in smaller amounts in the kidneys, heart, muscles, and pancreas can serve as a stress biomarker in fish, particularly in response to physiological stressors (Soni *et al*., 2017). The general objective of this study is to assess the dietary effects of microalga supplementation on growth performance and stress biomarkers in Koi carp (*Cyprinus rubrofuscus*) cultivated in a recirculatory aquaculture system.

## MATERIALS AND METHODS

The study was carried out at the Teaching and Research farm of the Department of Fisheries and Aquaculture Technology, The Federal University of Technology Akure, Ondo State. One hundred and seventy healthy Koi Carp, C. *rubrofuscus* fingerlings were procured from Pristine farm in Ibadan, Nigeria. The fish were distributed randomly into the recirculatory aquaculture system at ten fish per tank in three replicates.

The experimental design was conducted over 56 days in 15 recirculatory system tanks with 5 treatments in total (including the control), with each treatment containing 3 replicates (triplicates). Each treatment was represented by different supplementation levels of Spirulina-Additives. The graded levels of the Spirulina-Additives were 0%, 25%, 50%, 75%, and 100% per 100g for each diet, denoted as T1 (Control), T2, T3, T4, and T5 in diets 1, 2, 3, 4, and 5 for C. *carpio*. All data were collected and recorded before and after the experimental trial. The blood and liver of the fish was collected for ALT (Alanine aminotransferase) and AST (Aspartate aminotransferase) analysis.

### Statistical Analyses of Data

All data collected were checked for normality using one-way analysis of variance (ANOVA), and homogeneity of variance was tested using Levene's test to determine significant differences in the means. Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS 22.0 for Windows). Where significant differences were found, the means were separated using Duncan's multiple range test. A probability level of less than 0.05 was used to indicate significant differences among the treatments.

## RESULTS AND DISCUSSION

Water quality during the experimental trial were at a stable condition suitable for Koi carp aquaculture. The growth and nutrient utilization parameters for each treatment were measured and is shown in Table 1. Treatment 2 had the highest protein content, aligning with the observations of Robinson *et al.,* (2020) on the importance of protein-rich diets in supporting optimal animal performance. The result showed there were significant differences ($P \leq 0.05$) in the growth and nutrient utilization parameters with treatment 4 having the best protein efficiency ratio, feed conversion ratio and feed efficiency ratio.

The results from the stress biomarker analysis indicated that *Spirulina platensis* reduces liver stress and enhances liver function in C*yprinus rubrofuscus* fingerlings, as evidenced by the decreasing ALT and AST levels in the liver. Ahmed *et al.,* (2016) observed that dietary Spirulina supplementation in Nile tilapia reduced ALT and AST levels, indicating lower stress levels and better liver function, which corresponds to the decreasing ALT and AST trends seen in the current study for C*yprinus rubrofuscus*.

**Table 1:** Growth and nutrient utilization parameters of *Cyprinus robrofuscus* fed with spirulina diet during the 56 days experimental trial

| TRTS | T1 | T2 | T3 | T4 | T6 |
|---|---|---|---|---|---|
| IW | $0.62 \pm 0.01^{a}$ | $0.69 \pm 0.01^{c}$ | $0.67 \pm 0.02^{b}$ | $0.63 \pm 0.01^{a}$ | $0.68 \pm 0.02^{bc}$ |
| FW | $1.08 \pm 0.01^{a}$ | $1.07 \pm 0.01^{a}$ | $1.12 \pm 0.02^{a}$ | $1.19 \pm 0.02^{b}$ | $1.08 \pm 0.05^{a}$ |
| WG | $0.47 \pm 0.02^{b}$ | $0.38 \pm 0.01^{a}$ | $0.45 \pm 0.03^{b}$ | $0.56 \pm 0.02^{c}$ | $0.39 \pm 0.05^{a}$ |
| %WG | $75.86 \pm 3.97^{b}$ | $54.82 \pm 1.85^{a}$ | $67.58 \pm 5.35^{b}$ | $89.44 \pm 3.93^{c}$ | $57.58 \pm 7.14^{a}$ |
| FI | $0.97 \pm 0.36^{a}$ | $0.74 \pm 0.03^{a}$ | $0.75 \pm 0.06^{a}$ | $0.79 \pm 0.10^{a}$ | $0.68 \pm 0.16^{a}$ |
| FCR | $2.10 \pm 0.86^{a}$ | $1.94 \pm 0.09^{a}$ | $1.67 \pm 0.04^{a}$ | $1.39 \pm 0.13^{a}$ | $1.72 \pm 0.22^{a}$ |
| FER | $0.52 \pm 0.17^{a}$ | $0.52 \pm 0.03^{a}$ | $0.60 \pm 0.01^{ab}$ | $0.72 \pm 0.07^{b}$ | $0.59 \pm 0.08^{ab}$ |
| SGR | $1.13 \pm 0.36^{a}$ | $0.72 \pm 0.39^{a}$ | $0.78 \pm 0.33^{a}$ | $0.88 \pm 0.07^{a}$ | $0.82 \pm 0.16^{a}$ |
| PER | $1.50 \pm 0.50^{a}$ | $1.48 \pm 0.07^{a}$ | $1.71 \pm 0.04^{ab}$ | $2.06 \pm 0.21^{b}$ | $1.68 \pm 0.23^{ab}$ |
| %SURV | $90.00 \pm 0.00^{a}$ | $90.00 \pm 0.00^{a}$ | $90.00 \pm 0.00^{a}$ | $90.00 \pm 0.00^{a}$ | $60.00 \pm 0.00^{b}$ |

Data presented are means and standard deviation (Mean ± SD) for ten fish from three replicates (n=3) *Values with different superscripts on the same row indicate significant difference at P≥0.05.

**Stress Biomarkers**

The results from the stress biomarker analysis indicated that *Spirulina platensis* reduces liver stress and enhances liver function in *Cyprinus rubrofuscus* fingerlings, as evidenced by the decreasing ALT and AST levels in the liver as shown in Table 2. However, the increase in blood AST at higher inclusion levels suggests other non-liver-related stress factors may be at play. These findings support the use of Spirulina as a dietary supplement for improving liver health in fish but also highlight the need for further research into the systemic effects of high Spirulina inclusion levels on overall fish health.

Ahmed *et al.*, (2016) observed that dietary Spirulina supplementation in Nile tilapia reduced ALT and AST levels, indicating lower stress levels and better liver function, which corresponds to the decreasing ALT and AST trends seen in the current study for *Cyprinus rubrofuscus*.

The increase in blood AST with Spirulina inclusion may suggest that while liver stress is reduced, other factors like metabolic or muscular stress could be responsible for the elevated levels. This could be due to the higher metabolic demands of the fish as they convert *Spirulina* into biomass, a hypothesis that has been explored by researchers such as Aluru *et al* (2005) and Soni *et al.*, (2017).

**Table 2:** ALT and AST level in Blood and Liver of Koi Carp (*Cyprinus rubrofuscus*) Fingerlings Fed with *Spirulina Platensis* Diet

| Treatment | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| Blood (ALT) | $24.87 \pm 0.32^{d}$ | $20.01 \pm 0.27^{c}$ | $18.66 \pm 0.23^{b}$ | $18.19 \pm 0.29^{b}$ | $14.67 \pm 0.04^{a}$ |
| Blood (AST) | $15.18 \pm 0.39^{a}$ | $24.35 \pm 0.63^{b}$ | $24.55 \pm 1.21^{b}$ | $25.22 \pm 0.36^{b}$ | $30.15 \pm 0.35^{c}$ |
| Liver (ALT) | $19.87 \pm 0.32^{d}$ | $15.69 \pm 0.16^{c}$ | $15.28 \pm 0.11^{c}$ | $14.25 \pm 0.05^{b}$ | $13.43 \pm 0.01^{a}$ |
| Liver (AST) | $22.01 \pm 0.27^{d}$ | $20.35 \pm 0.07^{c}$ | $18.03 \pm 0.18^{b}$ | $17.36 \pm 0.70^{b}$ | $15.58 \pm 0.30^{a}$ |

Data presented are means and standard deviation (Mean ± SD) for ten fish from three replicates (n=3) *Values with different superscripts on the same row indicate significant difference at P≥0.05 in ALT- Alanine aminotransferase, AST- Aspartate aminotransferase.

## CONCLUSION

Treatment 4 with 75% inclusion of *Spirulina platensis* has the highest nutrient utilization performance in the diet of the fish. The study showed that spirulina is a viable ingredient in the culture of ornamental fish

such as *Cyprinus rubrofuscus* and it is therefore recommended.

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# ASSESSMENT OF GROWTH AND NUTRIENT UTILIZATION OF *Clarias gariepinus* FINGERLINGS FED DIFFERENT INCORPORATION LEVELS OF PREPARED *Moringa oleifera* SEED MEAL

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**ABSTRACT**
*The research assessed the capabilities of Moringa oleifera seed meal as a potential alternative for fish meal in the diet of Clarias gariepinus fingerling. Five isocaloric and isonitrogenous diets were prepared from M. oleifera seed meal at inclusion levels of 0%, 20%, 40%, 60%, and 80% to replace fish meal (B90min/S72hrs). These diets were administered to the fingerlings over a period of twelve weeks. Growth and nutrient utilization metrics of fish were assessed. The fish given the control diet showed the greatest increase in weight (12.77±1.14g), but this did not show a statistically significant difference from the 20% dietary treatment. The fish exhibited the smallest feed conversion ratio, as noted in 20% dietary treatment and there was no significant difference in protein efficiency ratios among the five dietary treatments. The diet containing 20% M. oleifera seed meal inclusion level supported strong growth. Even at an 80% substitution level, the fingerlings maintained good health.*

**Keywords:** Fish meal; growth; performance; feed utilization; moringa seed meal

## INTRODUCTION

Growth is commonly regarded as a reliable criterion for assessing nutrient status. According to Gatlin (2010), meeting a fish's minimum dietary protein requirement or ensuring a balance of amino acids is crucial for accurately evaluating growth and health status.

Various plants are under investigation as possible substitutes for fish meal, and *Moringa oleifera* (Lam) has been recognized as a plant with these properties (Nsofor *et al.*, 2012). However, the elimination of undesirable anti-nutritional substances from plant protein sources is imperative to improve their nutritional quality and maximize their full potential as components in fish feed. The failure of aquaculture to meet the challenge of closing the widening gap between fish supply and demand in Nigeria, results from a number of factors including lack of quality feeds. Compost cribs and occasional animal droppings are usually the main feed input in ponds. These, however, can only promote limited growth and further growth is restricted by insufficiency of nutrients from primary production (Edwards *et al.*, 2000). Hence, this research aim to assess the growth and nutrient utilization of *Clarias gariepinus* when provided with diets incorporating different levels of prepared *Moringa oleifera* seed meal.

## MATERIALS AND METHODS

### Experimental Area

The trial took place at the Teaching and Research Fish Farm within the Department of Fisheries and Aquaculture at Usmanu Danfodiyo University in Sokoto. The geographical coordinates of the area were approximately 13° 07' 47.6" N Latitude and 05° 12' 11.3" E Longitude, situated at 275m elevation above sea level (Google MAP, 2015).

**Seed Collection and Preparation**
Dehydrated ripe *Moringa oleifera* fruits were sourced from Maiyafe Farm in Ungoggo, Kano State. The seeds were cleaned, dehusked to obtain kernels, shade-dried, and stored for later use.

**Diet Formulation and Production**
Five isocaloric, isonitrogenous diets containing 40% crude protein and 3,274–3,417 Kcal/kg metabolizable energy were formulated using Pearson's square method. *Moringa oleifera* seed meal (MSM) replaced fishmeal at 0% (Diet A), 20% (Diet B), 40% (Diet C), 60% (Diet D), and 80% (Diet E).

**Experimental Fish and Design**
A total of 300 *Clarias gariepinus* fingerlings (1.53 ± 0.02g; 6.21 ± 0.04cm) were sourced from NIFFR, New-Bussa, and acclimated for two weeks. They were then randomly stocked at 20 fish per concrete tank (1.0 × 1.0 × 1.0 m). Over 12 weeks, the fish were fed a 40% crude protein control diet two times (9:00am and 5:00pm) daily at 5% of their body weight.

**Fish Growth Measurements**
The following parameters on growth and nutrient utilization metrics were calculated: survival rate, weight gain, percentage weight gain, specific growth rate (SGR), condition factor, feed conversion ratio (FCR), feed conversion efficiency (FCE), gross feed conversion efficiency (GFCE), protein efficiency ratio (PER), and apparent net protein utilization (ANPU).

**Statistical Analysis**
The collected data was subjected to analysis of variance (ANOVA). Subsequent separation of means was conducted using Duncan's multiple range test (Duncan, 1955) with the SPSS computer software, version 20.0. Significance in the differences between mean values was recognized at the 0.05 probability level.

**RESULTS**
Table 1 presents the effects of different diets on fish growth. Survival rates ranged from 70.00 ± 13.23 (T4, 60% Moringa seed meal) to 78.33 ± 2.89 (control), with no significant differences ($p>0.05$) among treatments. Fish on the control diet had the highest weight gain (12.77 ± 1.14), which was not significantly different from T2 (20% Moringa seed meal). Weight gain decreased as the Moringa seed meal level increased, with T4 and T5 (60% and 80% replacement) showing the lowest gains. Percentage weight gain followed a similar trend. Specific growth rate (SGR) was highest in the control (2.26 ± 0.08) and T2 (2.12 ± 0.01), with no significant difference between them, and gradually declined with higher Moringa seed meal levels.

**Table 1:** Growth parameters of *Clarias gariepinus* fingerlings fed diets incorporating different concentrations of Moringa oleifera seed meal.

| | Treatments | | | | |
|---|---|---|---|---|---|
| Parameters | T1 (0%) | T2 (20%) | T3 (40%) | T4 (60%) | T5 (80%) |
| No of fish stocked | 20 | 20 | 20 | 20 | 20 |
| Mean initial weight (g) | 1.50±0.00 | 1.50±0.00 | 1.50±0.00 | 1.50±0.00 | 1.50±0.00 |
| Mean initial length (cm) | 6.17±0.06$^{a}$ | 6.17±0.06$^{a}$ | 6.13±0.06$^{a}$ | 6.17±0.06$^{a}$ | 6.17±0.06$^{a}$ |
| Survival rate (%) | 78.33±2.89$^{a}$ | 78.33±2.89$^{a}$ | 73.33±5.77$^{a}$ | 70.00±13.23$^{a}$ | 75.00±0.00$^{a}$ |
| Mortality rate (%) | 21.67±2.89$^{a}$ | 21.67±2.89$^{a}$ | 26.67±5.77$^{a}$ | 30.00±13.23$^{a}$ | 25.00±0.00$^{a}$ |
| Mean final weight (g) | 14.29±1.12$^{a}$ | 12.35±0.43$^{ab}$ | 11.08±0.13$^{b}$ | 8.48±2.27$^{c}$ | 8.21±0.36$^{c}$ |
| Weight gain (g) | 12.77±1.14$^{a}$ | 10.87±0.40$^{ab}$ | 9.57±0.12$^{b}$ | 6.97±2.25$^{c}$ | 6.70±0.35$^{c}$ |

| | | | | | |
|---|---|---|---|---|---|
| Percentage weight gain (%) | 849.13±72.06$^{a}$ | 720.39±27.85$^{ab}$ | 636.71±10.24$^{b}$ | 463.72±151.55$^{c}$ | 446.03±24.56$^{c}$ |
| Specific growth rate (%/day) | 2.26±0.08$^{a}$ | 2.12±0.03$^{ab}$ | 2.01±0.01$^{b}$ | 1.74±0.26$^{c}$ | 1.73±0.04$^{c}$ |
| Mean final length (cm) | 10.17±0.45$^{a}$ | 10.13±0.55$^{a}$ | 10.07±0.42$^{a}$ | 9.20±0.56$^{b}$ | 9.20±0.17$^{b}$ |
| Condition factor (K) | 1.36±0.11$^{a}$ | 1.20±0.15$^{ab}$ | 1.09±1.14$^{ab}$ | 1.14±0.49$^{ab}$ | 1.05±0.01$^{b}$ |

Mean in row having similar letter are not different significantly (p>0.05)

Table 2 shows nutrient utilization and food conversion results. Diet T2 (20% Moringa seed meal) had the lowest FCR (1.54 ± 0.03), though FCR increased with higher Moringa levels. However, differences in FCR and food conversion efficiency among all diets were not statistically significant (p>0.05). Protein efficiency ratio (PER) ranged from 0.20 ± 0.01 (T5) to about 0.27 (T2 and T3), with no significant differences. Apparent Net Protein Utilization (ANPU) also showed no significant variation, peaking at 7.85 ± 0.76 in T2 and dropping to 3.35 ± 0.26 in T5. PER and ANPU values followed a consistent declining trend with increased Moringa seed meal.

**Table 2:** Nutrient utilization metrics of C*larias gariepinus* when fed diets with different concentrations of *M. oleifera* seed meal.

| | Feed utilization | | | | |
|---|---|---|---|---|---|
| Parameters | T1 (0%) | T2 (20%) | T3 (40%) | T4 (60%) | T5 (80%) |
| Quantity of feed fed (g) | 317.44±20.19$^{a}$ | 262.32±26.20$^{b}$ | 240.26±19.40$^{b}$ | 224.43±31.57$^{b}$ | 220.44±6.21$^{b}$ |
| Feed conversion ratio (FCR) | 1.59±0.03$^{ab}$ | 1.54±0.11$^{a}$ | 1.72±0.19$^{ab}$ | 2.55±1.10$^{a}$ | 2.25±0.10$^{ab}$ |
| Feed conversion efficiency (FCE) | 53.97±0.91$^{a}$ | 56.74±3.97$^{a}$ | 55.51±3.73$^{a}$ | 44.84±6.98$^{b}$ | 43.50±1.55$^{b}$ |
| Protein efficiency ratio (PER) | 0.26±0.02$^{ab}$ | 0.27±0.02$^{a}$ | 0.27±0.03$^{a}$ | 0.22±0.03$^{ab}$ | 0.20±0.01$^{b}$ |
| Apparent net protein utilization (ANPU) | 7.82±0.38$^{a}$ | 7.85±0.76$^{a}$ | 5.13±0.88$^{b}$ | 3.91±1.53$^{bc}$ | 3.35±0.26$^{c}$ |

Means having similar letters are not statistically different (p>0.05)

## DISCUSSION

Growth performance indicators—mean weight gain (MWG), specific growth rate (SGR), and percentage weight gain (PWG)—declined as Moringa seed meal levels increased in the diet (Table 1). This aligns with findings by Richter *et al.* (2003) and Samkelisiwe and Ngonidzashe (2014), who reported reduced growth in fish with higher Moringa seed substitution. Condition factor values remained above 1.0 across treatments, indicating good health and effective diet utilization, consistent with Lagler (1956), who defined values above 1.0 as indicative of healthy fish. Survival rates showed no significant differences (p>0.05), with the highest values recorded in the control and 20% substitution treatments. This supports Alegbeleye (2005), who suggested that fish mortality could result from handling stress rather than anti-nutritional factors alone. Fish fed with a 20% substitution diet recorded the best feed conversion ratio (FCR), though differences across diets were not statistically significant (p>0.05). Higher substitution levels resulted in less efficient FCRs, likely due to reduced feed intake, as observed by Faturoti (1989). Apparent Net Protein Utilization (ANPU) showed no significant differences at 0–20% and 40–60% substitution levels, but declined with increasing Moringa seed meal, reflecting reduced protein quality and utilization.

## CONCLUSION

The feeding trial showed no significant difference (p>0.05) in fish survival across treatments. However, growth performance—mean weight gain, percentage weight gain, and specific growth rate—declined with increasing levels of Moringa seed meal in the diet. Nutrient utilization and feed conversion results indicated that fish fed a 20% substitution diet had the most favorable FCR, with no significant differences among diets. Protein efficiency ratio (PER) was highest at lower substitution levels (0–40%) and lowest at higher levels (60–80%), indicating better nutrient utilization at lower Moringa inclusion.

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# THE EFFECT OF COPRA MEAL AS A PARTIAL REPLACEMENT FOR FISHMEAL AND MAIZE MEAL ON GROWTH PERFORMANCE AND SURVIVAL OF *Clarias gariepinus* FINGERLINGS

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**ABSTRACT**

*This study evaluated the effect of copra meal (CM) as a partial replacement for fishmeal and maize meal on the growth performance and feed utilization of Clarias gariepinus. Five experimental diets were formulated: Control (0% CM), 5% CM, 10% CM, 15% CM, and 20% CM, each in triplicate. A total of 450 C. gariepinus fingerlings were stocked (30 fish per 100 × 80 × 100 cm³ tarpaulin pond) and fed the experimental diets for 70 days at 3% of body weight, twice daily (07:00 and 17:00 h). Results showed that fish fed 5% and 10% CM diets had weight gain and growth rates comparable ($p \geq 0.05$) to the control group, while further increases in CM inclusion (15–20%) significantly ($p \leq 0.05$) reduced growth performance. Specific growth rate did not differ significantly ($p \geq 0.05$) among treatments. Feed conversion ratio and protein efficiency ratio were similar to the control at 5% CM but declined significantly ($p \leq 0.05$) at higher inclusion levels. Survival rates were uniformly high (95.56–98.89%) across all treatments. In conclusion, copra meal can effectively replace up to 10% of fishmeal and maize meal in C. gariepinus diets without compromising growth or feed efficiency, beyond which performance declines.*

**Keywords:** Copra meal; Food indices; Growth indices; *Clarias gariepinus*; Survival rate

## INTRODUCTION

The coconut, referred to as the "tree of life" due to its diverse applications in the agricultural, food, pharmaceuticals, nutraceuticals, cosmetics, and engineering sector, is extensively cultivated in tropical and subtropical regions globally (Punzalan and Rosentrater, 2024). On a global scale, the demand and supply for coconut products has significantly increased with the coconut industry playing crucial role in the economies of producer countries (Zainol *et al*., 2023; Abeysekara and Waidyarathne, 2020). Copra is the fresh coconut meal dried to a low moisture content of 6 to 8% to concentrate the oil content and facilitate safe storage, as a traditional derivative of coconut (Punzalan and Rosentrater, 2024). Copra meal, also known as coconut meal, is an important feedstuff and a by-product of the oil extraction process from dried coconut kernels (Heuzé *et al*., 2015) and is often used as a protein source in the diets of fish. Copra meal protein lacks essential amino acids including lysine, methionine, threonine, and histidine, but comparatively rich in arginine (Swick, 1999). Therefore, to efficiently include copra meal into practical fish feed, supplementation with these limited amino acids is needed. Although copra meal is high in fiber and contains tannins, an anti-nutritional element (Mukhopadhyay and Ray, 1999), its usage is not considerably limited when these components are reduced. In 2017, the Government of Akwa Ibom State established the St. Gabriel Coconut Refinery in Mkpat Enin Local Government Area, with a daily

processing capacity of over one million coconuts and the potential to employ more than 3,000 workers.

The refinery is supported by the cultivation of two million hybrid coconut trees on 11,000 hectares across multiple local government areas, making it the largest coconut plantation in Africa. This scale of operation indicates a substantial generation of copra meal as a by-product, underscoring the need to explore diverse and sustainable utilization strategies. In Nigeria, the high cost of commercial fish feed and traditional feedstuffs have compelled fish farmers to seek economic and ecological alternatives to ensure continued fish production. Several studies have investigated the use of copra meal as a fishmeal replacement at various inclusion levels such as Mukhopadhyay and Ray (1999) for Rohu (*Labeo rohita*), Apines-Amar *et al*., (2015) for Milkfish (*Chanos chanos*), Harlina *et al*., (2021) for O*reochromis niloticus*, and Mamauag *et al*., (2019) for Grouper (*Epinephelus fuscoguttatus*). *Clarias gariepinus* is a widely farmed and highly valued fish species in Nigeria due to its hardiness, fast growth, disease resistance, high stocking density, acceptance of artificial diets, and strong market demand (Eyo and Ekanem, 2023; Eyo *et al*., 2024; Eyo *et al*., 2021; Gbuvboro *et al*., 2024). However, limited information is available on the incorporation of copra meal in the diet of C. *gariepinus*. Therefore, the objective of this study is to evaluate the effect of copra meal as a partial replacement for fishmeal and maize meal on the growth performance and food indices of C. *gariepinus*.

## MATERIALS AND METHODS

### Preparation of Copra meal and experimental feed formulation

Copra meal, a by-product of coconut oil extraction, was sourced from a local coconut oil producer in Uyo, Akwa Ibom State, and utilized for the formulation of experimental diets. The experimental diets (Table 1) were formulated using the trial-and-error method (Ekanem *et al*., 2010) to contain 40 % crude protein. Copra meal was included in the feed as follows: Diet A (0 % CM), Diet B (5 % CM), Diet C (10 % CM), Diet D (15 % CM), and Diet E (20 % CM).

**Table 1:** Gross composition of the experimental feed

| Ingredients | Diet A (Control) | Diet B (5 % CM) | Diet C (10 % CM) | Diet D (15 % CM) | Diet E (20 % CM) |
|---|---|---|---|---|---|
| Maize meal (MM) | 39.3 | 36.0 | 32.0 | 28.0 | 24.0 |
| Fish meal (FM) | 54.7 | 53.0 | 52.0 | 51.0 | 50.0 |
| Copra meal (CM) | 0.0 | 5.0 | 10.0 | 15.0 | 20.0 |
| Calcium powder | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Sodium chloride | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Lysine | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Methionine | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Corn flour | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Fish oil | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| **Total** | **100.0** | **100.0** | **100.0** | **100.0** | **100.0** |

### Experimental Design

The experiment was designed using Completely Randomized Design (CRD). Five experimental groups (including a control group) were set up in triplicate. Group 1 (Control) composed of fish fed the control diet without copra meal. Group 2 composed of fish fed a diet with 25% copra meal inclusion, Group 3 composed of fish fed a diet with 50% copra meal inclusion, Group 4 composed fish fed a diet with 75% copra meal inclusion and Group 5composed of fish fed a diet with 100% copra meal inclusion. Fifteen (15) tarpaulin ponds with dimension (100 by 80 by 100 $cm^3$) were stocked with 450 C. *gariepinus* fingerlings (30 in each tarpaulin) and acclimated for a period of fourteen (14) days. During this period, the fishes were fed twice daily with Multi feed to satiation. The fishes were thereafter starved for 24

hours before measuring their initial length and weight. The feeding trial lasted for 70 days, and feeding was done at 3% of their wet body weight twice daily by 07.00 and 17.00 hours.

**Proximate analysis of Copra meal and experimental diets**
Proximate analysis of Copra meal and experimental diets was done using AOAC (2005) methods. Ash, carbohydrate, crude protein, moisture contents and lipid were analysed.

**Growth performance and food indices**
The growth performance and food indices were calculated according to De Silva and Anderson (1995). The growth indices were weight gain (WG, g), percentage weight gain (PWG, %), growth rate (GR, g/day), specific growth rate (SGR, %/day) and percentage survival (PS, %). The food indices were feed intake (FI, g), food conversion ratio (FCR) and protein efficiency ratio (PER).

**Measurement of water quality parameters**
Physico-chemical parameters were measured biweekly and parameters measured include dissolved oxygen (HI9142 DO meter), pH (PHEP pH meter), temperature (thermometer), and ammonia (Nutrifan kit).

**Data analysis**
One-way analysis of variance (ANOVA) was used to evaluate the significant differences between treatment groups for growth and food indices. A significance level of $p \leq 0.05$ was considered statistically significant. Tukey's test was used for pairwise comparisons between groups.

## RESULTS AND DISCUSSIONS

**Proximate composition of Copra meal and experimental diets**
The proximate composition of Copra meal (CM) is as follows: crude protein (21.6 ± 0.03 %), crude fibre (14.0 ± 0.02 %), ash (6.9 ± 0.03 %), moisture (2.5 ±0.02 %), crude fat (9.4 ± 0.02 %) and carbohydrate (45.6 ± 0.06 %). For the experimental diets, crude protein ranged between 41.94 ± 0.04% in Feed A (0 % CM) to 41.68 ± 0.20% in Feed D (15 % CM). Crude fibre ranged between 7.31 ± 0.06% in Feed E (20 %) to 7.12 ± 0.03% in Feed A (0 % CM). Ash ranged between 5.32 ± 0.09% in Feed A (0 %) to 5.44 ± 0.06% in Feed E (20 % CM). Moisture ranged between 1.93 ± 0.60% in Feed C (10 %) to 1.82 ± 0.04% in Feed B (5 % CM). Crude fat ranged between 2.64 ± 0.02% in Feed D (15 %) to 2.56 ± 0.03% in Feed A (0 % CM). Carbohydrate ranged between 41.20 ± 0.12% in Feed B (5 %) to 41.00 ± 0.02% in Feed E (20 % CM). Table 2 shows the proximate composition of Copra meal and experimental diets.

**Table 2:** Proximate composition of the experimental diets

| Indices | Copra meal (CM) | Feed A (0 % CM) | Feed B (5 % CM) | Feed C (10 % CM) | Feed D (15 % CM) | Feed E (20 % CM) |
|---|---|---|---|---|---|---|
| Crude protein (%) | 21.6 ± 0.03 | 41.94 ± 0.04[a] | 41.81 ± 0.03[a] | 41.75 ± 0.06[a] | 41.68 ± 0.20[a] | 41.81 ± 0.03[a] |
| Crude fibre (%) | 14.0 ± 0.02 | 7.12 ± 0.03[a] | 7.18 ± 0.06[a] | 7.22 ± 0.03[a] | 7.25 ± 0.03[a] | 7.31 ± 0.06[a] |
| Ash (%) | 6.9 ± 0.03 | 5.32 ± 0.09[a] | 5.37 ± 0.03[a] | 5.41 ± 0.04[a] | 5.43 ± 0.03[a] | 5.44 ± 0.06[a] |
| Moisture (%) | 2.5 ±0.02 | 1.92 ± 0.02[a] | 1.82 ± 0.04[a] | 1.93 ± 0.60[a] | 1.85 ± 0.03[a] | 1.83 ± 0.03[a] |
| Crude fat (%) | 9.4 ± 0.02 | 2.56 ± 0.03[a] | 2.62 ± 0.04[a] | 2.60 ± 0.02[a] | 2.64 ± 0.02[a] | 2.61 ± 0.03[a] |
| Carbohydrate (%) | 45.6 ± 0.06 | 41.14 ± 0.04[a] | 41.20 ± 0.12[a] | 41.09 ± 0.03[a] | 41.15 ± 0.03[a] | 41.00 ± 0.02[a] |

*Values represent the mean ± standard error for the triplicate units. Mean values with the same superscripts are not significantly different ($P \geq 0.05$)

**Growth Performance and food indices**

The data from Table 3 demonstrates that increasing the inclusion level of Copra meal (CM) in C. *gariepinus* diets progressively reduces growth performance while maintaining survival rates. **Weight gain (g)** and **growth rate (g/day)** in fish fed diets with 5% and 10% Copra meal (CM) was not significantly different ($p \geq 0.05$) from the control diet but declined significantly ($p \leq 0.05$) as CM increased from 10% to 20%. This finding aligns with studies showing reduced growth in C. *gariepinus* fed high levels of plant-based substitutes due to lower protein quality or anti-nutritional factors (Eyo and Ivom, 2017; Ibidun *et al*., 2022; Abdul Hadi *et al*., 2022).

**Specific growth rate (%/day)** was not significantly different ($p \geq 0.05$) across all groups ranging from 2.64 ± 0.01 %/day (0 % CM and 10 % CM) to 2.65 ± 0.01 %/day (5 % CM, 15 % CM and 20 % CM). These findings suggest proportional growth efficiency relative to body size which persisted despite reduced absolute growth. **Feed intake** peaked at 10% CM (376.91 ± 3.86 g) but dropped at higher inclusion levels, likely due to reduced palatability or digestibility (Awom and Eyo, 2021).

**Food co**nversion ratio **protein** efficiency ratio of fish fed diet 2 with 5% Copra meal (CM) was not significantly different ($p \geq 0.05$) from the control diet but was significantly different ($p \leq 0.05$) as CM increased from 10% to 20%. Similar patterns were observed in C. *gariepinus* fed cassava leaf meal or other fibrous substitutes, where higher FCR correlated with lower nutrient availability (Ekanem *et al*., 2010).

**Table 3:** Growth performance and food indices of C. *gariepinus* fed the experimental diets

| Indices | Group 1 (0 % CM) | Group 2 (5 % CM) | Group 3 (10 % CM) | Group (15 % CM) | Group (20 % CM) |
|---|---|---|---|---|---|
| Initial weight (g) | 6.37 ± 0.03 | 6.38 ± 0.02 | 6.34 ± 0.02 | 6.39 ± 0.01 | 6.38 ± 0.02 |
| Final weight (g) | 243.00 ± 1.15 | 241.33 ± 0.88 | 239.00 ± 0.58 | 212.67 ± 0.88 | 205.00 ± 1.15 |
| Weight gain (g) | 236.63 ± 1.13$^{a}$ | 234.96 ± 0.86$^{a}$ | 232.66 ± 0.56$^{a}$ | 206.28 ± 0.88$^{b}$ | 198.62 ± 1.14$^{c}$ |
| Growth rate (g/day) | 3.38 ± 0.02$^{a}$ | 3.36 ± 0.01$^{a}$ | 3.32 ± 0.01$^{a}$ | 2.94 ± 0.01$^{b}$ | 2.84 ± 0.02$^{c}$ |
| Specific growth rate (%/day) | 2.64 ± 0.01$^{a}$ | 2.65 ± 0.01$^{a}$ | 2.64 ± 0.01$^{a}$ | 2.65 ± 0.01$^{a}$ | 2.65 ± 0.01$^{a}$ |
| Feed intake (g) | 364.41 ± 1.61$^{a}$ | 368.10 ± 5.74$^{a}$ | 376.91 ± 3.86$^{a}$ | 336.93 ± 2.77$^{b}$ | 340.27 ± 1.64$^{c}$ |
| Food conversion ratio | 1.54 ± 0.01$^{a}$ | 1.57 ± 0.02$^{a}$ | 1.62 ± 0.02$^{b}$ | 1.63 ± 0.01$^{b}$ | 1.71 ± 0.02$^{c}$ |
| PER | 1.55 ± 0.01$^{a}$ | 1.52 ±0.02$^{a}$ | 1.47 ± 0.02$^{b}$ | 1.46 ± 0.01$^{b}$ | 1.39 ± 0.02$^{c}$ |
| Survival rate (%) | 98.89 ±1.11$^{a}$ | 97.78 ± 1.11$^{a}$ | 98.89 ±1.11$^{a}$ | 95.56 ± 1.11$^{a}$ | 98.89 ±1.11$^{a}$ |

*Values represent the mean ± standard error for the triplicate experimental group. Mean values with different superscripts are significantly different ($P \leq 0.05$)

**Survival rates** remained high (95.56–98.89%) across all groups, indicating CM does not compromise survival despite affecting growth performance at higher inclusion levels. In this study, the results of physico-chemical parameters showed that mean pH ranged between 6.91 ± 0.04 in Group D to 6.96 ± 0.04 in Group A, mean dissolved oxygen 4.80 ± 0.14 mg/l in Group D to 4.88 ± 0.04 mg/l in Group C, mean temperature ranged between 29.64 ± 0.33 °C in Group E to 29.91 ± 0.06 °C in Group E and mean ammonia ranged between 0.02 ± 0.04 mg/l in Group B to 0.04 ± 0.02 mg/l in Group D. These values fell within the range recommended by Boyd (1979) for growth, survival, and good health of freshwater fish.

## CONCLUSION

In conclusion, the optimal Copra meal (CM) inclusion appears to be 10%, beyond which growth and feed efficiency decline. Further studies on copra meal in fish diets should focus on improving its nutritional quality through processing, optimizing inclusion levels across species and life stages, and evaluating health, growth, and economic sustainability impacts.

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# EFFECT OF BASIL (*Ocimum gratissimum* L.) LEAF AQUEOUS EXTRACT ON GROWTH PERFORMANCE AND CARCASS COMPOSITION OF *Oreochromis niloticus* LINNAEUS, 1758 FINGERLINGS

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**ABSTRACT**
*This study was carried out to assess the effect of Ocimum gratissimum leaf aqueous extract on growth and carcass composition of Oreochromis niloticus fingerlings. Five iso-nitrogenous (29.78–30.39%) diets containing 0g (control), 2g, 4g, 8g and 16g Ocimum leaf extract (g/kg) were fed to triplicate groups of fish with initial weight (3.28±0.03 - 3.36±0.05g) for 90 days. Ocimum leaf extract significantly (p≤0.05) improved the growth of O. niloticus with the highest mean weight gain (9.83±0.31g), specific growth rate (2.54±0.03), feed intake (20.04±0.40g) and protein efficiency ratio (1.63±0.02) recorded in a diet supplemented with 8g/kg Ocimum leaf extract. Regression analysis indicated a polynomial relationship between growth parameters and dietary Ocimum leaf extract levels. The optimum Ocimum leaf extract level was 7.8g/kg diet for mean weight gain. The highest carcass crude protein (47.80±1.33%) and apparent protein digestibility (86.67%) were recorded in a diet supplemented with 8g/kg Ocimum leaf extract. The diet supplemented with 8g/kg Ocimum leaf extract showed the highest mean weight gain (9.83±0.31g).*

**Keywords:** *Ocimum gratissimum*, Apparent digestibility, Nile tilapia, Growth performance

## INTRODUCTION

Phytogenic plants with traditional medicinal usage have been identified as potential feed additives which can provide beneficial effects as immunostimulants to promote growth performance, antioxidation, and immune response in fish (Abdel-Tawwab *et al*., 2018; Omitoyin *et al*., 2019; Poolsawat *et al*., 2022).
*Ocimum gratissimum*, commonly referred to as "scent leaf" or clove basil is an aromatic herbaceous, a native plant to Africa and grows virtually in tropical and subtropical regions (Bayoub *et al*., 2010; Ugbogu *et al*., 2021). Ugwu *et al*. (2014) reported that the extract of O. *gratissimum* increases the primary and secondary anti-body and possesses immunostimulatory effects. Several studies have reported that the leaf has a wide range of bioactive compounds with antimicrobial properties such as eugenol, linaol, methyl cinnamate, camphor, and thymol (Ugbogu *et al*., 2021). As aquafarming continues to expand in a bid to meet the targeted protein needs of the ever-rising global population, strategies to reduce the incidence of diseases due to culture-related stress must be devised, as antibiotic use is not an option. Recently, in aquaculture, a great deal of attention has been placed on the use of phyto-based additives, which have the inherent potential to mitigate disease-causing agents and promote environmentally friendly aquaculture.

The intensive production of farmed fish with compounded feeds has largely increased mainly due to the growth of aquaculture production, and because it is the most efficient way of production to meet the fish demand (Olsen and Hasan, 2012; Munguti *et al*., 2021). The Nile tilapia, *Oreochromis niloticus* is considered one of the most important fish species in tropical and sub-tropical aquaculture (FAO, 2012; Prabu *et al*., 2019). It serves as an important source of animal protein and income throughout the world (Sosa *et al*., 2005; Schar *et al*., 2020).
Various works to use phytobiotics as feed supplements to improve fish growth, health, and immunity

have been reported for example; Abdel-Tawwab *et al*. (2018) studied growth and immune response of *Clarias gariepinus* (B.), to dietary clove basil, *Ocimum gratissimum*, leaf extract and its susceptibility to *Listeria monocytogenes* infection. Fatima *et al*. (2022) studied the enhancement of immune response and resistance to *Vibrio parahaemolyticus* in Tilapia fish (*Oreochromis mossambicus*) by dietary supplementation of *Portieria hornemannii*. However, there is a paucity of information on the effect of basil (*Ocimum gratissimum*) leaf aqueous extract on growth performance and carcass composition of *Oreochromis niloticus* fingerlings.

## MATERIALS AND METHODS

### Experimental Diets Preparation

The feed ingredients used for the experiment were purchased from Sabon-Gari market, Zaria, Kaduna State, Nigeria. The ingredients were processed and milled to fine particle size. Five (5) experimental diets (Diets 1 to 5) were formulated to be isonitrogenous (29.78–30.39% crude protein) with varying levels of *O. gratissimum* leaf aqueous extract (0, 2, 4, 8 and 16g/kg). The basal diet (control diet - 0g/kg of *Ocimum* leaf extract) was prepared by blending yellow maize, wheat bran, soybean meal, fish meal, corn starch, chicken intestine, palm oil, premix, lysine and methionine made as a dough, pelletized and then air-dried, smashed into reduced required sizes. Supplemented diets (2, 4, 8 and 16g/kg of *Ocimum* leaf extract) were formulated using the same ingredients for the basal diet in which *Ocimum* leaf extract was supplemented. The fish were fed to satiation thrice daily. The experimental diets were weighed before the commencement of the feeding trial and at the end of the feeding trial to determine the amount of feed administered in each experimental tank. The feeding of experimental fish lasted for ninety (90) days.

### Experimental fish and conditions

A total number of 800 fingerlings of *O. niloticus* were procured from a reputable fish farm in Kano State, Nigeria. The fish were transported in a 50L plastic container to the Fisheries Research Laboratory of the Department of Biology, Faculty of Life Sciences, Ahmadu Bello University Zaria, Nigeria, where they were acclimatised in holding tanks with dechlorinated tap water and fed commercial feed (Coppens) at 5% of the biomass for two weeks. The *O. niloticus* with an initial mean body weight ranging from 3.28±0.03 g to 3.36±0.05 g were randomly distributed into plastic tanks at a stocking rate of fifteen (15) fish per tank. Each tank measured 30.0 cm × 20.0 cm × 25.0 cm and contained 35 L of water. The treatments consisted of five dietary levels of *Ocimum* leaf extract: 0 g/kg (control), 2 g/kg, 4 g/kg, 8 g/kg, and 16 g/kg. Each treatment was replicated in triplicate tanks, resulting in a total of forty-five (45) fish per treatment. Thereafter, batch weighing and length measurement of fish were done to ascertain their initial mean weight in grams and initial mean length in centimetres, using a top-loading weighing balance (AT. M A 123) and fish measuring board, respectively, before the commencement of the experiment and at the end of the experiment.

### Growth Measurements and Feed Efficiency

The body weight (g) and length (cm) of individual fish of each experimental tank were recorded during the experimental period using a weighing balance and fish measuring board respectively. Mortalities were recorded as they occurred. Parameters that were used in evaluating growth performance in this study were weight gain by fish (WG), specific growth rate (SGR), percentage survival rate (PSR), feed conversion ratio (FCR), gross feed conversion efficiency (GFCE), and the protein efficiency ratio (PER).

### Apparent Digestibility Coefficient and Proximate Analysis

The direct determinations of digestibility were used in this study by relating the total quantity of nutrients (protein, carbohydrates, lipids as well as calorific values) in a known quantity of feed consumed.

The apparent digestibility coefficients (ADC) for the nutrients of the diets were calculated as follows (Bureau *et al*., 1999; Forster, 1999):

$$\text{ADC}(\%) = \frac{\text{nutrient intake} - \text{nutrient in faeces}}{\text{nutrient intake}} \times 100$$

Proximate analysis of major dietary ingredients, experimental diets, fish whole body and faecal matter samples were carried out according to AOAC (2000) procedures. The proximate analysis followed the methods described by the AOAC (2000). Components such as moisture, crude protein, crude lipid and ash were analyzed.

**Water Quality Monitoring**

Parameters Water quality parameters such as temperature (27.31-27.48°C), pH (7.29-7.37), electrical conductivity (206.67$\mu$) and total dissolved solids (103.33-105.33±1.26mg/l) were monitored daily using the Hanna Model instrument (Model No-626 973-01) respectively. Dissolved oxygen (7.13±0.17mg/l), was determined using the method described in APHA (2007).

**Data Analysis**

Shapiro-Wilk and Levene's tests were used to check the normality of the data and homogeneity of variance respectively. The data collected was subjected to analysis of variance (ANOVA). Tukey's test was used to separate the means where significant and the test of significance was at 5% P-level. Regression analysis was employed to establish a relationship between Ocimum levels and mean weight gain. R-statistical software (version 4.1.2) for Windows and GraphPad prism (version 9.0) were used for data analysis.

**Results and Discussion**

The water quality parameters obtained in this work were within the range recommended for the culture of O*reochromis niloticus* (Ibrahim *et al*., 2018; Abd El-Hack *et al*., 2022). The O*cimum* leaf extract in this study did not affect the water quality parameters. As long as the diets are properly prepared, feeding O. *niloticus* diets containing O*cimum* leaf extract does not result in a decline in water quality parameters. Abd El-Hack *et al*. (2022) reported a temperature range of 22 - 27$^{o}$C, a pH range from 6.5 – 9.0 and dissolved oxygen of 6.3 – 9.6mg/l, as optimum and best for high growth performance in cultured tropical fish.

The inclusion of O*cimum* leaf aqueous extract influences the growth performance and feed utilization of O*reochromis niloticus* fingerlings, as evidenced by fish fed an 8g/kg diet that resulted in a mean weight gain of 13.18±0.27g and a feed conversion ratio of 2.04±0.03 (Table 1). The improvement in the growth performance and feed efficiency in O*cimum* leaf extract fed groups could be due to the ability of the bioactive compounds to trigger the secretion of digestive enzymes, thereby resulting in nutrient utilization and muscle growth. Abdel-Tawwab *et al*. (2018) reported that extract of O. *gratissimum* improves the growth performance and feed utilization of African catfish. Similarly, Omitoyin *et al*. (2019) reported that *Psidium guajava* extract in the diet of O*reochromis niloticus* improved growth performance, exhibited better feed conversion ratio and protein efficiency ratio. The presence of certain phytochemical constituents such as thymol and phenol may be responsible for improved growth in diets supplemented with O*cimum* leaf extract, as revealed by Hafsan *et al*. (2022) that thymol in the diet of rainbow trout can improve fish growth performance.

The high feed intake (20.04±0.40g) recorded in the diet supplemented with 8g/kg O*cimum* leaf extract was similar to the report of Abdel-Tawwab *et al*. (2018) who observed that fish performance and feed

intake were significantly enhanced with clove basil leaf meal extract with feed intake of *Clarias gariepinus* to be in a dose-dependent manner and its optimum level was 12 g/kg diet. The effect of basil extract could be attributed to the aromatic flavour which could improve feed intake and thereby provide enough nutrients to improve fish growth. Furthermore, the result from the regression analysis from this study suggests *Ocimum* leaf extract inclusion level is 7.81g/kg of diet for optimal growth performance of *Oreochromis niloticus* (Figure 1). Growth and feed intake in O. *niloticus* may be dose-dependent manner and its optimum level was 8g/kg diet.

**Table 1**: Growth and nutrient utilization of *Oreochromis niloticus* fed a diet with different levels of *Ocimum* Leaf Extract for 90 days

| Parameters | *Ocimum* leaf extract levels (g/kg diet) | | | | | *p*-value |
|---|---|---|---|---|---|---|
| | 0 | 2 | 4 | 8 | 16 | |
| Mean initial weight (g) | 3.31±0.09 | 3.26±0.02 | 3.32±0.04 | 3.36±0.05 | 3.28±0.03 | 0.765 |
| Mean final weight (g) | 7.51±0.21$^{c}$ | 9.71±0.61$^{bc}$ | 10.87±0.32$^{ab}$ | 13.18±0.27$^{a}$ | 9.55±1.05$^{bc}$ | <0.001 |
| Mean weight gain (g) | 4.20±0.28$^{c}$ | 6.45±0.59$^{bc}$ | 7.55±0.30$^{ab}$ | 9.83±0.31$^{a}$ | 6.28±1.03$^{bc}$ | <0.001 |
| Specific growth rate (%) | 1.59±0.08$^{c}$ | 2.06±0.10$^{abc}$ | 2.24±0.04$^{ab}$ | 2.54±0.03$^{a}$ | 2.01±0.20$^{bc}$ | 0.002 |
| Feed intake (g) | 12.40±0.28$^{c}$ | 16.51±0.96$^{b}$ | 18.14±0.59$^{ab}$ | 20.04±0.40$^{a}$ | 16.11±0.10$^{b}$ | <0.001 |
| Feed conversion ratio | 2.97±0.14 | 2.61±0.30 | 2.41±0.05 | 2.04±0.03 | 2.73±0.51 | 0.241 |
| Protein efficiency ratio | 1.14±0.05 | 1.31±0.17 | 1.40±0.03 | 1.63±0.02 | 1.28±0.21 | 0.144 |
| Survival rate (%) | 97.78±2.22 | 100.00±0.00 | 100.00±0.00 | 97.78±2.22 | 100.00±0.00 | 0.58 |

Values (means +SE) in the same row with different superscripts differ significantly ($p \leq 0.05$)

intake were significantly enhanced with clove basil leaf meal extract with feed intake of *Clarias gariepinus* to be in a dose-dependent manner and its optimum level was 12 g/kg diet. The effect of basil extract could be attributed to the aromatic flavour which could improve feed intake and thereby provide enough nutrients to improve fish growth. Furthermore, the result from the regression analysis from this study suggests *Ocimum* leaf extract inclusion level is 7.81g/kg of diet for optimal growth performance of *Oreochromis niloticus* (Figure 1). Growth and feed intake in O. *niloticus* may be dose-dependent manner and its optimum level was 8g/kg diet.

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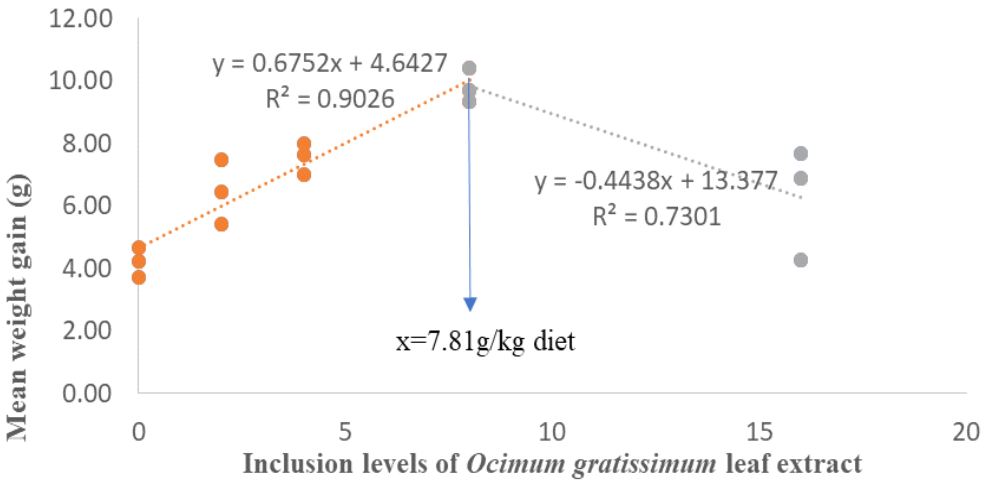



**Figure 1**: Relationship between weight gain (g) of *Oreochromis niloticus* and *Ocimum* Leaf Extract inclusion levels

The carcass proximate composition of the experimental fish was affected by the inclusion of *Ocimum* leaf extract, which was particularly associated with a significant increase in crude protein (47.80±1.33%) content and a decrease in lipid content (13.57±0.68%) as observed in fish fed a diet supplemented with 8g/kg *Ocimum* leaf extract (Table 2), this revealed that the increase in weight was not due to the accumulation of fat by the experimental fish. This is consistent with the findings of Abasali and Mohamad (2010) that recorded an increase in total protein content in common carp fed with herbal immunostimulants diets. In another study, Ullah *et al*. (2021) observed elevated protein and lipid content levels in *Labeo rohita* fed diet supplemented with dietary leaf extracts of Black pepper *Piper nigrum*.

The fish fed an 8g/kg diet showed an 86.67% apparent protein digestibility (APD), indicating that the addition of *Ocimum* leaf extract had an impact on this parameter (Figure 2). The energy obtained in this experiment and the apparent digestibility of crude protein were both high (>60%). The results were significantly lower than those reported by Fagbenro and Olurole (2016) in their investigation of the nutritional digestibility of *Oreochromis niloticus* (Cichlidae) and *Clarias gariepinus* (Clariidae) in cassava leaf protein concentrate. An important criterion for assessing a fish diet's quality and capacity to produce new tissues is apparent protein digestibility.

**Table 2**. Carcass composition of *Oreochromis niloticus* fed a diet with different levels of *Ocimum* Leaf Extract

| Parameters (%) | *Ocimum* leaf extract levels (g/kg diet) | | | | | *p*-value |
|---|---|---|---|---|---|---|
| | 0 | 2 | 4 | 8 | 16 | |
| Crude protein | $28.87\pm0.33^{c}$ | $41.13\pm1.03^{b}$ | $43.73\pm0.45^{ab}$ | $47.80\pm1.33^{a}$ | $40.16\pm0.99^{b}$ | 0.000 |
| Ether extract | $17.60\pm0.35^{a}$ | $14.60\pm0.32^{b}$ | $14.70\pm0.31^{b}$ | $13.57\pm0.68^{b}$ | $14.77\pm0.30^{b}$ | <0.001 |
| Ash content | 15.50±0.65 | 13.57±0.32 | 15.03±0.43 | 13.20±1.18 | 14.33±0.52 | 0.178 |
| Nitrogen-free extract | $22.10\pm0.60^{a}$ | $19.95\pm1.03^{ab}$ | $17.92\pm0.33^{b}$ | $18.15\pm0.72^{b}$ | $20.60\pm0.25^{ab}$ | 0.005 |
| Moisture content | $14.60\pm0.85^{a}$ | $11.09\pm0.39^{b}$ | $8.62\pm0.06^{cd}$ | $7.28\pm0.15^{d}$ | $9.47\pm0.43^{bc}$ | <0.001 |

Values (means +SE) in the same row with different superscripts differ significantly ($p\leq0.05$)

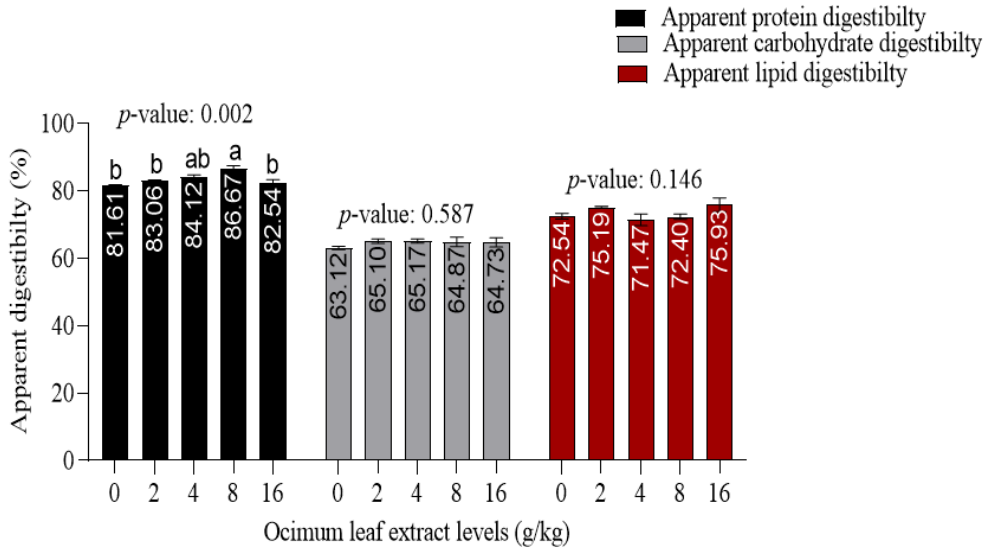



**Figure 2:** Apparent digestibility of *Oreochromis niloticus* fed a diet with different levels of *Ocimum* leaf extract. Values are mean ± SE, bars that are not sharing a common superscript letter (a, b, c) differ significantly at $p< 0.05$.

## CONCLUSION

The diet supplemented with 8g/kg *Ocimum* leaf extract showed the highest mean weight gain (9.83±0.31g), specific growth rate (2.54±0.03), and protein efficiency ratio (1.63±0.02). Similarly, the diet supplemented with 8g/kg *Ocimum* leaf extract had the best feed conversion ratio (2.04±0.03). The *O. niloticus* that were fed on a diet supplemented with 8g/kg of *Ocimum* leaf extract had the highest apparent protein digestibility (86.67%) and crude protein (47.80±1.33%) for carcass composition.

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# GROWTH PERFORMANCE OF *Clarias gariepinus* FINGERLINGS FED DIET CONTAINING GRADED LEVELS OF VELVET BEAN (*Mucuna pruriens*) SEED MEAL

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**ABSTRACT**
*This study assessed the growth performance of Clarias gariepinus fingerlings fed diet containing graded levels of Mucuna pruriens seed meal as a replacement of soya bean meal. The study was conducted at the Teaching and Research Farm of the Department of Fisheries and Aquaculture, Federal University Dutse. The Mucuna seeds were toasted and grounded into a meal. One hundred and fifty fingerlings of Clarias gariepinus were stocked in the indoor experimental plastic tanks. The tanks were stocked with 10 fingerlings each and replicated thrice for each treatment. A 40% crude protein diet was formulated with replacement level of soya bean with Mucuna seed meal of 0, 10, 20, 30 and 40%, respectively. The fish were fed daily with the experimental diet at 5% of their body weight. Data on growth indices were collected and subjected to One-way analysis of variance (ANOVA). The study revealed significant difference (P≤0.05) in the growth performance of the fed fingerlings with different replacement levels. As the level of the Mucuna seed meal increases, the growth performance becomes better. In conclusion, Mucuna seed meal has great potential to be utilized as a plant protein source without compromising the quality of the fish feed.*

**Keywords**: Growth performance, *Clarias gariepinus*, *Mucuna pruriens*

## INTRODUCTION

Fish is a good source of protein food and means of livelihood to many African populace (Mustapha, 2013). The demand for fish food has been on the increase with increasing human populace (FAO, 2010; FAO, 2012). *Clarias gariepinus* is generally considered to be one of the most important tropical fresh water fish species for aquaculture (Dada and Wanah, 2003). The *Mucuna pruriens* belongs to the family *Fabaceae* and has been described as a multipurpose plant which is used extensively both for its nutritional and medicinal properties (Adepoju and Odubena, 2009). It is twinning and tropical legume known as velvet bean and of common names such as: cow-itch, cow hage, Bengal beans, itchy bean, buffalo bean and velvet bean (English), while it's called *Agbara* (Igbo), *Yerepe* (Yoruba) and *Karara* (Hausa) (Manyham *et al.*, 2004). Soya bean meal (SBM) is one of the most nutritious of all plant protein sources (Batal *et al.*, 2000). Due to its high protein content, high digestibility and relatively well-balanced amino acid profiles, it is widely used as feed ingredient for many aquaculture species (Storebakken *et al.*, 2000). It is currently the most used plant protein source in fish feed. Despite its nutritional value and potential, Mucuna seed has remained an under-utilized food crop as a result of the presence of anti-nutritional factors in it (Mugendi *et al.*, 2010). To reduce or eliminate the anti-nutritional factors, improve nutritional qualities and also increase the utilization of legumes, many food processing methods can be adopted (El-suhaibani *et al*,. 2020). This study was conducted to evaluate the effect of replacing soya bean with *Mucuna seed* meal in the diet of catfish, *Clarias gariepinus* (Burchell 1822).

## MATERIALS AND METHOD

### Study area

The research was conducted in the Teaching and research fish farm of the Department of Fisheries and Aquaculture, Federal University Dutse, Jigawa State, Nigeria. It is located at latitudes 11.00°N and 13.00°N and longitudes 8.00°E and 10.15°E, respectively in the Sudan Savannah agro-ecological zone of

Nigeria.

**Experimental fish**One hundred and fifty (150) *Clarias gariepinus* fingerlings with average body weight of 3g were were stocked into a $1m^2$ plastic experimental tanks and were allowed to acclimatize for three days while they were fed floating pelleted commercial diet before the commencement of the experiment.

**Experimental diet**

The diets were formulated to provide 40% crude protein (Table 1). The control Diet had 0% *Mucuna pruriens* seed meal (MPSM) and was designated as T1. The other diets contain 10, 20, 30 and 40% MPSM, which were designated as T2, T3, T4 and T5, respectively.

**Experimental design**

Fifteen (15) tanks were installed in the laboratory and each stocked with 15 *Clarias gariepinus* fingerlings in a completely randomized manner. The fish were acclimatized for 72 hours to empty their stomach before commencing the feeding experiment. Fish weight and length were measured using top loading sensitive digital scale (Model: SF - 400) and measuring board, respectively, to obtain the initial mean weight before the experiment commences and at the end of the experiment to obtain the final mean weight. The fish were fed thrice a day; (morning 8:00am, afternoon 1:00pm and evening 5:00pm) at 5% of their body weight. The formulated diet has soya bean meal being replaced with Mucuna seed meal at the level of 0% (control) i.e. without *Mucuna* seed meal, 10, 20, 30 and 40%, respectively.

**Table 1:** Composition (%) of the experimental diet

| Feed ingredients | Replacement level (%) of *Mucuna pruriens* seed meal | | | | |
|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | 40 |
| Fishmeal | 22.50 | 22.50 | 22.50 | 22.50 | 22.50 |
| Groundnut cake | 22.50 | 22.50 | 22.50 | 22.50 | 22.50 |
| Soya bean Meal | 22.50 | 20.50 | 18.00 | 15.75 | 13.50 |
| Mucuna seed meal | 0.00 | 2.25 | 4.50 | 6.75 | 9.00 |
| Yellow maize | 11.25 | 11.25 | 11.25 | 11.25 | 11.25 |
| Wheat offal | 11.25 | 11.25 | 11.25 | 11.25 | 11.25 |
| Methionine | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Lysine | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Premix | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Salt | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Ascorbic acid | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Dicalcium phosphate | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Cassava starch binder | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 |
| Palm oil | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Total | 100 | 100 | 100 | 100 | 100 |

The experiment was replicated in triplicates and feed was administered to the tanks manually at the specified quantity on a specific point to avoid pollution of water. The fish was weighed biweekly in order to adjust the amount of feed to be administered accordingly. At the end of the culture period of the fish, the following growth parameters were recorded using the following formulae:

i. Weight Gain (WG) = $W_1 - W_0$ Where; $W_1$ = final body weight, $W_0$ = initial body weight

ii. Average daily weight gain (ADWG) (g/day) = $\frac{W1-W0}{T}$, where T = culture period (days)

iii. Specific Growth Rate (SGR) (%/day) = $\frac{W1-W0}{T} \times 100$

iv. Feed Conversion Ratio (FCR) = $\frac{\text{Feed intake (g)}}{\text{Weight gain (g)}}$

v. Protein Efficiency Ratio (PER) = $\frac{\text{Weight gain (g)}}{\text{Protein intake}}$

vi. Protein intake (PI) = Total feed intake (g) × Crude protein in diet, where, FI = 5% body weight of fish per day

vii. Condition factor (K) = $\frac{K}{L3} \times 100$ Where: W = Final weight of fish (g), L = Final total length of fish (cm)

viii. Survival rate (%) = $\frac{S1}{S2} \times 100$

Where: $S_1$ = Number of fish at the end of experiment, $S_2$ = Number of fish at the beginning of experiment

**Statistical analysis**

The data obtained from the study was subjected to One-way analysis of variance (ANOVA). The difference between the means was determined using LSD at 5% confidence level with aid of Statistix 8.0 for window.

## RESULTS

**Growth performance of *Clarias gariepinus* fingerlings fed Diets with MSM Replacing SBM**

The mean growth performance of *Clarias gariepinus* fed with Mucuna seed meal (MSM) as replacement of soya bean meal (SBM) is presented in Table 2. There was no significant difference (P≤0.05) in the mean initial length, final length and initial weight across the groups fed diets with 0, 10, 20, 30 and 40% replacement level of MSM with SBM.

**Table 2**: Mean growth performance of *Clarias gariepinus* fingerlings fed diets containing Mucuna seed meal

| Parameters | Levels (%) of SBM replaced with MSM | | | | |
|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | 40 |
| MIL (cm) | 8.31±1.10$^{a}$ | 7.59±0.46$^{a}$ | 7.55±0.50$^{a}$ | 7.83±0.50$^{a}$ | 7.30±0.21$^{a}$ |
| MFL (cm) | 8.79±0.20$^{a}$ | 8.55±0.34$^{a}$ | 8.87±0.35$^{a}$ | 9.01±0.70$^{a}$ | 9.01±0.34$^{a}$ |
| MIW (g) | 3.50±0.46$^{a}$ | 3.64±0.66$^{a}$ | 3.70±0.57$^{a}$ | 3.65±0.62$^{a}$ | 3.62±0.34$^{a}$ |
| MFW (g) | 4.91±0.81$^{b}$ | 5.07±0.75$^{ab}$ | 5.52±0.43$^{a}$ | 5.80±1.69$^{a}$ | 5.78±0.82$^{a}$ |
| MWG (g) | 1.41±0.39$^{b}$ | 1.43±0.12$^{b}$ | 1.82±0.16$^{a}$ | 2.15±1.09$^{a}$ | 2.16±0.87$^{a}$ |
| SGR (%/day) | 0.25±0.15$^{b}$ | 0.27±0.06$^{b}$ | 0.67±0.10$^{a}$ | 0.71±0.46$^{a}$ | 0.72±0.26$^{a}$ |
| ADWG (g) | 0.03±0.01$^{b}$ | 0.03±0.01$^{b}$ | 0.04±0.00$^{ab}$ | 0.05±0.02$^{a}$ | 0.05±0.02$^{a}$ |
| FCR | 1.09±0.36$^{a}$ | 1.11±0.08$^{a}$ | 1.11±0.14$^{a}$ | 1.07±0.53$^{a}$ | 1.05±0.19$^{a}$ |
| FCE (%) | 91.74±29$^{a}$ | 90.09±90$^{a}$ | 90.09±90$^{a}$ | 93.46±82$^{a}$ | 95.24±65$^{a}$ |
| K | 0.72±0.09$^{a}$ | 0.81±0.03$^{a}$ | 0.81±0.03$^{a}$ | 0.78±0.04$^{a}$ | 0.79±0.06$^{a}$ |
| SR (%) | 63.33±20$^{b}$ | 63.33±11$^{b}$ | 90.00±10$^{a}$ | 79.67±50$^{ab}$ | 86.67±11$^{ab}$ |

a, b, c, d = Means values in the same row with different superscript are significantly different (P≤0.05).

**Keys:** MIW = Mean Initial weight, MFW = Mean Final weight, MWG = Mean Weight gain, SGR = Specific growth rate, ADWG = Average daily growth rate, FCR = Feed conversation ratio, K = Condition factor, SR = Survival rate, MFL = Mean Final length, MIL = Mean Initial Length.

The mean final weight, weight gain, specific growth rate and daily weight gain follow similar pattern with increase in weight as the level of MSM increases. The group fed diet with 20, 30 and 40% replacement level, respectively had significantly better (P≤0.05) weight gain than the group fed control diet and diet with 10% replacement level. There was no significant difference (P>0.05) in the food conversion ratio (1.05 – 1.11), feed conversion efficiency (90.09 – 95.24%) and condition factor (0.72 – 0.81). The survival rate however, was significantly (P≤0.05) higher in the treatment group fed diet with 20, 30 and

40% replacement level, while the least survival rate was recorded in the treatment group fed control diet (63.33%) and 10% (63.33%) of MSM.

## DISCUSSION

### Growth performance of *Clarias gariepinus* fed diet with MPSM

The weight gain recorded in this study increases as the level of *Mucuna pruriens* seed meal increases, and ranges between 1.41 – 2.16, which corroborates the findings by Nwanna (2003) who also recorded progressive increase in weight gain in the experimental fish as the inclusion of fermented shrimp head waste increased in the diet of *Clarias gariepinus*. Fagbenro (1996) however opined that other than looking at growth responses, the digestibility of nutrients in feedstuffs could be used to assess the suitability and nutritive value of feedstuffs or diets in fishes. This is because the digestibility of individual ingredient is the diet is considered as one of the important factors affecting the growth of fish (Cho *et al.*, 1985; De Silva *et al.*, 1996). The FCR value in diet containing 10% MCM was better but not significantly different ($P>0.05$) from those fed control diet. This suggests that the fish were able to utilize the nutrients furnished by the diets even better than in the control diet. Faturoti and Lawal (1986) recorded similar results in *Oreochromis niloticus* fed a combination of supplementary feed and organic manure. Specific growth rate (SGR) was highest (0.72%/day) in 40% MSM and least (0.15%/day) in fingerling fed with 20% MSM replacement. This result corroborates the report of Amisah *et al.*, (2009) whose values of SGR were like those obtained in this study, and that of Ochume (2013) and Hassan *et al*. (2015). The condition factor ranged between 0.81 and 0.79. This indicates the robustness and general well-being of the fish fed graded levels of toasted *Mucuna pruriens* seed meal. This aligns with the findings of Odo *et al*., (2016) who documented a similar value for condition factor. Similarly, the values recorded in this study are within the range (0.6 to 1.0) reported by Amisah *et al.*, (2009). The least survival rate was 63.33% while the highest was 90%. Fish mortality recorded in some treatments might be attributed to the effect of some extraneous factors. In related experiments, Alegbeleye (2005) reported that mortality might not be attributed to the presence of anti-nutrients in the diets alone but also to any other extraneous factors such as stress resulting from handling and the season.

## CONCLUSION

This study has demonstrated that the seed of *Mucuna pruriens* have the potential to partly replace soya beans at not more than 40%. This would considerably reduce expenditure on soya beans without compromising growth performance and feed utilization of the African catfish (*Clarias gariepinus*).

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# PROXIMATE COMPOSITION OF FISH FEED FORMULATEDWITH UNFERMENTED WASTES FROM DIFFERENT PLANT SOURCES

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**ABSTRACT**

*This study examines the proximate composition of fish fed with formulated feed of agricultural wastes from Soybean and Bambara nut. Proximate analysis was conducted to determine crude protein, crude fat, ash content, crude fiber, moisture, and carbohydrate levels in the formulated feed. Results revealed significant differences (P≥0.05) in moisture content, ash, crude protein, and crude fibre Moisture content ranged from 8.47% to 11.74%, ash contents: 9.36% to 9.82%, crude fiber: 9.35% to 11.75%, fats: 11.43% to 14.46%, and carbohydrates: 13.58% to 19.67%. These values demonstrated a balanced nutritional profile with moisture and fiber levels to ensure stability and digestibility, while ash and carbohydrate content provide minerals and energy density, respectively. The study highlights the potential of utilizing unfermented agro-waste and addresses environmental challenges associated with agro-waste disposal.*

**Keywords**: Aquaculture, proximate analysis, Agricultural wastes, Feed stuffs

## INTRODUCTION

Aquaculture is one of the world's fastest-growing food production sectors, accounting for nearly 50% of fisheries products (FAO,2018). In Nigeria, catfish is a key species in aquaculture, valued highly in the market (FAO, 2019). It is known that *Clarias gariepinus* significantly contributes to the overall fish production in Nigeria's culture systems. Feed is essential for providing the nutrients fish needs for growth, and other biological activities. Fish requires a balanced diet containing carbohydrates, fats, proteins, vitamins, and minerals, along with fiber and moisture, for optimal growth and harvest (Aniebo *et al.*, 2009).

Unfermented waste materials from soybeans, maize and bambara nut would provide insight to their potential application in animal feed production, as a source of bioenergy, and other industrial purposes (Oshodi,et al 2016). It is believed that these waste materials will help in evaluating the nutrient content requirement of fish and their suitability for incorporation into various food products. But the unavailability of comprehensive research work has limited the development of sustainable waste management strategies and the utilization of these by-products (Goyal *et al*, 2019). Existing research work often focuses on the proximate composition of whole crops or processed products rather than the waste materials derived from them, thereby limiting people from getting all the nutritional content available in some of these wastes.

This study focuses on unfermented waste from soybean, maize, and bambara nut, which are significant crops in many regions of Anambra State. Soybean waste, for instance, is known for its high protein content, while maize is substantially carbohydrates (Akinfemi *et al.*, 2017). Efficient management of agricultural wastes from soybean, maize, and bambara nut will lead to circular agricultural systems whereby waste is transformed into valuable resources (Chivenge *et al.*, 2017). Studies shows that the unfermented wastes could serve as organic fertilizers to improving soil health and crop yield (Ogundipe *et al.*, 2018). And most importantly, animal feed formulation that incorporates by-products from these

crops can help mitigate feed shortages and reduce feed costs in livestock production (Nzayisenga *et al.*, 2020). By establishing good proximate composition, farmers and feed manufacturers can formulate balanced rations that optimize animal growth and productivity. Thus, utilizing agricultural waste will align with economic goals to support small holder farmers to maximize their crop outputs while minimizing wastes (Kumar *et al.*, 2016). Enhanced knowledge of the feed composition will result in better products and value addition of agricultural products. There has been some research into the composition of fermented by-products, unfermented waste has received limited attention. This study aims to fill this gap and provide a comprehensive analysis of the proximate composition of these unfermented wastes.

## MATERIALS AND METHODS

### Collection of samples

The materials for the study were collected from two (2) markets (Eke-Awka in Awka, Osi market in onitsha) both in Anambra State.

Fish feed formulation

Feed formulation took place at Fidelity feed mill in Imo State. An experimental diet that contains 40% crude protein was formulated using Pearson square method. The feed stuff includes the following; Yellow maize, Fish meal, Soyabean meal, Bambaranut, Vitamin premix, Bone meal, Methionine, Lysine, Vitamin C, Vegetable oil, Starch (Groundnut cake), Salt. Five different rations were formulated form the experimental diet where 0%, 25%, 50%, 75% and 100% inclusions of the unfermented feed stuffs were incorporated (Table 1), while taking them to the feed mill where they were properly grinded, mixed, pelleted and ovendried

**Table 1:** Percentage Composition of experimental diet

| Ingredients | 0%(Control) | 25% | 50% | 75% | 100% |
|---|---|---|---|---|---|
| Yellow maize wastes | - | 6.25 | 12.5 | 18.75 | 25.0 |
| Soyabean wastes | - | 9.5 | 19.0 | 28.5 | 38.0 |
| Bambara nut wastes | - | 6.25 | 12.5 | 18.75 | 25.0 |
| Fish meal | 38.0 | 28.5 | 19.0 | 9.5 | - |
| Groundnut Cake | 50.0 | 37.5 | 25.0 | 12.5 | - |
| Vitamin premix | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Bone meal | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| Methionine | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Lysine | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Vitamin C | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Vegetable oil | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Starch | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Salt | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Total | 100. 00 | 100.00 | 100.00 | 100.00 | 100.00 |

### Proximate Analysis Procedures

The proximate composition analysis was conducted at Alpha Boss Laboratory, located in Ichida, Awka, Anambra State

### Moisture content determination

Moisture content was determined according to the standard method of AOAC (2010). A petri-dish was washed and dried in the oven. Exactly 2 g of the sample was weighed in a petri dish. The weight of the petri dish and sample were noted before drying. The petri-dish and sample were put in the oven and heated at 100 $^{0}$C for 1 hour, the result was noted, and heated for another 1 hour until a steady result was obtained and the weight was noted. The drying procedure is continued until a constant weight is obtained.

**Calculation**

$$\% \text{ moisture content} = \frac{W1 - W2\ X\ 100}{weight\ of\ samle}$$

Where: W1 = weight of petri dish and sample before drying
W2 = weight of petri dish

**Ash content determination**

Ash content was determined according to the standard method of AOAC (2010). Empty platinum crucible was washed, dried and the weight was noted, exactly 2 g of wet sample was weighed into the platinum crucible and placed in a muffle furnace at 500 $^{o}$c for 3 hours. The sample was cooled in desiccators after burning and weighed.

**Calculation**

$$\% \text{ Ash content} = \frac{W3 - W1\ X\ \frac{100}{1}}{W2 - W1}$$

Where; W1 = weight of empty platinum crucible
W2 = weight of platinum crucible and sample before burning
W3 = weight of platinum and ash

**Fiber content determination**

Fiber content was determined according to the standard method of AOAC (2010). Defat about 2 g of material with petroleum ether (if the fat content is more than 10%). Boil under reflux for 30 minutes with 100 ml of a solution containing 1.25% of $H_2SO_4$ per 100 ml of solution. Filter the solution through linen or several layers of cheese cloth on a fluted funnel, wash with boiling water until the washings are no longer acid. Transfer the residue to a beaker and boil for 30 minutes with 100 ml of a solution containing 1.25 NaOH per 100 ml. Filter the final residue through a thin but close pad of washed and ignited asbestos in a Gooch crucible, dry in an electric oven and weigh. Incinerate, cool and weigh..

**Calculation**

The loss in weight after incineration x 100 is the percentage of crude fiber

$$\% \text{ crude fiber} = \frac{\text{weight of fiber x 100}}{\text{Weight of sample}}$$

**Protein content determination**

Protein content was determined according to the standard method of AOAC (2010). Exactly 0.5 g of sample was weighed into a 30 ml kjehdal flask (gently to prevent the sample from touching the walls of the side of each and then the flasks was stoppered and shaken). Then 0.5 g of the kjedahl catalyst mixture was added. The mixture was heated cautiously in a digestion rack under fire until a clear solution appeared. The clear solution was then allowed to stand for 30 minutes and allowed to cool. After cooling about 100 ml of distilled water is added to avoid caking and then 50 ml was transferred to the kjedahl distillation apparatus. A 100 ml receiver flask containing 5 ml of 2 % boric acid and indicator mixture containing 5 drops of Bromocresol blue and 1 drop of methylene blue is placed under a condenser of the distillation apparatus so that the tap was about 2o cm inside the solution. The 5 ml of 40 % sodium hydroxide was added to the digested sample in the apparatus and distillation commenced immediately until 50 drops gets into the receiver flask, after which it was titrated to pink colour using 0.01 N Hydrochloric acid.

**Calculations:**

$$\% \text{ Nitrogen} = \frac{\text{Titre value} \times 0.01 \times 14 \times 100}{\text{Wight of sample}}$$

$$\% \text{ Protein} = \% \text{ Nitrogen} \times 6.25$$

**Fat content determination**

Fat content determination was determined according to the standard method of AOAC (2010). Dry 250 ml clean flasks in oven at 105 to 110 $^0$C for about 30 minutes. Transfer into a desiccator and allowed to cool. Weigh correspondingly labeled, cooled flasks. Fill the flasks with about 300 ml of petroleum ether (boiling point 60 $^0$C), plug the extraction thimble lightly with cotton wool and assemble the soxhlet apparatus and allow to reflux for about 6 hours. Remove thimble with care and collect petroleum ether in the top container of the set – up and drain into a container for re-use. When flask was almost free of petroleum ether, remove and dry at 105 to 110 $^0$C for 1 hour. Transfer from the oven into a desiccator and allow cooling and weighing.

$$\% \text{ fat} = \frac{\text{weight of fat} \times 100}{\text{Weight of sample}}$$

**Carbohydrate content determination**

Carbohydrate content was determined according to the standard method of AOAC (2010).

% Carbohydrate = 100 – (% Protein + % Moisture + % Ash + % Fat + % Fibre)

**Data analysis**

The one way analysis of variance (ANOVA) was used to compare the mean of the variables. The difference between the mean was separated using Turkey HSD at a significant level of 5% and the statistical analysis done using R-Statistical software (R-Program, 2023).

**RESULTS**

Table 2: Shows the proximate composition of formulated feeds in the study The results show a significant difference in moisture content. The highest value was recorded in 100% (11.47), followed by 75% (10.85), 50% (10.83), 25% (10.77), and the control (8.47). For ash content, there was a significant difference (P>0.05) among 25%, 50%, and 100%, but no significant difference between the control and 75%. In crude protein, there was no significant difference between 25% and 50%, but there was a significant difference between the control, 75%, and 100%. For crude fiber, no significant difference was observed among 50%, 75%, and 100%, but a significant difference was noted between the control and 25%.Regarding fat content, a significant difference was observed among the control, 25%, and 50%, while no significant difference was found between 7%5 and 100%. Lastly, for carbohydrates, there was no significant difference between the control and 75%, but a significant difference was observed among 25%, 50%, and 10%0.

**Table 2:** Proximate Composition of Formulated Feeds

| Parameters | Control | 25%(UF) | 50%(UF) | 75%(UF) | 100%(UF) |
|---|---|---|---|---|---|
| Moisture | $8.47 \pm 0.31^{a}$ | $10.77 \pm 0.28^{b}$ | $10.83 \pm 0.04^{b}$ | $10.85 \pm 0.03^{b}$ | $11.74 \pm 0.03^{c}$ |
| Ash | $9.36 \pm 0.06^{c}$ | $8.81 \pm 0.03^{a}$ | $9.04 \pm 0.04^{ab}$ | $9.41 \pm 0.11^{c}$ | $9.82 \pm 0.05^{d}$ |
| Crude Protein | $42.11 \pm 0.15^{d}$ | $33.49 \pm 0.04^{a}$ | $34.59 \pm 0.02^{a}$ | $35.41 \pm 0.12^{b}$ | $38.71 \pm 0.07^{c}$ |
| Crude Fibre | $9.35 \pm 0.12^{b}$ | $7.26 \pm 0.22^{a}$ | $11.67 \pm 0.17^{c}$ | $11.83 \pm 0.05^{c}$ | $11.75 \pm 0.06^{c}$ |
| Fat | $11.43 \pm 0.36^{b}$ | $9.39 \pm 0.08^{a}$ | $13.74 \pm 0.21^{c}$ | $14.45 \pm 0.07^{d}$ | $14.46 \pm 0.02^{d}$ |
| Carbohydrate | $19.67 \pm 0.13^{b}$ | $30.25 \pm 0.39^{d}$ | $20.21 \pm 0.16^{bc}$ | $18.15 \pm 0.15^{b}$ | $13.58 \pm 0.06^{a}$ |

Means with the same superscript within rows are not significantly different at P > 0.05/

## DISCUSSION

### Proximate composition

The results in Table 1 show that the proximate composition of fish fed with formulated unfermented soybean, maize, and Bambara nut waste changes as the level of unfermented waste increases. The moisture content progressively rises from 8.47% in the control to 11.74% in the 100UF(unfermented) treatment. Also, ash content increases slightly, indicating a rise in mineral composition as more unfermented waste is added, with values higher than those reported by Olanipekan *et al*. (2012) for Bambara nut. However, the crude protein content decreases significantly, with the control group having the highest protein level. This contradicts Anhwange and Adoo (2016), who stated that legumes typically have protein contents between 17% and 30%.There is also a noticeable increase in crude fiber content as the unfermented waste levels rise, with the 100UF (unfermented)treatment having the highest fiber content. Fat content follows a similar trend, showing a significant rise with the highest value in the 100UF (unfermented) treatment. On the other hand, carbohydrate content declines with increasing levels of unfermented waste. The control group has the highest carbohydrate content, while the 100UF ( unfermented )treatment shows a marked reduction.

### Moisture content

The results presented in Table 1 show that the moisture content of the samples ranges from 8.47% to 11.74%. This contradicts the findings of Jipara *et al.* 2021, who reported moisture content in feed ranging between 8.20% and 10.00%. The moisture content observed in this study falls within the desirable range, as Joshi *et al.* (2021) reported that higher moisture levels promote mold growth and feed decomposition, while lower moisture levels enhance the shelf life of fish feed.Among the samples, the 100UF (unfermented) treatment had the highest at 11.74% whereasthe control group exhibited the lowest moisture content at 8.47%. The 25UF (unfermented) treatment saw a significant increase in moisture (10.77%) compared to the control, while 50UF and 75UF showed minimal differences (around 10.83% and 10.85%).A significant difference was observed between the control and 100UF treatments, while no significant differences were found between the 25UF, 50UF, and 75UF treatments.

### Ash Content

The ash content presented in Table 1ranges from 9.36% to 9.82%, indicating the mineral composition in the fish feed, was slightly similar to the report of Solomon andOyategbe, (2016)which had its ash content to falls between 6% and 9%. The ash content observed in this study is relatively high, which, as reported by several researchers, suggests a higher concentration of minerals in the feed. These minerals contribute essential nutrients and assist in the breakdown of fats, proteins, and carbohydrates.

In this study, there was a significant difference in ash content between the 25UF, 50UF, and 100UF treatments, indicating substantial ash contributions in these groups. However, no significant difference was found between the control and 75UF treatments.

### Crude Protein

Protein is the primary growth-promoting factor in fish feed. The protein requirement of fish is influenced by various factors, including fish size, water temperature, feeding rate, the availability and quality of natural foods, and the overall digestible energy in the diet. As shown in Table 2, the crude protein content in the feed ranges from 42.11% to 33.49%. The control treatment exhibits the highest crude protein content at 42.11%, while the 25UF ( unfermented)treatment has the lowest at 33.49%, primarily due to the use of lower-quality inputs as protein sources.Bambara nut and soybean are legumes, whereas maize is a cereal. According to Anhwange and Atoo (2016), bambara nut has a protein content of 18%, while soybean contains 40%. When combined with maize, which has a crude protein content of 8-11%, the overall protein content of the formulated feed can range from 30% to 48%. The results from this study indicate that the formulated feed using unfermented agricultural waste has a relatively low protein

content when included in fish meal. This is consistent with the findings of Fasakin *et al.* (2015), who reported that C*laria sgariepinus* requires 40-45% crude protein in its diet for optimal growth. There was a significant difference in crude protein levels between the control, 75UF, and 100UF treatments, while no significant difference was observed between the 25UF and 50UF treatments.

**Crude fibre**

The crude fiber content, as shown in Table 2 ranged from 9.35% to 11.75%. The treatment with the highest crude fiber is 75UF (unfermented) at 11.83%, while the lowest crude protein content was recorded in 25UF( unfermented (at 7.26%. The results indicate a significant difference between the control and 25UF. However, no significant difference was observed between the50UF, 75UF, and 100UF.In fish feed, the recommended crude fiber content is between 3-6%. Therefore, the values obtained in this study are relatively high. This increased fiber content could aid digestion, but it should be moderated, as fish have a limited capacity to digest fibrous material (Olaniyi and Onyenuga, 2013; Oyekale et al, 2012).

**Fats**

The results presented in the table 2 shows that the fat content ranges from 11.43% to 14.46%, with the highest at 100 UF (unfermented) at 14.46%and the lowest value observed at 25UF (unfermented) at 9.36%. Joshi *et al.* (2021) reported that lipids/fats generally make up 10-15% of the feed, which aligns with the findings from Table 2. The study also reveals a significant difference between the control, 25UF, and50UF, groups, although no significant difference was observed in other comparisons.

**Carbohydrates**

The carbohydrate content in the table 2 above ranges from 13.58% to 30.25%, with the highest level observed in the 25UF (unfermented) treatment (30.25%) and the lowest in the 75UF (unfermented) treatment (18.15%). These results indicate that the carbohydrate levels in the feed are within the desirable range, consistent with the findings of Joshi *et al.* (2021), who reported that carbohydrates typically make up 20-30% of commercial fish feed. In this study, there was a significant difference in carbohydrate content between the control and 75UF treatments, while the 25UF, 50UF, and 100UF treatments did not show significant differences.

## CONCLUSION

The proximate composition analysis of fish feed formulated using unfermented waste from soybean, maize, and Bambara nut in parts of Anambra State, Nigeria showed that agricultural by-products can be effectively utilized as a sustainable and cost-efficient feed sources for aquaculture thereby reducing feed cost. The waste materials provided a considerable amount of crude protein, fats and carbohydrates, minerals, which are essential for the growth and health of fish. The feed also showed a low moisture content, enhancing its shelf stability and reducing the risk of spoilage.

**Recommendations**

Based on the findings of this study, the following recommendations are proposed:

i. Local fish farmers in Anambra State and other parts of Nigeria should be encouraged to adopt this feed formulation, given its cost-effectiveness, accessibility, and nutritional balance. This will contribute to enhanced fish growth and production while reducing feed costs.
ii. Farmers should be provided with practical training on how to effectively formulate and store the feed. Proper storage practices will help maintain the nutritional value of the feed and minimize spoilage, ensuring that the feed remains effective over time.
iii. Further studies are recommended to optimize the nutritional profile of the feed by adjusting the proportions of the waste materials or incorporating other locally available ingredients. This will help

ensure a balanced diet for different fish species and improve overall fish health and performance.

iv. Government agencies, agricultural organizations and aquaculture stakeholders should offer support through promoting the adoption of this waste-based feed to contribute to sustainable aquaculture practices and effective waste management in the region.

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# EFFECTS OF BOILING TIME AND FERMENTATION ON PROXIMATE COMPOSITION OF JUJUBE (*Ziziphus mauritiana*) SEED MEAL

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**ABSTRACT**
*This study examined the effects of different boiling and fermentation time periods on the proximate composition of Ziziphus mauritiana (jujube) seed meal. Seeds were boiled for 20, 30, and 40 minutes while fermentation was done for 24, 48, and 72 hours. The results showed that fermentation significantly affected moisture and ash contents, with moderate changes observed in crude fat and protein levels. Boiling improved both protein and fibre contents while reducing fat. The highest protein content (14.10 ± 1.82%) was recorded in seeds boiled for 30 minutes, while highest fibre content (5.55±1.04%) was recorded in seeds boiled for 40 min whereas the greatest ash content (12.30 ± 0.12%) was observed after 72 hours of fermentation. Seeds fermented for 48 hours had the highest moisture content of (11.82±1.19), while fat increased (6.39±0.29) in seed fermented for 24hours.These findings indicate that both processing methods can be optimized to enhance specific nutritional components of jujube seed meal. Boiling is more effective for increasing protein and fibre, while fermentation helps retain fat and enrich mineral content, highlighting the seed meal's potential as a valuable feed ingredient.*

**Key words:** *Ziziphus Mauritania*, fermentation, boiling, proximate composition

## INTRODUCTION

Conventional livestock feed ingredients in Nigeria are becoming increasingly scarce and expensive, largely due to growing competition between human and animal dietary needs (Durunma *et al.*,1999). In response, animal nutritionists are exploring alternative feed resources that are readily available, cost-effective, and easy to process, and not staple foods for humans (Mayes, *et al.*, 2012) One such potential alternative is the jujube seed, derived from the fruit of the *Ziziphus mauritiana* tree. Traditionally used in herbal medicine, jujube seeds are known to be rich in nutrients such as protein, fiber, and essential minerals. However, they require proper processing to improve their nutritional quality and bioavailability. The *Ziziphus mauritiana* tree, a member of the Rhamnaceae family, is considered one of the oldest known medicinal plants. It thrives in a variety of climatic conditions, especially in subtropical and tropical regions (Liu *et al.*,2020) China, with more than 700 jujube varieties, is the world's largest producer, contributing nearly 90% of the global supply with an annual output of approximately 4.5 million tons. The leaves are rich in bioactive compounds like saponins, flavonoids, and triterpene acids, known for their antioxidant and anti-inflammatory properties. Furthermore, ethanolic aqueous extracts of wild jujube leaves have shown notable effects on the central nervous system (Liu et al., 2020) . Several researches have been done on processing methods of seeds such as (Onegbu *et al* 2013) worked on boiled ukpo seed. Nsa E.E *et a*l (2011) worked on castor oil seeds, and (A haji *et al* 2024) researched on C*ajanus cajan*. The objectives of this study are to evaluate the effects of varying boiling durations and fermentation periods on the proximate composition of *Ziziphus mauritiana* seed meal, and to compare the nutritional profiles resulting from these two processing methods.

## MATERIALS AND METHODS

### Experimental Study Area

The experiment was carried out at the Laboratory, Department of Fisheries and Aquaculture, Faculty of

Renewable Natural Resources, Federal University Dutsin-ma, Dutsin-ma local Government area of Katsina State.

**Experimental Seed and Sampling**

Seed collection: Jujube fruit (*Ziziphus mauritiana*) were bought from the Dutsin-Ma new market in Dutsin-Ma metropolis, Katsina state. The pulp was separated from the seed by soaking in water then dried for 3 days (72 hours).

**Treatment Application**

Boiling method: The jujube seed (3kg) was boiled for 20, 30 and 40 minutes, allowed to cool and dried. The boiling process was carried out following the method of Onuegbu *et al*. (2013) with slight modification in the boiling durations. The seeds were then ground into powder and stored for further analysis.

Fermentation method: The fermentation was carried out following the method of Dauda *et al*., (2023) with little modifications. 3kg of Jujube seed powder was inoculated with 30g of commercial dry yeast, *Saccharomyces cerevisiae* cell density of 3 x 106 cell g-1, and mixed with distilled water until it homogenized, then it was left to ferment for 24, 48 and 72 hours in an airtight container at 30 to 37°c which is the optimal growth temperature for *S. cerevisiae*. The fermented sample was dried and stored before further analysis.

**Proximate analysis**

The fermented and boiled Jujube seed powder (*Z. mauritiana)* were taken to the Central laboratory at Umaru Musa Yar'adua University Katsina and was subjected to proximate analysis following the standard methods of AOAC (2016).

**Data Analysis**

Data were presented using mean±standard deviation, after testing for normality and homogeneity of variance, they were subjected to one-way analysis of variance (ANOVA) at 5% level of probability. Tukey's test was used to separate the different means.

## RESULT AND DISCUSSION

Table 1 shows that moisture content varied across the different boiling times. Jujube seeds boiled for 20 minutes had a moisture content of 9.00%, while those boiled for 30 minutes had a slightly higher content of 10.06%. Seeds boiled for 40 minutes exhibited the highest moisture content at 10.31%. The control group had a moisture content of 9.43%. Despite these differences, there was no significant difference ($p \geq 0.05$), indicating that the boiling time does not significantly impact moisture content. This result is consistent with findings on chickpeas and lentils having moisture contents ranging from 8% to 11%, with minimal impact from short-term boiling (Stone *et al*., 2021. This suggests that jujube seeds maintain a stable moisture range that does not fluctuate significantly with the duration of boiling. The ash content increased with boiling time, with seeds boiled for 20 minutes having 6.46%, while those boiled for 30 and 40 minutes showing 7.81 and 6.95% respectively. The control had a lower ash content of 2.85%. The result showed significant difference ($p \leq 0.05$) among the treatments, particularly with the control differing significantly from the 30-minute boiling time ($p = 0.022$). Increases in ash content with boiling are indicative of greater mineral leaching. This trend aligns with the results on other seeds where longer boiling times enhance mineral extraction (Suleiman *et al.*, 2022).

The increase in ash content suggests that boiling might improve the availability of essential minerals in jujube seeds. Crude fibre content was highest in seeds boiled for 40 minutes 5.55%, followed by those boiled for 30 minutes (4.02%) and 20 minutes (3.35%). The control exhibited the lowest fibre content

2.87%. The result showed significant differences ($p \geq 0.05$) among treatments, indicating that boiling time might not have a substantial effect on fibre content across different conditions. Similar findings are reported in flax and chia, where boiling tends to increase fibre content due to the expansion and hydration of seeds (Gibreemeskal *et al.*, 2024). Thus, the observed increased fibre content in boiled jujube seeds is consistent with these reports. Crude protein content was notably higher (14.10%) in seeds boiled for 30 minutes, compared to those boiled for 40 minutes (13.41%) and 20 minutes (11.31%). The control had the lowest protein content with 4.05%. The results showed significant differences ($p \leq 0.05$) between the control and the boiled treatment groups. This observation correlates with research showing that heat treatment can affect protein content and digestibility (Rivera del rio *et al.*, 2022).

Boiling often denatures proteins, which can impact their availability and concentration (Nguyen *et al.*, 2020). The higher protein content in boiled jujube seeds suggests enhanced protein availability or concentration due to the boiling process. Crude fat content was highest in seeds boiled for 20 minutes (3.95%), followed by 40 minutes (3.66%) and 30 minutes (3.29%). The control had the highest fat content of 6.15%. The control was significantly different ($P \leq 0.05$) from the boiled samples. This reduction in fat content with boiling aligns with other studies where boiling leads to fat loss due to leaching (Lee and Kim 2018). The findings suggest that boiling reduces the fat content in jujube seeds, which could influence their overall caloric and nutritional profile. Boiling jujube seeds significantly improves the protein, fibre, and mineral content, while reducing fat content. However, boiling for 30–40 minutes appears optimal for enhancing the nutritional value of jujube seeds. These findings support the use of thermal processing as an effective method for improving the dietary quality of underutilized plant seeds.

Table 1. Proximate Composition (%) of Boiled Jujube Seed Meal

| Sample | Moisture Content | Ash Content | Crude Fibre | Crude Protein | Crude Fat |
|---|---|---|---|---|---|
| Control | 9.43 ± 0.01$^{a}$ | 2.85 ± 0.05$^{c}$ | 2.87 ± 0.02$^{c}$ | 4.05 ± 0.04$^{c}$ | 6.15 ± 0.04$^{a}$ |
| B 20 | 9.00 ± 3.41$^{a}$ | 6.46 ± 0.52$^{b}$ | 3.35 ± 0.30$^{b}$ | 11.31 ± 1.16$^{b}$ | 3.95 ± 0.16$^{b}$ |
| B 30 | 10.06 ± 0.81$^{a}$ | 7.81 ± 0.62$^{b}$ | 4.02 ± 1.32$^{b}$ | 14.10 ± 1.82$^{a}$ | 3.29 ± 0.25$^{b}$ |
| B 40 | 10.31 ± 3.20$^{a}$ | 6.95 ± 1.82$^{a}$ | 5.55 ± 1.04$^{a}$ | 13.41 ± 1.20$^{a}$ | 3.66 ± 0.95$^{b}$ |

Different letters as superscript in each row indicate significant differences ($p \leq 0.05$)

Key: B20 (Boiled for 20 mins), B30 (Boiled for 30 mins), B40 (Boiled for 40mins)

Table 2 shows results for fermented jujube seeds. Ash content varied significantly ($p \leq 0.05$) across treatments, ranging from 7.33% in F48 to 12.30% in F72. Treatment F72 had the highest ash content, which significantly higher than all other treatments, indicating that the longer fermentation times (72 hours) may enhance the mineral concentration in the sample. This could be attributed to the breakdown of organic matter, resulting in a more concentrated mineral content (Nanditha *et al.*, 2021). Treatments F48 and control showed significantly lower ash values, with F48 having the lowest among the treatments. Such variations in ash content reflect the mineral release dynamics during the fermentation process. Moisture content varied from 4.73% in F72 to 11.82% in F48, with F72 showing the lowest moisture content. Treatment F48 exhibited the highest moisture content, significantly different from other treatments ($p \leq 0.05$). This increase in moisture content could be due to the hydration of organic materials during fermentation or the increased metabolic activity of microorganisms, which might result

in higher water retention (Bai *et al.*, 2020). Longer fermentation times, such as F72, likely led to water loss due to microbial consumption of substrates or evaporation. Crude fibre content decreased progressively from 3.44% in F24 to 2.88% in F72, with F24 having the highest fibre content ($p \leq 0.05$). This suggests that shorter fermentation durations (24 hours) lead to a greater release of fibre from the seed matrix. Treatment F72 on the other hand, exhibited the lowest fibre content, which may be due to the degradation of fibre into simpler carbohydrates or other compounds over a prolonged fermentation period (Olaitan *et al.*, 2022).

This trend aligns with previous studies of Liao *et al* (2020) which shows that fermentation can cause cell wall breakdown, leading to changes in dietary fibre composition. Crude fat content was significantly lower in the longer-fermented samples. The F72 sample had the lowest fat content (3.65%), which was significantly different from the other treatments ($p \leq 0.05$). Treatment F48 (5.53%) and F24 (6.39%) showed higher fat contents, with F24 having the highest (6.39%). The reduction in fat content in the longer-fermented samples might be due to the metabolic activity of microorganisms, which could consume fat or convert it into other metabolic products (Rodrigues *et al.*, 2020). These results are consistent with findings that fermentation processes often reduce fat content by breaking down lipids into simpler compounds (Melini *et al.*, 2019). Crude protein content ranged from 11.57% in F72 to 12.73% in F24, with F24 treatment showing the highest protein content ($p \leq 0.05$). The F72 sample, though showed a high protein level, was the lowest among the fermented treatments. These results suggest that shorter fermentation times (24 hours) lead to higher protein retention, possibly due to the fermentation process promoting protein synthesis by microorganisms (Zhang *et al.*, 2019). The F48 sample exhibited a moderate protein content, significantly lower than F24, but still higher than the control. This indicates that fermentation enhances protein bioavailability, although extended fermentation times may not always lead to the highest protein levels. Fermentation is an effective method for enhancing the nutritional profile of the samples, with the most beneficial outcomes observed after 24 hours of fermentation, especially in terms of protein content and fat retention. The mineral concentration appears to increase with longer fermentation periods, while moisture content decreases. These findings have important implications for improving the functional properties of fermented products in the food and feed industry.

**Table 2:** Proximate Composition (%) of Fermented Jujube seed

| SAMPLE | Ash | Moisture | Crude Fibre | Crude Fat | Crude Protein |
|---|---|---|---|---|---|
| Control | $10.24 \pm 0.55^{a}$ | $6.19 \pm 0.36^{a}$ | $3.22 \pm 0.37^{a}$ | $5.10 \pm 0.69^{a}$ | $12.64 \pm 0.64^{a}$ |
| F24 | $8.48 \pm 0.66^{b}$ | $9.10 \pm 1.82^{b}$ | $3.44 \pm 0.36^{b}$ | $6.39 \pm 0.29^{b}$ | $12.73 \pm 1.56^{a}$ |
| F48 | $7.33 \pm 0.13^{c}$ | $11.82 \pm 1.19^{c}$ | $3.10 \pm 1.29^{c}$ | $5.53 \pm 2.24^{c}$ | $12.44 \pm 2.46^{a}$ |
| F72 | $12.30 \pm 0.12^{d}$ | $4.73 \pm 0.20^{d}$ | $2.88 \pm 0.24^{c}$ | $3.65 \pm 0.31^{d}$ | $11.57 \pm 1.54^{a}$ |

Different letters as superscript in each row indicate significant differences ($p \leq 0.05$)
**Key:** F24 (Fermented for 24 Hours), F48 (Fermented for 48 Hours) F72 Fermented for 72 Hours)

## CONCLUSION

The nutritional value of jujube seed meal was improved through two processing methods, which are boiling and fermentation with boiling showing the most significant enhancements. Boiling method is therefore recommended for use in processing fish feed ingredient and should be further tested on different seeds to assess their effectiveness as a potential feed ingredient.

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# STUDIES ON THE COMPARATIVE PERFORMANCE OF DIFFERENT STARTER DIETS IN *Clarias gariepinus* (Burchell, 1822) FINGERLINGS

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**ABSTRACT**

*This research was carried out to ascertain the effect of different starter feeds on the growth, performance and survival of Clarias gariepinus (Burchell 1822) fingerlings. A total of 225 Clarias gariepinus (Burchell 1822) fingerlings were randomly selected and reared for six (6) weeks. Three different dietary treatments, which are Control, Treatment A (Commercial feed A), and Treatment B (Commercial feed B) were fed to triplicate groups of fish in a completely randomized design. The parameters monitored included weight gain and length increase, feed conversion ratio (FCR), and percentage (%) survival rate. The data collected was subjected to analysis of variance at 5% significant level. Control (83.3g) recorded the highest weight gain, Commercial feed A (74.0g) was next, then Commercial feed B (23.3g). Length increase has recorded the fish fed with control feed (12.7cm) followed by the one fed with Commercial feed A(10.9cm) then the one with Commercial feed B (8.00cm). Percentage (%) survival rate was recorded highest by the fish fed with Commercial feed B (88.0%) followed by the one fed with Commercial feed A (81.6%) then the control (77.3%). This study also showed that growth and weight gain of Clarias gariepinus fed with Control performed far better than the other treatments.*

**Keywords**: *Clarias gariepinus*, fingerlings, starter diets, fish feed, aquaculture.

## INTRODUCTION

Feed is one of the major inputs in aquaculture production and fish feed technology is one of the least developed sectors of aquaculture particularly in Africa and other developing countries of the world (Boyd *et al.*, 2023)Feed is the largest cost generally in catfish production, accounting for more than 50 percent of total variable costs, so how fish are fed directly affects profitability of catfish farming. High cost of fish feed has been observed as one of the major problems militating against aquaculture development in Nigeria (Ogunji *et al*., 2017). The overall aim of this research project is to evaluate and compare the effectiveness of different starter diets on the growth performance of *Clarias gariepinus* fingerlings.

## MATERIALS AND METHODS

### Procurement and Transportation of experimental fish

Two hundred and twenty-five (225) *Clarias gariepinus* fingerlings commonly called the African catfish were used for this experimental study for 42 days.

### Experimental system and design

The experiment was carried out using a total of nine (9) transparent tanks of 20 litres capacity each. The fish were acclimated for seven (7) days and were fed with Control feed of 0.8mm twice daily at 5% body weight Twenty-five fingerlings of African catfish (*Clarias gariepinus)* were randomly selected and allocated to each tank with each treatment having a total of seventy-five (75) fingerlings. At end of the acclimation the fish specimen was divided into three (3) Treatment groups of Control(C) feed, Treatment A (Commercial Feed A) and Treatment B (Commercial feed B). Other materials

**Feeding of Fish and Sampling for Growth Parameters**

Subsequently measurements were taken every week interval. Fingerlings were fed twice daily (morning and evening) by 5% of their body weight. The Fish tank were covered with a mesh net which served for protection against predators and to prevent escape of fish from the Fish tank. Sampling collection was done weekly. The fish was observed daily to check for mortality. Dead floating fish were removed and the record taken. The fingerlings were scoped out using hand net. A stand-by plastic bowl with a clean water was used to put the fingerlings after each trial measurement to reduce stress. The weight of each fingerling in a bowl for each treatment was taken using a sensitive weighing scale and the length of each fingerling was also measured with a meter rule. These measurements were recorded.

**Statistical Analysis**

Data collected were subject to analysis of variance (ANOVA) as described by Akindele (2004). Significant difference in mean were evaluated at 5% significance level using SPSS.

## RESULTS

**Table 1:** Growth Parameters and Survival of C*larias gariepinus* Fingerlings

| Parameters | Control | Commercial Feed A | Commercial Feed B |
|---|---|---|---|
| Total Initial Weight (g) | 4.3 | 2.6 | 2.3 |
| Total Final Weight | 83.3 | 74.0 | 23.3 |
| Final weight gain g/fish | 1.11 | 0.98 | 0.31 |
| Total weight gain | 79.0 | 71.4 | 21.0 |
| Initial length (cm/fish) | 2.7 | 3.6 | 3.1 |
| Total Final length (cm) | 12.7 | 10.9 | 8.0 |
| Total length gain | 10.0 | 7.3 | 4.9 |
| Feed Intake(g) | 4.2 | 3.7 | 1.2 |
| Initial Stocking Density | 75 | 75 | 75 |
| Final Stocking Density | 58 | 62 | 66 |
| Survival (%) | 77.3 | 81.6 | 88.0 |
| Specific Growth Rate (SGR) | 0.04 | 0.03 | 0.02 |
| Feed Conversion Ratio (FCR) | 1.37 | 1.19 | 0.39 |

## DISCUSSIONS

Growth parameters and survival are great tools for evaluating the effect of feed and its value on fish species (Auta et al., 2013). Growth in fish depends on the food intake and a host of intrinsic factors. Previous studies have shown that feed composition and nutrient quality of fish feed is a major determinant to the performance of the African catfish and many other fish species (Keremah and Esquire, 2014).

Auta *et al*. (2013) previously reported that high growth rate recorded in fingerlings fed may be attributed to the high nutritive value of the feeds given. According to Cornélio *et al.*, (2014), the quality of a feed is a function of how well that feed meets the nutrient requirement of a fish. Findings of this study showed that the three (3) feeds fed had effect on the growth and weight of C*larias gariepinus* fingerlings.The finding shown that weight of C*larias gariepinus* fingerlings given Control feed keep increasing weekly on a very rapid level followed by that of Commercial feed A and least Commercial feed B). It is an evident from the findings of this study that nutrition is an important factor that affect growth of fish.

## CONCLUSION AND RECOMMENDATION

It is recommended that Commercial feed A for use in feeding C*larias gariepinus* from fingerlings stage to

adult stage followed by Commercial feed B on the basis of their high percentage survival without compromising their growth performance. Also, similar feed experiments should be carried out more often to identify better compounded starter feed for a better growth and production of fish fingerlings under different culture conditions and period.

**ACKNOWLEDGEMENT**
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# EFFECT OF TIGERNUT (*Cyperus esulentus L.)* SUPPLEMENTED DIETS ON THE FECUNDITY, FERTILIZATION, HATCHABILITY OF EGGS AND HATCHLINGS SURVIVAL IN C*larias gariepinus*

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**ABSTRACT**

*This study evaluated the effect of tiger nut (Cyperus esulentus) supplemented diet on fecundity, fertilization, and hatchability and survival rate of Clarias gariepinus hatchlings. Twenty female brood stock with weight ranged from 859g to 1000g were sourced. Nine experimental diet of 40% crude protein containing 0%, 5%, 10%, 15% and 20% of wet and dry tiger nut respectively were formulated and fed to the female brood stock at 3% of body weight twice daily for 30 days. Data on fecundity, percentage fertilization, and hatchability and survival rate were collected and analysed using two-way ANOVA. The fecundity of the fish result shows that there is significant difference between the wet and dry tiger nut supplementary diet with TSD 15 showing the highest value for the wet and dry followed by TSD 05 and TSD 10 which were significantly different from other treatments and the control. The result of the fertilization shows no significant difference between wet and dry control, TSD 5, TSD 10 respectively, but is significantly different for TSD 15 and TSD 20. The hatchability result shows the control with no significant difference between the wet and dry treatments of hatchability, TSD 20, TSD 15, TSD 10 also shows no significant difference between the wet and dry treatments except for TSD 5 which shows significant difference. TSD 10 of the dry treatment shows the highest value while TSD 15 has the lowest value. The survival rate result shows that there is a significant difference between wet and dry tiger nut diet in TSD 00, TSD 05, TSD 10 and TSD 15. TSD 15 have the highest significant value in survival rate more than any other treatments in wet experimental diet This study has shown that inclusion of tiger nut in the feed of fish enhance fecundity, fertilization, hatchability and survival of C. gariepinus fry.*

**Keywords:** Tiger nut, Fecundity, Fertilization, Hatchability and C*larias gariepinus*.

## INTRODUCTION

Tiger nut are edible tubers with a sweet nutty flavour Tiger nut has several varieties (black, brown and yellow) and they have been described as an important food of high nutritional and economic values (Oguntona and Akinyele, 1995). It yields more milk upon extraction and contains lower fat and more protein (Okafor and Okolo, 2003). Tiger nut has considerably high levels of fibre, protein, carbohydrates especially natural sugars (Soluble Glucose), potassium and phosphorus. Although, tiger nut is gluten and cholesterol free, it is rich in essential amino acids (lysine, threonine and cysteine), oil, oleic acids, Vitamins C and E and very low in sodium content. Medically, it is regarded as a digestive tonic, having a heating effect on the digestive system and alleviating flatulence. The nut is used in the treatment of boil, cold, polio, and ulcers (Chevalier, 1990).

Among the culturable fish in Nigeria includes C. *gariepinus*, which is a major tropical aquaculture species in Africa (Ayinla and Akande, 1988) and it has a very good commercial value in Nigerian markets (Ayinla *et al.*, 1994). Fish seed production is an important aspect of aquaculture that has witnessed continuous

research and innovation for increased fish production. Artificial propagation methods constitute the major practicable means of providing enough quality seed for rearing in confined fish enclosure waters such a fish ponds, reservoirs and lakes (FAO, 2006).

Common practices in hatcheries such as transportation, handling, cleaning, use of chemicals, overstocking, water quality problems are not the only factors that may negatively influence fish reproduction (Adeparusi *et al.*, 2010) but quality of eggs is also suspected. These common factors affect fertilization success in both artificial and natural reproduction, resulting in the production of low-quality fish seeds (Adeparusi *et al*., 2010). The study aimed at assessing the efficacy of tigernut (C*yperus esulentus L*.) supplemented diets of the fecundity, fertilization, hatchability of eggs and hatchlings survival in C*larias gariepinus*

## MATERIALS AND METHODS

### Research Area

The research was carried out at the Department of Aquaculture and Fisheries Management Fish Farm, Shabu-Lafia Campus. Nasarawa State University Keffi, Lafia is located on latitude $8^0 35^0$N, longitude $8^0 32^0$E and altitude 181.53m above sea level with mean temperature of $34^0$C, relative humidity of 40-86% and average day light of 9-12hours. (NIMET, 2011)

### Collection and Acclimation of Experimental Fish

Twenty (20) female experimental C. *gariepinus* brood stock of weight between 650g-1000g were sourced from a commercial farm in Lafia, Nasarawa State. The brood stocks were acclimated for one weeks in concrete holding tanks during this period, they were fed with commercial diets of 40% crude protein twice daily at 3% of their body weight.

### Experimental Diet Preparation.

The feedstuff and tiger nut were obtained from various market in Nasarawa State, Nigeria. Part of the tiger nut was sun dried and then grounded into fine powder. Treatment diets were formulated to provide 40% crude protein.

The ingredients were milled to small particles size and graded level of dry tiger nut meal was added at 0% (control diet), 5%, 10%, 15% and 20% inclusion level. Ingredients including vitamin premix and tiger nut meal (dry) were thoroughly mixed to obtain a homogenous mass. The feed was pelletized using extruder machine and the pellets were sun-dried immediately to required minimum moisture level for storage.

**Table 1:** Composition of experimental diet

| S/N | COMPONENTS | TREATMENTS | | | | |
|---|---|---|---|---|---|---|
| | | DTSD 0% (ctrl) | DTSD 5% | DTSD 10% | DTSD 15% | DTSD 20% |
| 1 | Fish meal (kg) | 16.06 | 16.06 | 16.06 | 16.06 | 16.06 |
| 2 | Soybean meal (kg) | 18.98 | 18.48 | 17.98 | 17.48 | 16.98 |
| 3 | Groundnut cake (kg) | 20.44 | 20.44 | 20.44 | 20.44 | 20.44 |
| 4 | Millet (kg) | 14.60 | 14.60 | 14.60 | 14.60 | 14.60 |
| 5 | Wheat offal (kg) | 16.06 | 16.06 | 16.06 | 16.06 | 16.06 |
| 6 | Cassava flour (kg) | 11.20 | 11.20 | 11.20 | 11.20 | 11.20 |
| 7 | Vitalyte premix (kg) | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 |
| 8 | Lysine (kg) | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 |
| 9 | Methionine (kg) | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 |
| 10 | Salt (kg) | 0.61 | 0.61 | 0.61 | 0.61 | 0.61 |
| 10 | **TOTAL** | **100** | **100** | **100** | **100** | **100** |
| Additives | Dried Tiger nut meal (%) | 0.00 | 0.50 | 1.00 | 1.50 | 2.00 |

DTSD: Dried Tiger nut Supplemented Diet

**Experimental Setup**
The experimental brood stocks were starved 24 hours to the commencement of the experiment. The experimental brood stocks were fed with the varying inclusion level of the experimental diet twice daily at 3% of their body weight per day for a period of seven weeks. The quantity of feed was adjusted based on the weight attained by the fish fortnightly throughout the feeding trial. The water quality standard was strictly monitored while the water in each tank was completely changed twice a week and tanks were washed regularly to ensure optimum quality of the culture medium and healthy condition of the fish according to Adewole and Owolabi (2007).

**Growth Assessment**
The following indices was used to determine the biological evaluation of growth performance of the experimental fish according to methods described by Jobling (1983).

**Mean Weight Gain (MWG)**
The weight gains of fish in each treatment group was taken. All fish per treatment was individually weighed on a spring weighing balance and the respective means was recorded.

**Percentage Mean Weight Gain (PMWG)**
This was calculated using the formula:

Percentage mean weight gain $= \frac{Wf\text{-}Wi}{Wi}$ Where, $W_f$ is final mean weight and $W_i$ is initial mean weight

**Reproductive performance**
Fecundity estimation was done using volumetric sub-sampling (wet method) as described by Okaeme, *et al*. (2013). The egg sac was carefully weighed after cleaning the blood stain and removing attached tissues. The egg sac is then placed in 100ml of diluted water in a measuring cylinder and the volume (V) recoded. A small sample of the eggs was gotten from the egg sac and placed in 5ml of dilute water in a measuring cylinder and the volume (v) was recorded. The egg sample was counted and recorded as (n) and was calculated using the formulae below:

$$X/n = V/v$$

Where X= Unknown number of eggs in the total sample collected, n= Number of eggs counted in sample,
V= Total displaced volume, v= Volume of the sample

**Egg Quality Assessment and Larval Production**
After seven weeks of feeding trial, two females were randomly selected per dietary treatment, weighed and injected with ovaprim hormone according to manufacturer's recommended dosage of 0.5/kg body weight. The Fish was kept in a bowl for 12 hours (twelve hours) as latency period and eggs was collected by manual stripping of the sexually gravid females while milt from the male fish prepared for the experiment was used for the fertilization of eggs. The incubators were kept well oxygenated with aerators while the ambient temperature (hatchery) was kept within $28^0$C and eggs hatched after approximately 24 hours of incubation in plastic tanks.
The percentage of egg fertilized as well as the percentage number of eggs hatched and percentage survival was computed according to the methods described by Ayinla (1988):

% Egg Fertilized = No. of eggs incubated − No. of opaque eggs / Total no. of eggs incubated × 100.
% Egg Hatching = No. of whitish broken eggs / No. of eggs fertilized × 100
% Survival = No. of hatchling alive up to larvae stage / Total number of hatchlings × 100, which was determined after $10^{th}$ day of hatching.

**Statistical Analysis**

Data obtained were analysed by two-way Analysis of variance (ANOVA) and significant mean differences was separated at 0.05 probability level as described by Steel *et al*. (1997).

## RESULTS

Result of proximate analysis of formulated diet of the experiment is presented in table 2. Result of moisture, ash and crude protein show that DTSD 10, 15 and 20 were significantly the same but they were significantly higher than the control.

Result shows that Ether extract and Nitrogen free extract of treatment DTSD 20 was significantly higher than other treatments.

**Table 2:** Proximate composition of the experimental diet (Dry Tiger Nut)

| Treatments | Moisture | Ash | Crude protein | Ether extract | Crude fibre | Nitrogen Free extract |
|---|---|---|---|---|---|---|
| DTSD 00 | $11.58\pm5.00^{b}$ | $14.21\pm0.50^{b}$ | $39.35\pm0.00^{b}$ | $14.05\pm5.00^{e}$ | $2.27\pm5.01^{d}$ | $18.46\pm1.50^{e}$ |
| DTSD 05 | $11.58\pm9.85^{b}$ | $14.21\pm9.30^{b}$ | $39.42\pm7.74^{ab}$ | $14.16\pm1.09^{d}$ | $2.31\pm6.19^{cd}$ | $36.63\pm4.21^{d}$ |
| DTSD 10 | $11.61\pm8.30^{a}$ | $14.24\pm2.50^{a}$ | $39.44\pm3.71^{a}$ | $14.26\pm3.18^{c}$ | $2.33\pm7.00^{bc}$ | $36.28\pm2.10^{c}$ |
| DTSD 15 | $11.62\pm1.50^{a}$ | $14.25\pm5.33^{a}$ | $39.47\pm6.63^{a}$ | $14.37\pm1.55^{b}$ | $2.36\pm0.15^{ab}$ | $35.90\pm7.11^{b}$ |
| DTSD 20 | $11.63\pm1.55^{a}$ | $14.25\pm9.31^{a}$ | $39.49\pm1.85^{a}$ | $14.48\pm1.92^{a}$ | $2.38\pm0.77^{a}$ | $35.55\pm9.27^{a}$ |

DTSD 00= Dry Tiger nut supplemented diet 0% (control), DTSD 05= Dry Tiger nut supplemented diet 5%, DTSD 10= Dry Tiger nut supplemented diet 10%, DTSD 15= Dry Tiger nut supplemented diet 15% , DTSD 20= Dry Tiger nut supplemented diet 20%

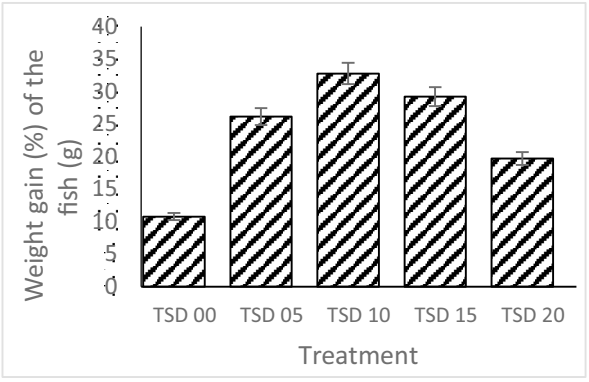



Figure 1: Average weight (%) of C. *gariepinus* female fed experimental diet for 30days

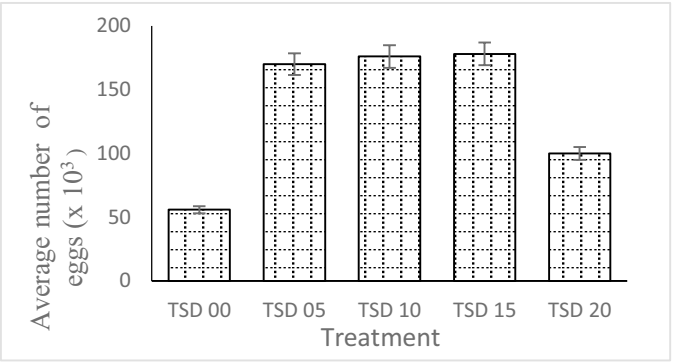



Figure 2: Average number of egg of C. *gariepinus* female fed experimental diet for 30days

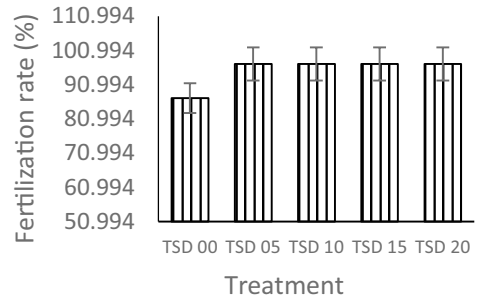



Figure 3: Effect of tiger nut experimental diet on Fertilization rate of C. *gariepinus* eggs

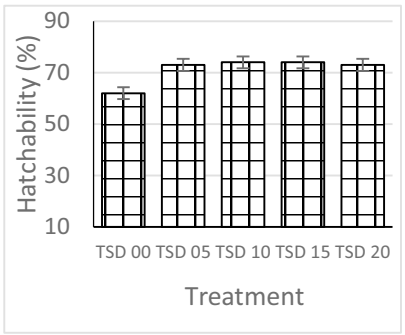



Figure 4: Effect of tiger nut experimental diet on the Hatchability Rate of C. *gariepinus* fry

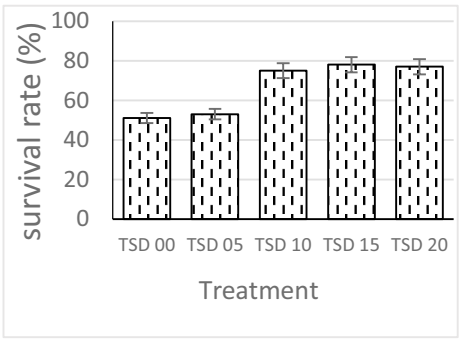



Figure 5: Effect of tiger nut supplementary diet on Survival Rate of C. *gariepinus* hatchlings

TSD 00= Tiger nut supplementary diet 0% (Control)
TSD 05= Tiger nut supplementary diet 5% inclusion level
TSD 10= Tiger nut supplementary diet 10% inclusion level
TSD 00= Tiger nut supplementary diet 15% inclusion level
TSD 00= Tiger nut supplementary diet 20% inclusion level

Result of ANOVA show that there is significant difference between the treatments. The dried tiger nut treatment diet was significantly higher than that of wet. Treatment TSD 10 value recorded were significantly higher than that of other treatments. Treatment TSD 20 for wet tiger nut treatment had the lowest recorded value for weight of egg with egg sac.

The result for the average number of eggs in fish shows that there is significant difference between the wet and dry tiger nut supplementary diet. TSD 15 shows the highest value for the wet and dry followed by TSD 05 and TSD 10. There is no significant difference between TSD 05 and TSD 10 but are significantly different from other treatments and the control. TSD 15 also shows the highest value for the wet and it is significantly different from the control and other treatment. TSD 05 and TSD 10 are not significantly different from each other in the experimental diet. TSD 15 also showed highest value for the dry and it is significantly different from the control and other treatments among the dry tiger nut experimental diet.

The result of the fertilization shows no significant difference between wet and dry control, TSD 5, TSD 10 respectively, but is significantly different for TSD 15 and TSD 20. There is no significant difference between the control, TSD 5 and TSD 10 respectively for the dry treatment but there is significant difference for TSD 15 and TSD 20 record the lowest value for dry treatment. The wet treatment only shows significant difference for TSD 15, while control, TSD 5 TSD 10 and TSD 20 shows no significant difference.

The effect of tiger nut supplementary diet on C. *gariepinus* hatchability rate is presented in figure 4.
The control shows no significant difference between the wet and dry treatments of hatchability, TSD 20, TSD 15, TSD 10 also shows no significant difference between the wet and dry treatments except for TSD 5 which shows significant difference. TSD 10 of the dry treatment shows the highest value while TSD 15 has the lowest value. TSD 5, TSD 20 and control has no significant difference, between them, but are significantly different from TSD 15 and TSD 5, while TSD 5 records the lowest value.
The effect of tiger nut supplementary diet on survival rate of C. *gariepinus* hatchling is presented in figure 5.

The result shows that there is a significant difference between wet and dry tiger nut diet in TSD 00, TSD 05, TSD 10 and TSD 15. TSD 15 have the highest significant value in survival rate more than any other treatments in wet experimental diet while TSD 05 of the dry tiger nut experimental diet has the significant value for survival rate.

## DISCUSSION

The general increase in body weights of the experimental fish in all the treatments in this study indicated that the diets were adequate in dietary protein and other nutrients required by female catfish. The increase in body weight might be attributed to the proper absorption and utilization of the nutrient-rich tiger nut.

The result of this study shows that tigernut supplemented diet affects the fecundity, hatching rate and percentage survival of C. *gariepinus* larval. Similar result was reported when ethanol extract of *Gacinia*

*kola* seed was used as fertility-promoting agent in C. *gariepinus* (Dada and Ajilore, 2001). Adesanya *et al*. (2007) reported an increase in the sperm count of wistar rats after treatment with ethanol extract of G. *kola* seed for 6 weeks.

This seeds of C*yperus esculentus* has been reported to be very nutritious (Paigen *et al*., 1987), rich in mineral content especially vitamin E, phosphorus and potassium, resistant to peroxidation. They contain fatty acids (palmitic acid, stearic acid, oleic acid and linoleic acid), alkaloids that affect glucagons and thyroid stimulating hormones, saponins and tannins that are known to have antimicrobial activity, as well as other physiological activities (Sofoworo, 1993; Evans, 2005). In this study, the larval of the fish fed on diets 5% and 15% tiger nut supplementary diet survived well than the ones placed on other diets. Since most of the losses in hatchery are recorded at the critical transitional period of moving from endogenous feeding to exogenous feeding, any effort made to improve the quality of the egg will surely increase the survival of the larval (Davy and Chouinard, 1980).

## CONCLUSION

Tiger nut supplementary diet improved the reproductive performance of cultured African catfish, C. *gariepinus* by enhancing fecundity, fertilization, hatchability and survival of C. *gariepinus* fry.

## RECOMMENDATIONS

This study established the efficacy of tiger nut seed meal as fertility enhancer and hatchling survival in C. *gariepinus* and should be encouraged as it will minimize the dependence on synthetic drugs as fertility enhancing agents.

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# EFFECT OF PHYTOCHEMICALS OF *Phoenix dactylifera* L. SEEDS AND *Laportea aestuans* L. LEAVES ON SOME REPRODUCTIVE BIOMARKERS OF *Heterobranchus bidorsalis*

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**ABSTRACT**
*This study evaluated the effects of dietary phytochemicals from Phoenix dactylifera (date palm) seeds and Laportea aestuans (West Indian wood nettle) leaves on the reproductive performance of Heterobranchus bidorsalis, a commercially important African catfish. Flavonoids, phenolic acids, alkaloids, and carotenoids were quantified following standard procedures from the two plant sources, revealing significant (P<0.05) compositional differences. Four experimental isonitrogenous diets were formulated (Diet A - Control, Diet B - P. dactylifera at 0.25g/kg of diet, Diet C - L. aestuans ground leaves at 0.25g/kg of diet and Diet D - mixture of P. dactylifera (0.125g/kg) and L. aestuans (0.125g/kg) and fed to sexually mature fish over 10 weeks, followed by assessments of serum hormone profiles (dopamine, estrogen, testosterone, cortisol), gonadosomatic index (GSI), and ovarian developmental stages. P. dactylifera seed flour exhibited high flavonoid and phenolic acid contents, while L. aestuans leaves were rich in carotenoids. Fish fed diets containing P. dactylifera (Diet B) showed significantly higher estrogen and cortisol levels and improved GSI in males, whereas females on L. aestuans supplemented diet (Diet C) exhibited the most advanced oocyte development and elevated hormone levels, except testosterone. Histological analysis revealed that diets A (control) and C favored oocyte maturation to post-vitellogenic stages. The results suggest that specific phytochemicals can modulate fish reproductive hormones and ovarian development in a dose- and compound-dependent manner, with antioxidant-rich botanicals showing the most promise for enhancing reproductive performance in aquaculture.*

**Keywords:** *Developmental Stages, Laportea aestuans, Phoenix dactylifera, Phytochemicals, Steroid Hormones.*

## INTRODUCTION

Phytochemicals influence fish egg development through their role as hormone modulators, antioxidants, or potential stressors, impacting oocyte growth, egg quality, embryonic survival, and hatching success in a complex, stage-dependent manner (Nakano and Wiegertjes, 2020; Sepehrfar *et al*., 2023). They can affect the development and maturation of fish oocytes primarily through their interaction with hormonal pathways and cellular processes, often with dose-dependent and species-specific effects (Chakraborty *et al*., 2014).

Different developmental stages of fish eggs, from primary growth oocytes to vitellogenic stages and post-fertilization embryos, may vary in their susceptibility to phytochemical effects. The primary growth stage involves critical biosynthesis and hormonal signaling, where endocrine disruptors can block maturation pathways; later embryonic stages may be more vulnerable to oxidative damage or toxic insult affecting survival and morphology (Brown *et al*., 2014).

Date palm (*Phoenix dactylifera* L.) trees are members of the Arecaceae family. According to reports, date seeds are used in traditional medicine to cure a number of illnesses, including diabetes, obesity, cancer,

heart disease, and reproductive dysfunction (Parvin *et al*., 2015). West Indian Wood Nettle (*Laportea aestuans*) is an annual herb of the Urticaceae family. According to Al-Mamary (2015), *L. aestuans* is a rich source of bioactive substances with antibacterial and antioxidant qualities, including alkaloids, flavonoids, and tannins. The aerial portion of *L. aestuans* (Urticaceae) is used to heal wounds and has been shown to have anti-inflammatory, antibacterial, and antioxidant properties (Oloyede and Ayanbadejo, 2014).
The African catfish, *Heterobranchus bidorsalis* (Geoffroy Saint-Hilaire, 1809), is a big, facultative air breathing member of the Clariidae family that is indigenous to the Nile, Senegal, Gambia, Volta, Niger, Benue, and Lake Chad rivers. It is commercially harvested for human consumption (Azeroual *et al*., 2010).

Phytochemicals are being integrated into aquaculture nutrition to sustainably boost reproductive outcomes, fish health, and productivity by supporting hormonal balance and reducing oxidative damage (Shastak and Pelletier, 2023). Careful evaluation of specific phytochemicals and exposure contexts is necessary for understanding their net effects on fish reproductive development.

## MATERIALS AND METHODS

### Source of *Phoenix dactylifera* seeds and *Laportea aestuans* leaves Sample Preparation

*Phoenix dactylifera* seeds and *Laportea aestuans* leaves were obtained around Nasarawa town and close to dumpsite in Nasarawa town, respectively. *Phoenix dactylifera* seeds (Voucher No: ABUHO1684) and *L. aestuans* leaves (Voucher No: ABUHO16493) were identified at the Herbarium Unit of the Department of Botany, Ahmadu Bello University, Zaria. *Phoenix dactylifera* seeds and *L. aestuans* leaves were prepared to remove bad seeds and winnowed to remove dirt, the seeds and leaves were weighed and dried. The sun-dried seeds and leaves were milled into fine flour with a feed mill and mortar and pestle, respectively. The samples were shade-dried at room temperature and stored in air tight containers.

### Determination of Phytochemicals

Flavonoid, phenolic acid, alkaloid and carotenoid contents were determined using spectrophotometric methods recommended by Mukadam *et al*. (2021).

### Mature Fish Husbandry Condition, Diets and Feeding Protocol

The experimental fish were acclimatized for 14 days. Sixteen (16) mature fish were stocked at 2kg/10m$^2$ into rectangular concrete tanks at a ratio of 2♀(female):2♂(males). Four isonitrogenous diets were prepared, comprising of Diet A - Control, Diet B - *P. dactylifera* at 0.25g/kg of diet (Ahmad *et al*., 2017), Diet C - *L. aestuans* ground leaves at 0.25g/kg of diet (Adetunji *et al*., 2021; Jafari *et al*., 2022) and Diet D - mixture of *P. dactylifera* at 0.125g/kg and *L. aestuans* at 0.125g/kg were formulated at 30% protein content using Pearson's square method and fed to the fish for 10 weeks at 4% body weight twice a day (Oniya *et al*., 2015).

### Collection of Blood and Gonad Samples, and Fixation

Blood was collected cardiac puncture (Mikulikova *et al*., 2022) with 5 ml heparinized syringes after sedation, centrifuged at 1000 rpm for 15 mins to obtain serum and transported to the laboratory in plain vials. Fish samples were dissected to harvest the ovaries, which were fixed in Neutral Buffered Formalin (10% NBF) and preserved in 70% ethanol for histology (Kirschbaum and Formicki, 2020).

### Determination of Gonadosomatic index and Hormonal Profile of *Heterbranchus bidorsalis* Blood

Gonadosomatic indices of the fish were calculated as follows following the recommendation of Anderson and Gutreuter (1983).

$$GSI = \frac{Gonald\ weight\ (g)}{(Body\ weight\ (g))} \times 100$$

The steroid hormonal profile of each fish was quantified using ELISA kit (estrogen using kit with catalogue no: CSB-E13017fh; Lot: C2489421809 manufactured by CUSABIO BIOTECH Co, China; cortisol using kit with catalogue no. ER1651 and testosterone using kit with catalogue no: ER1462-HS manufactured by Fine Test; and dopamine using kit with catalogue no: CK-bio-14551 manufactured by Shanghai Coon Koon Biotech Co., Ltd China). All assays were carried out following the manufacturer's instructions. All hormonal assays were carried out at the Department of Human Anatomy, Faculty of Medicine, Ahmadu Bello University, Zaria.

**Histology of *Heterobranchus bidorsalis* Ovaries**

The histology of ovaries was carried out according to the recommendations of Kirschbaum and Formicki (2020). The ovaries were dehydrated, cleared, infiltrated, embedded, sectioned, stained and mounted. The slides were viewed and oocytes were counted using a microscope with the aid of Zeiss Axio Scope A1 equipped with Zeiss AxioCam ERc5s camera.

**Data Analyses**

Student's T-test was used to determine if there was significant difference ($P \leq 0.05$) between the phytochemicals of *P. dactylifera* seeds and *L. aestuans* leaves. One-way ANOVA was used to test significant difference ($P \leq 0.05$) between the GSI, hormonal profile and developmental stages of *H. bidorsalis* eggs across diets. Duncan's multiple range test was used to separate the means. All analyses were carried out using SPSS version 25.

## RESULTS AND DISCUSSION

The phytochemicals of *P. dactylifera* seeds and *L. aestuans* leaves are presented in Table 1. *Phoenix dactylifera* had the highest values of flavonoids, phenolic acid and alkaloids, while *L. aestuans* had highest value of carotenoids. All the phytochemical contents varied significantly ($P<0.05$).

Flavonoid, phenolic acids and carotenoid protect reproductive cells from oxidative stress and enhance ovary development (Nakano and Wiegertjes, 2020; Sepehrfar *et al.*, 2023). High content of alkaloid is associated with disruption of estrogen and testosterone which in turn leads to abnormal reproductive development and gonad maturity (Sepehrfar *et al.*, 2023), however the level of alkaloid reported in this study is significantly low.

**Table 1:** Phytochemicals of *Phoenix dactylifera* seeds and *Laportea aestuans* leaves

| | *P. dactylifera* | *L. aestuans* | P value | Acceptable Limit |
|---|---|---|---|---|
| Flavonoids (mg QE/g) | 126.16 ± 4.25 | 98.56 ± 2.13 | 0.028* | 150 – 600 mg/kg |
| Phenolic acid (mg TAE/g) | 274.25 ± 5.54 | 133.36 ± 1.45 | 0.002* | 150 – 600 mg/kg |
| Alkaloids (mg/g) | 11.75 ± 0.25 | 7.88 ± 0.38 | 0.013* | 150 – 600 mg/kg |
| Carotenoids (μg/g) | 30.17 ± 1.21 | 240.11 ± 4.11 | 0.000* | 100 – 140 mg/kg |

Means are presented. P values with superscript (*) across rows vary significantly (P≥0.05). Acceptable limits: Righi *et al*. (2021); Akter *et al*. 2024.

The hormonal profile of male *H. bidorsalis* fed *P. dactylifera* seeds and *L. aestuans* leaves is presented in Table 2. Diet A had the highest dopamine content. Diet B gave the highest estrogen and cortisol contents, which elicited the best gonado somatic index. All hormonal contents varied significantly ($P<0.05$) across diets except for testosterone content. The hormonal profile of female *H. bidorsalis* fed *P. dactylifera* seeds and *L. aestuans* leaves is presented in Table 3. Diet D gave the highest dopamine content. Diet C

gave the highest estrogen content. Diet B gave the highest cortisol content. Fish fed Diet A had the best gonado somatic index. All hormonal contents varied significantly ($P<0.05$) across diets except for testosterone content. The lower amount of estrogen and testosterone gotten from fish fed diet D can be attributed to inhibitory effect of flavonoid from both *P. dactylifera* seeds and *L. aestuans* leaves, on the fish. As flavonoid inhibits steroidogenic enzymes like 3-hydroxysteroid dehydrogenase which is responsible for biosynthesis of steroid hormones in fish (Bugel and Tanguay, 2018). High amounts of hormones in diet C can be due to the modulatory roles played by alkaloid and carotenoid, and the ability of both phytochemicals to reduce oxidative stress (Chakraborty *et al.*, 2014).

**Table 2:** Hormone profile and gonado somatic index of Male *Heterbranchus bidorsalis* fed *Phoenix dactylifera* seeds and *Laportea aestuans* leaves

| | DOP (pg/ml) | EST (pg/ml) | TEST (ng/ml) | CORT (ng/ml) | GSI |
|---|---|---|---|---|---|
| Diet A | $58.06 \pm 0.75^{a}$ | $122.72 \pm 0.29^{a}$ | $1.83 \pm 0.07^{a}$ | $769.95 \pm 1.05^{d}$ | $0.040 \pm 0.002^{b}$ |
| Diet B | $34.65 \pm 0.35^{d}$ | $123.02 \pm 0.12^{a}$ | $1.76 \pm 0.03^{a}$ | $1128.45 \pm 0.56^{a}$ | $0.144 \pm 0.016^{a}$ |
| Diet C | $47.40 \pm 0.60^{c}$ | $100.52 \pm 0.40^{b}$ | $1.93 \pm 0.05^{a}$ | $900.83 \pm 1.18^{b}$ | $0.060 \pm 0.005^{b}$ |
| Diet D | $39.62 \pm 0.39^{b}$ | $102.42 \pm 1.57^{b}$ | $1.71 \pm 0.04^{a}$ | $882.05 \pm 2.96^{c}$ | $0.049 \pm 0.003^{b}$ |
| P Value | 0.000 | 0.000 | 0.092 | 0.000 | 0.003 |

Means are presented. Means with same superscript along columns do not vary significantly (P≥0.05). DOP = Dopamine, EST = Estrogen, TEST = Testosterone, CORT = Cortisol, GSI = Gonado Somatic Index.

**Table 3:** Hormone profile and gonado somatic index of Female *Heterbranchus bidorsalis fed Phoenix dactylifera seeds and Laportea aestuans leaves*

| | DOP (pg/ml) | EST (pg/ml) | TEST (ng/ml) | CORT (ng/ml) | GSI |
|---|---|---|---|---|---|
| Diet A | $45.59 \pm 0.32^{c}$ | $102.25 \pm 0.26^{c}$ | $1.85 \pm 0.03^{a}$ | $466.05 \pm 1.05^{d}$ | $0.562 \pm 0.029^{a}$ |
| Diet B | $46.67 \pm 0.23^{c}$ | $117.64 \pm 0.36^{b}$ | $1.85 \pm 0.06^{a}$ | $1213.55 \pm 3.46^{a}$ | $0.353 \pm 0.020^{c}$ |
| Diet C | $57.05 \pm 0.96^{b}$ | $120.75 \pm 0.75^{a}$ | $1.98 \pm 0.03^{a}$ | $934.15 \pm 2.07^{b}$ | $0.468 \pm 0.004^{b}$ |
| Diet D | $62.98 \pm 0.03^{a}$ | $115.85 \pm 0.85^{b}$ | $1.90 \pm 0.01^{a}$ | $880.59 \pm 1.52^{c}$ | $0.377 \pm 0.024^{c}$ |
| P Value | 0.000 | 0.000 | 0.131 | 0.000 | 0.007 |

Means are presented. Means with same superscript along columns do not vary significantly (P≥0.05). DOP = Dopamine, EST = Estrogen, TEST = Testosterone, CORT = Cortisol, GSI = Gonado Somatic Index.

The developmental stages of the eggs in the ovaries of female *H. bidorsalis* fed *P. dactylifera* seeds and *L. aestuans* leaves are presented in Table 4. Fish fed diets A and C were able to advance more oocytes. All developmental stages varied significantly ($P\leq0.05$) across diets except for the perinucleolar and vitellogenic stages. Diets A and C which had the highest GSI for the female fish also had more oocytes at the last two stages of development, which are the most mature oocytes.

**Table 4:** Developmental stages of the eggs in the ovaries of Female *H. bidorsalis* fed *P. dactylifera* seeds and *L. aestuans* leaves.

| Developmental stages | Diet A(%) | Diet B(%) | Diet C(%) | Diet D(%) | P Value |
|---|---|---|---|---|---|
| Oogonia Stage | $23^{b}$ | $32^{a}$ | $20^{b}$ | $32^{b}$ | 0.001 |
| Chromatin Nucleolar Stage | $35^{b}$ | $48^{a}$ | $44^{ab}$ | $62^{b}$ | 0.005 |
| Perinucleolar Stage | $2^{a}$ | $0^{a}$ | $4^{a}$ | $0^{a}$ | 0.213 |
| Cortical Alveoli Stage | $6^{b}$ | $17^{a}$ | $8^{ab}$ | $0^{b}$ | 0.050 |
| Vitellogenic Stage | $16^{a}$ | $0^{a}$ | $5^{a}$ | $3^{a}$ | 0.078 |
| Post-Vitellogenic Stage | $18^{ab}$ | $3^{b}$ | $19^{a}$ | $3^{b}$ | 0.050 |

Means are presented. Means with same superscript across rows do not vary significantly ($P \geq 0.05$)

## CONCLUSION

Natural phytochemicals commonly found in herbal or plant-based fish feeds can act as modulators of fish hormonal systems. While some can act as endocrine disruptors others generally support hormonal health mostly through antioxidant and stress-mitigation roles.

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# EFFECT OF *Azanza garckeana* (GORON TULA) PULP POWDER ON GROWTH PERFORMANCE of *Clarias gariepinus* BROODSTOCK

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**ABTRACTS**

*This study determined the phytochemical and proximate composition of dried Azanza garckeana (Goron Tula) pulp powder and its effects on the growth performance of Clarias gariepinus. Five diets were formulated at 0, 10g, 20g, 30g, and 40 g/kg inclusion levels of pulp pwder designated as T1, T2, T3, T4, and T5 respectively. A total of 120 Clarias gariepinus were randomly assigned across treatments (8 fish per replicate, 3 replicates per treatment in a completely randomized design. Fish were fed ad-libitum for 56 days. The result showed that dried Azanza garckeana pulp contains high amount of crude fibre (35.75%), nitrogen free extract (20.78%), moisture (13.93 %), ash (12.31%), crude protein (10.44%) and fat (6.80%) respectively. The nutritional composition of the experimental diets showed that T1 has the least moisture content of (8.03%), T2 have the highest moisture content of (8.95%), with least in fat in T1(21.2%), CF with least in T1 (3.77%), and highest in T5 (8.43%), NFE T1 has the highest while T5 has the lowest. There was significant difference ($p < 0.05$) in the weight gain of male Clarias gariepinus broodstock fed the experimental diets. Male broodstock fed diet T3 had the significantly highest weight gain compared with other treatments groups and the control while male broodstock fed diet T5 had significantly lowest weight gain. The results further showed that there was significant difference ($p > 0.05$) in the weight gain of the female broodstocks fed the experimental diets than male broodfish. The results of this study revealed that the use of Azanza garckeana bulb powder as an additive in the feed of C. gariepinus is beneficial to improve growth performance, Based on the findings, it is recommended that dried Azanza garckeana pulp powder be incorporated into the diets of Clarias gariepinus broodstock at (20 g/kg) inclusion levels to improve growth performance*

**Key words:** *Clarias gariepinus, Azanza garckeana.* phytochemical, proximate

## INTRODUCTION

Aquaculture production of *Clarias gariepinus* has been practiced for a long time in Africa. According to Huisman and Richter (1987), the African catfish, C. *gariepinus* is a popular commercial fish species found in Africa, Europe, China, and Brazil, and is one of the most promising species for aquaculture production due to its distinct genetic and productive characteristics.

The *Azanza garckeana* (F. Hoffm.) Exell and Hillc commonly known as Goron Tula, (kola of Tula) in Hausa, belong to the family Malvaceae. In Nigeria, it is grown only in Tula village of Gombe State. It is a multipurpose edible fruit of tropical Africa. It is an important medicinal and food plant commonly used in Northern Nigeria as herbal medicines (Ahmed *et al.*, 2016). *Azanza garckeana* has also been reportedly use in traditional medicine for treatments of management of more than 20 human diseases and ailments. Multiple classes of bioactive metabolites including amino acids, alkaloids, ascorbic acid, carotenoids, flavonoids, glucosides, phenols, lipids, tannins and saponins have been isolated from *A. garckeana* (Akinnifesi *et al.*, 2004).

## MATERIALS AND METHODS

### Study Area

The study was conducted at the Research Farm of Department of Aquaculture and Fisheries Management, Nasarawa State University Keffi, Shabu-Lafia Campus Lafia, Nasarawa State. Lafia is located on latitude 8° 35'N, longitude 8° 32'E, latitude 181.53m above sea level with a mean temperature of 34°C, relative humidity of 40-86% and average day light of 9-12h (NIMET, 2024).

### Collection, processing, and preparation of *A. garckeana* meal.

The fruit *A. garckeana* was purchased from Lafia Market, Nasarawa State, Nigeria. The seeds were removed from the pulps and the pulp sun-dried. The dried pulp was pounded into powdered form using pestle and mortar. The pounded pulp was sieved using Bs 0.8 mm mesh sieved, packed, and kept under room temperature in a black polythene bag until required.

### Experimental feed and design:

The study employed a Complete Randomized Design (CRD) having the treatment of different inclusion levels of 0, 10g, 20g, 30g, and 40 g/kg designated as T1, T2, T3, T4, and T5 respectively. A total of 120 *Clarias gariepinus* will be randomly assigned across treatments (8 fish per replicate, 3 replicates per treatment). *Clarias gariepinus* was fed at Ad-libitum for 28 days. Weight measurements was taken weekly, and Growth performance computed.

### Chemical Analysis

Phytochemical and proximate analysis of the pulp of *A. garckeana* was carried out in the laboratory.

### Growth Performance

The following parameters was determined from the feeding trials according to .....

| Nutrients | % Composition |
|---|---|
| Moisture | 13.93 |
| Ash | 12.31 |
| Crude protein | 10.44 |
| Fat | 6.80 |
| Crude fibre | 35.74 |
| NFE | 20.78 |

### Phytochemical Composition of Dried *Azanza garckeana* Pulp Meal

Table 2 represent the results of phytochemical composition of dried Azanza garckeana pulp meal. The results revealed that 100g of the plant contain tannin (8.87 mg), alkaloids (8.73 mg), saponin (8.73 mg), flavonoids (5.87 mg) and phenols (4.56 mg).

**Table 2:** Phytochemical composition of *Azanza garckeana* pulp meal

| Phytochemicals | Composition (mg/100g) |
|---|---|
| Alkaloids | 8.73 |
| Saponin | 8.73 |
| Flavonoids | 5.87 |
| Phenols | 4.56 |
| Tanin | 8.87 |

### Nutritional Composition of the Experimental Diets

The results of the nutritional composition of the experimental diets presented in Table 3 showed that T1 has the least moisture content of (8.03%), T2 have the highest moisture content of (8.95%), with least in fat in T1 (21.2%), and crude fibre was least in T1 (3.77%), and highest in T5 (8.43%), NFE was highest in T1, while T5 had the lowest.

**Table 3:** Proximate composition of the experimental diets

| | Treatments | | | | |
|---|---|---|---|---|---|
| **Parameters** | **T1** | **T2** | **T3** | **T4** | **T5** |
| Moisture (%) | 8.03 | 8.95 | 8.65 | 9.58 | 9.05 |
| Ash (%) | 8.08 | 9.08 | 10.55 | 10.7 | 11.08 |
| Crude protein (%) | 39.19 | 40.25 | 40.88 | 42.60 | 42.75 |
| Fat (%) | 21.2 | 21.15 | 22.5 | 23.51 | 24.05 |
| Crude fibre (%) | 3.77 | 4.17 | 6.53 | 8.27 | 8.43 |
| NFE (%) | 19.73 | 16.4 | 10.89 | 5.34 | 4.64 |

### Weight gain of Male and Female *Clarias gariepinus* Brood stock Fed Varying Inclusion Levels of died *Azanza garckeana* Pulp Meal Diet

Figure 1 present the results of weight gain of male and female brood stock fed varying inclusion levels of dried *Azanza garckeana* pulp meal diet. The result showed that there was significant difference ($p < 0.05$) in the weight gain of male *Clarias gariepinus* brood stock fed the experimental diets. Male brood stock fed diet T3 had the significantly highest weight gain compared with other treatments groups, while male brood stock fed diet T5 had significantly lowest weight gain. The results further showed that there was no significant difference ($p > 0.05$) in the weight gain of the female brood stocks fed the experimental diets.

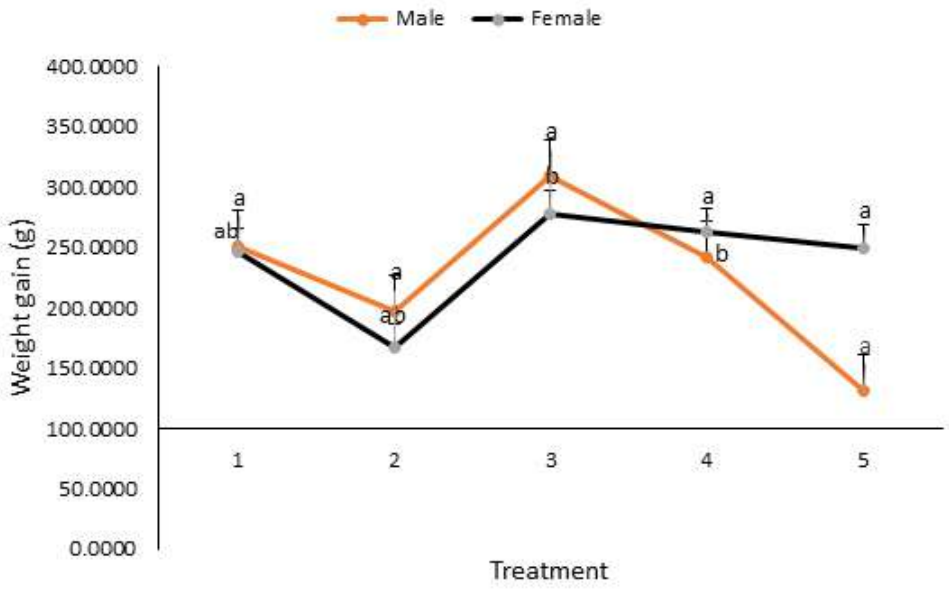



**Figure 1:** Weight gain (g) of Male and Female *Clarias gariepinus* Broodstock fed Varying Inclusion Levels of dried *Azanza garckeana* Pulp Meal Diet.

## DISCUSSION

### Proximate analysis content of *Azanza garckeana* pulp

*Azanza garckeana* pulp contains moisture, ash, crude fat, crude fiber, protein, and nitrogen free extracts (NFE) in varying proportion. Moisture content is important during the mixing stage in the food manufacturing process as water affect the quality and consistency of the product and its preservation

(Willaiams et al., 2020). The low moisture content of 13.93 % obtained in this study makes it is easier to preserve the plant (Umar et al., 2011). The moisture content obtained in this study is in line with that of Williams et al. (2020), Momodu et al., (2020), while Oniya et al. (2015) reported higher value (26.0 %) than that of this study.

The mineral contents in ash are important for building strong teeth, bones, blood clotting, reduce pain after exercise, regulate heart bit and assist in muscle contraction in human (Williams et al., 2020). The ash content in the extract of *Azanza garckeana* was 12.31 % indicating that the pulp contains minerals and more organic components. The ash value obtained in this study is higher than 4.53 % reported by Williams et al. (2020) but it is in line with 11.2 % reported by Ochokwu et al. (2014).
Crude protein is required for the growth and maintenance of tissues, causes bio-chemical reaction that take place within and outside the cell, act as a messenger that aid communication between cells, tissue and organs, it provides structure, maintain proper pH, boost immune health, transport and store nutrients and provides energy (Williams et al., 2020). The lower crude protein content 10.44 % suggested that *Azanza garckeana* cannot supply the required protein needed for fish growth and survival therefore it must be supplemented with other protein food sources. Similar crude protein values were also reported by Williams et al. (2020), Ochukuw et al. (2014) and Oniya et al. (2015), while Itodo et al. (2020)

Dietary fats serve as energy source, aid in the absorption of fat-soluble vitamins (Vitamin A, D, E and K), required for growth, immunological roles and reproduction. *Azanza garckeana* pulp contains high crude fat (6.80 %), suggesting that the pulp could be recommended as a good source of food supplements for patient with lipid or fat induced disorder. The fat content in this is tandem with 7.0 % reported by Ochokuw et al. (2014), but higher than 2.45 % reported by Williams et al. (2020), 1.27 % by Itodo et al. (2022), 1.0 % and by Oniya et al. (2015)

Crude fibers are not digestible in humans, but they aid in digestion. They are important in lowering plasma cholesterol and decreasing the incidence of colon cancer (Williams et al., 2020). The crude fiber content in the pulp extract is relatively low at 35.74 %. This result is in line with 38.0 % reported by Oniya et al. (2015), but lower than 41.3 % reported by Ochokwu et al., (2014) ad higher than 12.40 % by and 8.65 % Williams et al. (2020) and Itodo et al. (2022).

The value of NFE recorded in this study was higher than the ones reported (60.57 %) by Williams et al. (2020), 53.95 % by Itodo et al. (2022), and 29.0 % by Oniya et al. (2015). However, it is higher than 15.1 % reported by Ochokwu et al. (2014). The differences observed in the proximate values could be attributed to environmental factor variation (e.g. soil on which the plants were grown, prevailing temperature and soil moisture of the location of the tree). Therefore, based on the result of the proximate analysis *Azanza grackaena* pulp can be a source of raw material for fish feed industries.

The phytochemical analyses showed that the extracts contained phytochemicals exerting beneficial effects. Phytochemicals are naturally derived by plants and contain diverse bioactive compounds (Kumar et al., 2023). Tannins are described as plant-derived antinutrients reported to be responsible for decreases in feed intake, growth rate, feed efficiency, net metabolizable energy, and protein digestibility in experimental animals (Ryszard, 2007). Therefore, foods rich in tannins are of low nutritional value. *Azanza garckeana* pulp, shown to contain a very considerable quantity of phenols and flavonoids, has very high steroidogenic and antioxidant properties. However, Itodo et al. (2022), Yusuf et al. (2020a) and Yusuf et al. (2020b), reported higher levels of the phytochemical compounds in *Azanza garckeana* pulp. The differences recorded may be because of the location of the *Azanza garckeana* plant and the process of extraction.

*Azanza garckeana* pulp meal significantly influenced the nutritional composition of the experimental diets by increasing the dietary crude protein, ash, fats, and crude fibre contents also, reducing the NFE content with increasing levels. However, all the formulated diets meet the standard 40.0 % crude protein formulation requirement for C*larias gariepinus* broodstock, thereby suggesting that all the feeds are suitable for catfish broodstock conditioning. Craig et al., (2002) stated that prepared or artificial diets may either be complete or supplemental which supply all the ingredients necessary for optimal growth and health of the fish. The result of this study in in line with the reports of Ochukwu et al. (2014) who reported increase in dietary crude protein, fat, ash, and crude fibre contents, and decreased NFE content with increasing levels of *Azanza garckeana* pulp.

The result showed that there is no significant difference ($p > 0.05$) in the weekly growth of C*larias gariepinus* broodstock fed the experimental diets. However, C*larias gariepinus* fed with T3 (20 mg/kg) dried *Azanza garckeana* pulp meal diet had the highest growth at the 2nd, 3rd and 4th week respectively while C*larias gariepinus* fed with T4 (30 mg/kg) dried *Azanza garckeana* pulp meal diet had the highest growth in the 1st week. This result was in line with Amisa et al. (2009) which observations in growth performance of the African catfish fed varying inclusion levels of *Leucaena leucocephala* leaf meal reported that there was no significant difference ($p>0.05$) in the initial body weight, however final body weight, mean weight gain, feed conversion ratio and specific growth rate in 20% inclusion gave a better weight gain. In male, protein efficiency ratio was highest in fish fed 0% *A. garckeana* (0.051) but did not differ statistically ($p>0.05$) from the diets fed with 5%, 10%, 15%, and 20% *A. garckeana* pulp while in female diet, 5% *A. garckeana* recorded the highest PER.

## CONCLUSION AND RECOMMENDATION

The results of this study revealed that the use of *Azanza garckeana* bulb powder as an additive in the feed of C. *gariepinus* is beneficial to improve growth performance, This could be attributed to the synergistic actions of the bioactive molecules of each of the phyto-additives as growth promoting agents by enhancing the appetite and the state of health in the fish. Based on the findings, it is recommended that dried *Azanza garckeana* pulp powder be incorporated into the diets of C*larias gariepinus* brood stock at (20 g/kg) inclusion levels to improve growth performance.

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# PERFORMANCE OF *Clarias gariepinus* (BURCHELL, 1822) JUVENILES FED NON-CONVENTIONAL ANIIMAL PROTEIN AS FISH MEAL REPLACEMENT

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**ABSTRACT**
*A composite meal (CM) made up of 75% cattle blood meal and 25% chicken viscera meal was produced and used to formulate five iso-nitrogenous diets of 40% crude protein. The CM was used to replace fish meal at 0 % (control), 25%, 50%, 75% and 100% levels. One hundred and fifty (150) Clarias gariepinus juveniles of mean weight 7.97g were fed 5% body weight experimental diets for eight (8) weeks. There were significant difference (P<0.05) in growth performance and feed utilization for 50% replacement level with mean final weight of 69.13g compared to 100% replacement level of mean final weight 48.67g, FCR 1.51 compared to 2.36 for 100% replacement level. Thus, cattle blood meal and chicken viscera meals at 75% and 25% proportion could replace fish meal without compromising growth performance, FCR and survival of Clarias gariepinus juveniles.*

**Keywords:** Blood, Cattle, Chicken viscera, *Clarias gariepinus*, Fish meal, Growth performance

## INTRODUCTION

Fish meal is the coarse flour made from fresh raw fish or fish parts by cooking, pressing, drying and milling. The major source of fish meal is some harvested small marine fish, such anchovies, mackerel, sardines, menhaden and herring (FAO, 2018). The rapid development of aquaculture in the world depends largely on the availability of fish feed; which are traditionally based on fish meal as the main protein source (Hardy and Tacon, 2002). Being a source of protein, which is highly-priced, fish meal, is regarded as an essential ingredient in the diet of carnivorous and omnivorous aquatic organisms, mainly fishes (Alhazza *et al.*, 2019)

In replacement of the fish meal the protein sources must bring the ten essential amino acids (EAAs) required for fishes (Medale *et al.*, 2013). The utilization of blood meal in fish diet has also been recommended due to its high protein content. The protein content of blood meal has a poor amino acid balance with lysine being relatively high and very low in methionine and Isoleucine (Onunkwo *et al.*, 2018). Aladetohun *et al.* (2013) replaced fish meal with blood meal, thus formulated a 35% crude protein iso-nitrogenous diet for *Oreochromis niloticus* at 0%, 50% and 100%. Njieassam (2016) investigated the effect of using blood meal on growth and mortality of Catfish at 0%, 5%, 10% and 20% inclusion level against fish meal. Albeit, Alofa *et al.* (2019) reported a proximate composition of chicken visceral meal to be 90.0% dry matter, 32.2% crude protein, 22.0% crude lipids and 6.3% ash. Also, Redoy *et al.* (2021) reported poultry viscera to contain 93.1% dry matter and 57.3% crude protein, 37.4% either extract, 4.7% Ash, 0.85% calcium, 0.86% phosphorus and 0.04% sulphur. Oke *et al.* (2016) replaced fish meal with chicken viscera meal in the diet of *Clarias gariepinus* at 0%, 30% and 50% respectively.

## MATERIALS AND METHODS

### Study Area

The experiment was carried out in the Aquaculture production unit, National Agricultural Extension and Research Liaison Services, Ahmadu Bello University (NAERLS/ABU), Zaria, Nigeria between August-to-October, 2024; located within Guinea Savannah zone of Northern Nigeria at latitude $7^0$-to-$11^0 3^i$ N and longitude $7^0$-to-$7.44^0 40^i$ E.

**Collection and Processing of Cattle Blood Meal (CBM) and Chicken Viscera Meal (CVM)**
The CBM and (CVM) were collected from Zango Abattoir and Sabon gari market, Zaria. Thus, from freshly slaughtered cattle in clean 25L galloon and transported to study area. It was boiled immediately in an aluminium pot to 100$^0$C for ten (10) minutes to let water evaporate and destroy pathogens as described by Kirimia and Munguti (2016). The coagulated blood was then drained and crushed manually to increase the drying surface area. It was spread on a polythene liner and sun dried for 72 hours. The dried coagulant was milled with pistil and mortar to fine powder and stored in an air-tight polythene bags. The CVM (intestines) after collection were emptied of their contents and washed with clean water, drained and boiled in clean water to 100$^0$C for ten (10) minutes as described by Kpogue *et al.* (2019). After draining they were then oven dry at 60$^0$C for 24 hours and grinded with pistil and mortar to obtain CVM. The proximate composition of the Composite diet ingredients were presented in table 1.0

**Formulation of Experimental Diets**
Pearson's square method was used to formulate five iso-nitrogenous diets containing 40% crude protein. The gross composition of the experimental diets (Table 1) were milled separately to fine powder and weighed using digital scale, mixed into homogenous particles. The Fish Meal (FM) was replaced at 0% (control), 25%, 50%, 75% and 100% level. The Composite Meal (CM) was pelletized using 2 mm die-hand pelletizing machine. Table 2 presents the proximate composition of composite diets.

**Table 1:** Gross Composition of Experimental Diets

| Ingredient | 0% | 25% | 50% | 75% | 100% |
|---|---|---|---|---|---|
| Yellow maize | 12.97 | 15.25 | 17.41 | 19.50 | 21.40 |
| GNC meal | 26.51 | 25.75 | 25.03 | 24.30 | 23.70 |
| Soybean meal | 26.51 | 25.75 | 25.03 | 24.30 | 23.70 |
| Fish meal | 26.51 | 19.31 | 12.52 | 6.10 | 0.00 |
| Composite meal | 0.00 | 6.44 | 12.52 | 18.30 | 23.70 |
| Bone meal | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 |
| Minerals premix | 2.25 | 2,25 | 2.25 | 2.25 | 2.25 |
| Methionine | 2 | 2 | 2 | 2 | 2 |
| Lysine | 1 | 1 | 1 | 1 | 1 |
| Total | 100 | 100 | 100 | 100 | 100 |

**Table 2:** Proximate Composition of Experimental Diet Ingredients

| Ingredient | Moist (%) | CP (%) | EE (%) | CF (%) | Ash (%) | NFE (%) | GE (Kcal/J) |
|---|---|---|---|---|---|---|---|
| Yellow Maize | 9.13 | 8.9 | 3.48 | 11.6 | 3.81 | 63.1 | 3,447 |
| GNC meal | 9.09 | 43 | 5.2 | 6.0 | 5.8 | 30.9 | 2,400 |
| Soybean meal | 7.92 | 44 | 2.6 | 7.8 | 5.6 | 32 | 2,400 |
| Fish meal | 9.78 | 60 | 7.92 | - | 11.0 | 4.89 | 2,980 |
| Composite meal | 9.33 | 74.4 | 5.35 | 2.43 | 4.12 | 13.7 | 3,453 |

%Moist = % Moisture, %CP = % Crude Protein, %EE = % Either Extract, %CF = % Crude Fibre, %Ash = % Ash, %NFE = % Nitrogen Free Extract, GE= Gross Energy, GNC = Groundnut cake meal

## RESULTS AND DISCUSSION
The proximate compositions of the experimental diets were presented in Table 3 while the growth performance of *Clarias gariepinus* juveniles fed experimental diets were presented in Table 4.

**Table 3:** Proximate Composition of Experimental Diets Fed to C*larias gariepinus* Juveniles

| Parameter | 0% | 25% | 50% | 75% | 100% |
|---|---|---|---|---|---|
| Dry matter | 90.12 | 88.80 | 91.72 | 89.03 | 90.29 |
| Crude Protein | 44.19 | 43.13 | 43.50 | 42.13 | 39.31 |
| Crude fibre | 3.21 | 3.19 | 3.03 | 3.20 | 4.01 |
| Ether extract | 4.65 | 4.18 | 4.50 | 3.98 | 3.88 |
| Ash | 11.25 | 10.11 | 9.43 | 9.35 | 8.42 |
| Nitrogen Free Extract | 36.70 | 39.39 | 35.04 | 41.34 | 44.38 |

The proximate composition of the experimental diets showed that it contained 74.38% crude protein (CP) which is significantly (P<0.05) higher than 9.21% CP rumen content (RC) meal fed to C*larias gariepinus fingerlings* as reported by Olaniyi *et al.* (2008). However, the ether extract (2.81%) were lower while crude fibre (24.5%) were significantly (P<0.05) higher for RC. It also differs from the finding of Ojewole *et al*. (2022) when animal composite meal with 67.83% CP was fed to C. *gariepinus*. The variation may be due to the chemical composition or type of pasture consumed and the species differences (Olaniyi *et al*., 2008). C. *gariepinus* juveniles significantly (P<0.05) utilized experimental diets up to 50% inclusion level which is better than the 20% ability of feather meal as replacement for fish meal in C. *gariepinus* fry diets as reported by Wei-kang Chen *et al*. (2017).

**Table 4:** Growth Performance and Nutrient Utilization of C*larias gariepinus* Juveniles Fed Experimental Diets

| Parameter | 0% | 25% | 50% | 75% | 100% | P-value |
|---|---|---|---|---|---|---|
| IMW | 7.93±0.06 $^{a}$ | 7.93±0.06 $^{a}$ | 7.97±0.15 $^{a}$ | 7.97±0.06 $^{a}$ | 7.97±0.06 $^{a}$ | 0.17 |
| FMW | 62.90±18.59 $^{b}$ | 62.43±11.34 $^{b}$ | 69.13±6.45 $^{a}$ | 57.60±4.51 $^{b}$ | 48.67±5.92 $^{c}$ | 0.21 |
| MWG | 54.97±18.64 $^{b}$ | 54.5±11.39 $^{b}$ | 61.2±6.50 $^{a}$ | 49.6±4.61 $^{bc}$ | 40.7±5.86 $^{c}$ | 0.20 |
| %WG | 68.90±24.52 $^{b}$ | 70.67±11.59 $^{b}$ | 76.33±8.40 $^{a}$ | 60.67±5.25 $^{b}$ | 49.83±7.96 $^{c}$ | 0.23 |
| SGR | 3.58±0.64 $^{a}$ | 3.66±0.35 $^{a}$ | 3.79±0.12 $^{a}$ | 3.57±0.45 $^{b}$ | 3.03±0.38 $^{b}$ | 0.26 |
| %SR | 96.67±5.77 $^{a}$ | 96.67±5.77 $^{a}$ | 96.67±5.77 $^{a}$ | 86.67±1.55 $^{a}$ | 90.00±10.00 | 0.45 |
| FCR | 1.52±034 $^{a}$ | 1.54±0.36 $^{a}$ | 1.51±0.16 $^{a}$ | 1.96±0.07 $^{ab}$ | 2.36±0.62 $^{b}$ | 0.03 |
| FCE | 0.55±0.96 $^{ab}$ | 0.69±0.16 $^{b}$ | 0.63±0.07 $^{ab}$ | 0.52±0.02 $^{ab}$ | 0.44±010 $^{a}$ | 0.29 |
| PI | 378±89.8 $^{a}$ | 319±42.93 $^{a}$ | 370±9.12 $^{a}$ | 319±13.61 $^{a}$ | 324±7.80 $^{a}$ | 0.11 |
| PER | 1.38±0.23 $^{ab}$ | 1.71±0.36 $^{b}$ | 1.58±0.16 $^{ab}$ | 1.30±0.04 $^{ab}$ | 1.12±0.30 $^{a}$ | 0.22 |

Mean with same superscripts across the same row are not significantly (P>0.05) different
IMW = Initial Mean Weight, FMW = Final Mean Weight, MWG = Mean Weight Gain, %WG = % Weight Gain, SGR = Specific Growth Rate, %SR = % Survival Rate
FCR = Feed Conversion Ratio, FCE = Feed Conversion Efficiency, PI = Protein Intake, PER = Protein Efficiency Ratio

The mean weight gain (MWG), Feed Conversion Ratio (FCR) and Protein Efficiency Ratio (PER) were significantly (P<0.05) influenced by CBM and CVM inclusion levels in the experimental diets. The MWG of 50% experimental diet fed C. *gariepinus* juveniles were closer to MWG of 75% Chicken intestine meal (CIM) replacing fish meal in the diet of C. *gariepinus* fingerlings as reported by Barde *et al.* (2023).The least FCR (1.51) was shown by 50% fed C. *gariepinus* juveniles while the highest (2.36) was from 100% fed fish. This agreed with Oke *et al.* (2016) finding of FCR 1.11-to-1.19 for 50% CVM fed to C. *gariepinus* fingerlings at varying inclusion levels of 0%, 30% and 50%.. The PER values 1.71 and 1.12 recorded for 25% and 100% inclusion respectively may be attributed the non-palatability and digestibility of blood meal compared to fish meal. This is largely due to its amino acid imbalance (Hedji *et al*., 2014).

## CONCLUSION

A composite meal containing cattle blood meal (75%) and chicken visceral meal (25%) can effectively replace fish meal at up to 50% inclusion level in the diet of *Clarias gariepinus* juveniles, resulting in significantly ($P < 0.05$) improved growth performance, nutrient utilization and survival rate.

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# GROWTH PERFORMANCE OF *Clarias gariepinus* FINGERLINGS FED DRIED WATERMELON PEEL MEAL DIET IN CONCRETE PONDS AND OUTDOOR HAPAS NETS

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**ABSTRACT**

*The study investigated the growth performance of Clarias gariepinus fingerlings fed dried watermelon (Citrullus lanatus) peel meal as a replacement for maize in concrete ponds and outdoor hapas. Five experimental diets with watermelon peel meal replacing maize at 0%, 25%, 50%, 75% and 100% levels were formulated and administered to six hundred fingerlings of Clarias gariepinus in concrete ponds and outdoor hapas in a completely randomized design for ten weeks. At the end of the feeding trial, two fish samples from each of the treatment groups were randomly selected for blood haematological and blood biochemical analysis and it was observed that watermelon peel meal had no adverse effect on the haematological and blood biochemical parameters of the experimental fish. Inclusion of watermelon peel meal at 100% in the two culture systems demonstrated the best growth parameters such as mean final weight 33.23g and 43.30g, mean weight gain 26.79g and 36.75g, specific growth rate 2.17g and 2.56g, protein efficiency ratio 0.92% and 0.92% and feed conversion ratio 2.33% and 2.11%. Best growth performance and nutrients utilization was observed in the fish raised in hapas nets while optimum survival rate was observed in the concrete pond culture system*

**Keywords:** C*itrullus lanatus*, peel meal, concrete pond, outdoor hapas nets

## INTRODUCTION

High cost of fish conventional feedstuff causes low profit, losses and closure of some farms, adversely affecting aquaculture production. Maize which is the major source of energy is used as food by human, it is in high demand by industries for the production of human, animal and fish feeds and this makes the product and feeds expensive

The success in aquaculture operations depend on the quality of fish feeds since it determines the survival and growth of the fish (Jamabo *et al.*, 2019). Quality fish feed production in aquaculture is one of the major determinants of significant growth, efficiency in feed utilization, and flesh quality of the fish produced (Ogueji *et al.*, 2020). Fish feed represents almost 65 to 70% of the cost of production in aquaculture setting with protein (fish meal) being the most expensive nutrient in feed formulation (Aragão *et al.*, 2022). The production of high-quality feed is one of the significant obstacles that hinders the rapid growth of aquaculture in Nigeria (Udo and Dickson, 2017). A major component in sustainable aquaculture is fish feed development and discovery of novel feed ingredients (Ragaza *et al.*, 2023). As more than half of the cost in aquaculture production comes from feeds, different feed reduction schemes have been employed and adopted. Research is being done to find innovative sources of fish feed with the right nutritional values that can replace or augment conventional aquaculture or fish feed (Kaleem and Bio Singou Sabi, 2020). Watermelon peel is the tough, outer layer of a watermelon usually green on the exterior. The peel possesses large percentage of nutrients. It contains low calories and high content of vitamin A, vitamin C, potassium, vitamin $B_6$and zinc. It is loaded with citrulline, chlorophyll, amino acids, lycopene, phenolic compounds and flavonoids. The citrulline found in watermelon peels is reported to

play reproductive function. African catfish C*larias gariepinus*, is the most popularly cultured fish in Nigeria (Sogbesan and Ugwumba, 2006). This species has drawn attention of aquaculturists because of its biological attributes that include faster growth rate, resistance to diseases and possibility of high stocking density (Saad *et al*. 2009).

## MATERIALS AND METHODS

### Experimental site

This study was conducted in the teaching and research farm Faculty of Agriculture, Nasarawa State University Keffi, Lafia Shabu Campus.

### Collection and Processing of the Peel

Watermelon peels were collected from fruits sellers within Lafia Metropolis, washed and sliced to smaller pieces and were spread under the sun to dry. The dried watermelon peels were milled into fine particles using the hammer mill and stored for use.

### Experimental Setup and Management

### Diet Formulation

The experimental diets for C*larias gariepinus* fingerlings were formulated at 42% crude protein using the following fish feed ingredients; fish meal (FM), soybean meal (SM), maize meal (MM), ground nut cake meal (GNCM), watermelon peels meal (WMPM) and additives. Five experimental diets were formulated with watermelon peel meal replacing maize at varying inclusion levels; Diet 1 (DT1; 0%) as control, Diet 2 (DT2; 25%), Diet 3 (DT3; 50%), Diet 4 (DT4; 75%) and Diet 5 (DT5; 100%). All dietary ingredients were ground and mixed with cassava, lysine, methionine, vitamin-mineral premix and oil. Water was added gradually until a desirable paste-like consistency was obtained after which the mixture was pelletized through 2mm disc and sun dried. The pelletized feeds were then stored in air tight polythene bags, until required. Diet samples were subjected to proximate analysis.

**Table 1:** Gross composition of Experimental Diets to be fed to C*larias gariepinus* Fingerlings in Concrete ponds and Outdoor Hapas nets

| Ingredients | DT1 100MM:0WMP | DT2 75MM:25WMP | DT3 50MM:50WMP | DT4 25MM:75WMP | DT5 0MM:100WMP |
|---|---|---|---|---|---|
| Watermelon Peel | 0.00 | 4.50 | 9.00 | 13.30 | 18.00 |
| Maize meal | 18.00 | 13.30 | 9.00 | 4.50 | 0.00 |
| Fish meal | 18.00 | 18.00 | 18.00 | 18.00 | 18.00 |
| Soy bean meal | 31.91 | 31.91 | 31.91 | 31.91 | 31.91 |
| Groundnut cake | 20.09 | 20.09 | 20.09 | 20.09 | 20.09 |
| Cassava | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| Palm oil | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Mineral/Vitamin premix | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Lysine | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Methionine | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Total | 100 | 100 | 100 | 100 | 100 |

**Key**: MM – Maize meal, WMP – Watermelon Peels

## RESULTS

**Table 2:** Growth Performance of *Clarias gariepinus* fed varying inclusions levels of Watermelon Peel Meal based Diets in Concrete Ponds

| Par ameters | DT1 100MM:0 WMP | DT 2 75MM:25 WMP | DT3 50MM:50 WMP | DT4 25MM:75W MP | DT5 0MM:100 WMP | EMS | P value |
|---|---|---|---|---|---|---|---|
| MIW | 6.55 $^{a}$ | 6.55 $^{a}$ | 6.55 $^{a}$ | 6.55 $^{a}$ | 6.55 $^{a}$ | | 0.023 |
| MFW | 22.44 $^{e}$ | 23.51 $^{d}$ | 25.46 $^{c}$ | 31.71 $^{b}$ | 33.23 $^{a}$ | 0.0002 | 0.0000 |
| MWG | 15.96 $^{e}$ | 17.00 $^{d}$ | 18.96 $^{c}$ | 25 .30 $^{b}$ | 26.79 $^{a}$ | 0.0001 | 0.0000 |
| SGR | 1.66 $^{e}$ | 1.69 $^{d}$ | 1.82 $^{c}$ | 2.12 $^{b}$ | 2.17 $^{a}$ | 0.0001 | 0.0000 |
| FCR | 4.45 $^{a}$ | 3.93 $^{ab}$ | 2.79 $^{bc}$ | 2.11 $^{c}$ | 2.33 $^{c}$ | | 0.003 |
| PER | 0.53 $^{e}$ | 0.59 $^{d}$ | 0.66 $^{c}$ | 0.84 $^{b}$ | 0.92 $^{a}$ | 0.000 1 | 0.0000 |
| ANPU | 0.20 $^{a}$ | 0.13 $^{b}$ | 0.08 $^{e}$ | 0.10 $^{c}$ | 0.09 $^{d}$ | 0.0006 | 0.0374 |
| %Survival | 75.00 $^{b}$ | 78.33 $^{ab}$ | 93.33 $^{ab}$ | 96.67 $^{a}$ | 80.00 $^{ab}$ | | 0.023 |

**Means in the same row followed by the same superscripts are not significantly different (p>0.05)**

Key: MM = Maize Meal, WMP =Watermelon Peel, MIW = Mean initial weight, MFW = Mean final weight, MWG = Mean weight gain, SGR = Specific growth rate, FCR = Feed conversion ratio, PER = Protein efficiency ratio, ANPU = Apparent net protein utilization, %Survival = Survival rate, EMS = Error Mean Square

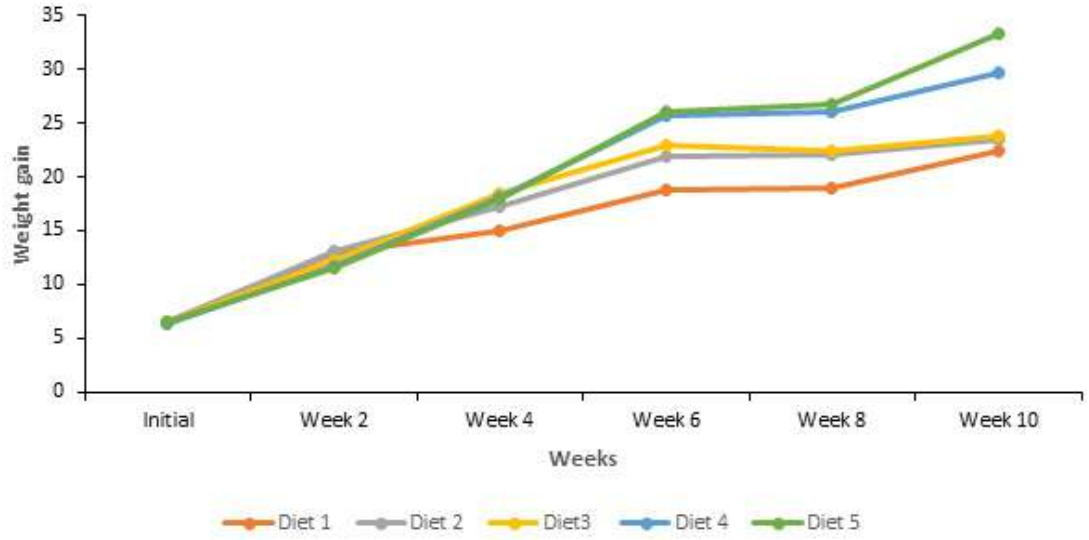



**Figure 1:** Weekly Growth Pattern of *Clarias gariepinus* fed varying inclusions levels of Watermelon (*Citrulls lanatus)* Peel Meal based Diet for Concrete Ponds

| Parameters | DT1 100MM:0 WMP | DT2 75MM:25 WMP | DT3 50MM:50W MP | DT4 25MM:7 5WMP | DT5 0MM:100 WMP | EMS | P value |
|---|---|---|---|---|---|---|---|
| MIW | 6.55 $^{a}$ | 6.55 $^{a}$ | 6.55 $^{a}$ | 6.55 $^{a}$ | 6.55 $^{a}$ | 0.0001 | 0.0001 |
| MFW | 24.70 $^{e}$ | 25.42 $^{d}$ | 31.30 $^{c}$ | 40.53 $^{b}$ | 43.30 $^{a}$ | 0.0252 | 0.0000 |
| MWG | 18.16 $^{d}$ | 18.79 $^{d}$ | 25.40 $^{c}$ | 33.48 $^{b}$ | 36.75 $^{a}$ | 0.1480 | 0.0000 |
| SGR | 1.85 $^{c}$ | 1.92 $^{c}$ | 2.25 $^{b}$ | 2.55 $^{a}$ | 2.56 $^{a}$ | 0.0011 | 0.0001 |
| FCR | 3.71 $^{a}$ | 3.37 $^{ab}$ | 2.65 $^{bc}$ | 2.08 $^{c}$ | 2.11 $^{c}$ | | 0.002 |
| PER | 0.46 $^{d}$ | 0.48 $^{d}$ | 0.64 $^{c}$ | 0.86 $^{b}$ | 0.92 $^{a}$ | 0.0001 | 0.0000 |
| ANPU | 0.26 $^{a}$ | 0.15 $^{d}$ | 0.22 $^{b}$ | 0.19 $^{c}$ | 0.19 $^{c}$ | 0.0001 | 0.0019 |
| %Survival | 81.67 $^{b}$ | 81.67 $^{b}$ | 93.33 $^{a}$ | 85.00 $^{ab}$ | 83.33 $^{ab}$ | | 0.037 |

Means in the same row followed by the same superscripts are not significantly different (p>0.05)

Key: MM = Maize Meal, WMP =Watermelon Peel, MIW = Mean initial weight, MFW = Mean final weight,

MWG = Mean weight gain, SGR = Specific growth rate, FCR = Feed conversion ratio, PER = Protein efficiency ratio, ANPU = Apparent net protein utilization, %Survival = Survival rate, EMS = Error

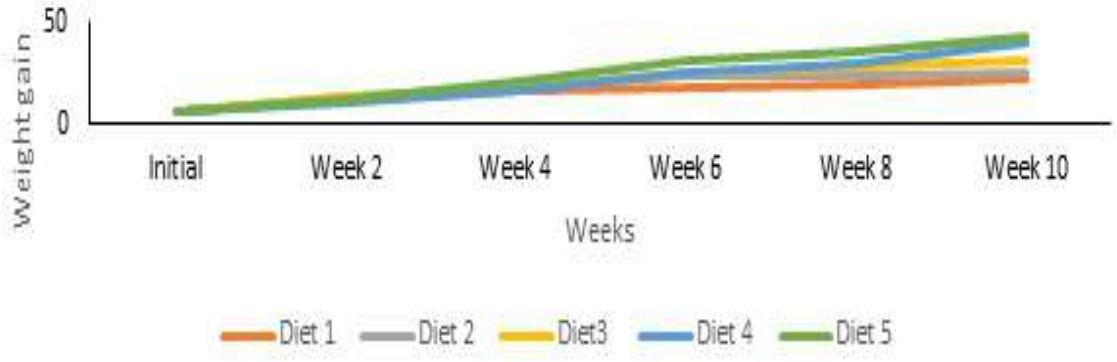



**Figure 2:** Weekly Growth Pattern of *Clarias gariepinus* fed varying inclusions levels of Watermelon (*Citrullus lanatus)* Peel Meal based Diet in Outdoor Hapas

**Table 4:** Haematological parameters of *Clarias gariepinus* fed varying inclusions of Watermelon Peel Meal based Diets in Concrete Ponds

| Parameters | DT 1 MM100:WMP0 | DT2 MM75:WMP25 | DT 3 MM50:WMP50 | DT4 MM25:WMP75 | DT 5 MM0:WMP100 | EMS | P-Value |
|---|---|---|---|---|---|---|---|
| PCV (%) | 22.99$^{a}$ | 22.99$^{a}$ | 22.99$^{a}$ | 20.00$^{c}$ | 22.00$^{b}$ | 0.0000 | 0.0000 |
| Hb (g/dl) | 8.30$^{a}$ | 7.21$^{c}$ | 7.61$^{b}$ | 6.40$^{d}$ | 7.19$^{c}$ | 0.0035 | 0.0000 |
| WBC(X10$^{3}$/ML) | 123.39$^{a}$ | 122.69$^{c}$ | 122.89$^{b}$ | 122.01$^{d}$ | 120.81$^{e}$ | 0.0000 | 0.0000 |
| MCV (fl) | 119.18$^{c}$ | 117.97$^{d}$ | 117.31$^{e}$ | 118.33$^{c}$ | 119.56$^{a}$ | 0.0000 | 0.0000 |
| MCH (g/dl) | 39.30$^{b}$ | 39.33$^{a}$ | 38.76$^{e}$ | 39.04$^{d}$ | 39.14$^{c}$ | 0.0000 | 0.0000 |
| MCHC (%) | 33.20$^{b}$ | 33.33$^{a}$ | 33.18$^{c}$ | 33.15$^{d}$ | 32.71$^{e}$ | 0.0000 | 0.0000 |
| TRBC(X10$^{12}$/L) | 1.98$^{a}$ | 1.82$^{d}$ | 1.95$^{b}$ | 1.67$^{e}$ | 1.85$^{c}$ | 0.0000 | 0.0000 |

**Means in the same row followed by the same superscripts are not significantly different (p>0.05)**
**Keys:** MM = Maize Meal, WMP = Watermelon Peel, EMS = Error Mean Square, MCV= Mean Cell Volume, MCH = Mean Cell Hemoglobin, MCHC = Mean Cell Hemoglobin Concentration, T. RBC = Total Red Blood Cell Count, PCV = Pack Cell Volume, Hb = Hemoglobin, WBC = White Blood Cell

**Table 5:** Haematological parameters of *Clarias gariepinus* fed varying inclusions levels of Watermelon Peel Meal based Diets in Outdoor Hapas nets

| Parameters | DT1 MM100:WMP0 | DT2 MM75:WMP25 | DT3 MM50:WMP50 | DT4 MM25:WMP75 | DT5 MM0:WMP100 | EMS | P-value |
|---|---|---|---|---|---|---|---|
| PCV (%) | 22.01$^{b}$ | 23.99$^{a}$ | 20.99$^{c}$ | 21.00$^{c}$ | 20.99$^{c}$ | 0.0001 | 0.0000 |
| Hb (g/dl) | 7.29$^{b}$ | 8.09$^{a}$ | 7.07$^{c}$ | 6.31$^{d}$ | 7.01$^{c}$ | 0.0058 | 0.0000 |
| WBC(X10$^{3}$/ML) | 122.61$^{b}$ | 124.81$^{a}$ | 121.89$^{c}$ | 119.29$^{e}$ | 120.79$^{d}$ | 0.0001 | 0.0000 |
| MCV (fl) | 118.26$^{d}$ | 121.81$^{c}$ | 1220$^{a}$ | 113.10$^{e}$ | 122.08$^{b}$ | 0.0001 | 0.0000 |
| MCH (g/dl) | 39.23$^{d}$ | 40.21$^{b}$ | 40.68$^{a}$ | 39.32$^{c}$ | 40.68$^{a}$ | 0.0001 | 0.0000 |
| MCHC (%) | 33.79$^{a}$ | 33.74$^{b}$ | 33.31$^{d}$ | 33.30$^{d}$ | 33.34$^{c}$ | 0.0001 | 0.0000 |
| TRBC(X10$^{12}$/L) | 1.87$^{b}$ | 1.98$^{a}$ | 1.86$^{b}$ | 1.78$^{c}$ | 1.71$^{d}$ | 0.0001 | 0.0000 |

**Means in the same row followed by the same superscripts are not significantly different (p>0.05)**
**Keys:** MM = Maize Meal, WMP = Watermelon Peel, EMS = Error Mean Square, MCV= Mean Cell Volume, MCH = Mean Cell Hemoglobin, MCHC = Mean Cell Hemoglobin Concentration, T. RBC = Total Red Blood Cell Count, PCV = Pack Cell Volume, Hb = Hemoglobin, WBC = White Blood Cell

## DISCUSSION

*Clarias gariepinus* fingerlings reared in the outdoor hapas nets demonstrated better growth performance compared to those reared in the concrete ponds even though the same quantity and quality of feed were administered in both rearing systems. This reflects the findings of Okunsebor *et al* (2013) who reported that C*larias gariepinus* fry reared in Hapa in-tank exhibited significantly superior growth than concrete tank. Ahmed *et al.,* (1997) also reported comparatively higher growth performance in hapa-in-tank (5.99 g) than the glass tank (3.74 g). Similarly, Agbebi *et al.,* (2009) successfully raised C*lariobranchus* fry in Hapa-in-tank and observed better growth performance at different stocking density. The variation in growth performances of C*larias gariepinus* in outdoor hapas to concrete ponds may be attributed to the availability of natural food (plankton) induced by decomposed and degraded uneaten artificial feed given to C*larias gariepinus* in the outdoor hapa nets. The high growth rate recorded for the fishes cultured in outdoor hapas nets suggest that, the fish grew faster in hapas than in concrete pond system which may be due to efficient water exchange as evident in the food conversion ratio (2.11) and specific growth rate (2.56) achieved which indicated effective feed utilization. Also, the best growth performance in hapas net systems may be due to limited swimming space which may enhance better accessibility to feed and less energy loss due to swimming and invariably better growth. In outdoor hapa system, all uneaten feed remained at the bottom and decompose with time.

Despite the higher fish weight gained recorded in the outdoor hapas net culture, the highest percentage survival rate 96.67% was recorded in treatment 4 (75% inclusion of water peel meal) in the concrete pond culture which is in agreement with previous researches which confirmed concrete ponds as best in term of survivability (Olanrewaju *et al*., 2009; Akinwande *et al*., 2009; Edward *et al*., 2010). High survival rate in the two culture systems indicated that C*larias gariepinus* is a hardy species and can survive stressful conditions.

The weekly growth pattern of C*larias gariepinus* fingerlings in the concrete ponds and outdoor hapas nets revealed significant difference in the weight of the fish at week two, four, six, eight and ten. The growth pattern was continuous as the experiment progressed, which is an indication that the diets were acceptable to the fish, also the environmental conditions of the culture systems were within the tolerable range for the fish. It may also indicate considerable stress tolerance in the culture species, because rearing systems made from net enclosures, especially in ponds are characterized by fouling, which stresses fish, especially by impairing water exchange and reducing dissolved oxygen Lovshin *et al.,* (1988).

Haematological parameters of the experimental fish from the concrete pond and outdoor happas nets revealed significant difference across the treatments. However, blood parameters were within the normal ranges for C*larias gariepinus*. Binukumari *et al.,* (2011) opined that blood chemistry and haematological measurement can provide valuable physiological indices that may offer critical feedback on different stressors. Rainzapaiva *et al.,* (2000) also opined that haematological characteristics of most fish have been studied and normal ranges values have been established and any deviation from the normal range may indicate disturbance in the physiological process. Haematological studies help in understanding the relationship of blood characteristics to the habitat and adaptability of the species to the environment. It is important to note that the fish's age, health, sex, diet, water quality, environmental conditions, and stress levels can influence the haematological parameters in individual fish. The haematological parameters for the experimental fish which were within the normal range is an indication that there was not much stress from the environment and the diet on the fish.

The blood biochemical parameters of *Clarias gariepinus* fingerlings reared in the concrete ponds and outdoor happas nets revealed significant difference across the treatments in the total protein and the glucose content.

The total protein content of the experimental fish may have been affected by water temperature, seasonal pattern, food, age or sex of the fish. In fish, proteins are among the main energy sources which play an important role in the maintenance of blood glucose, Shwetha *et al.,* (2012). The observed decrease in the total protein content of fish at 100% inclusion levels of watermelon peel meal in both culture systems could be linked with the level of anti-nutrients present in the diet. A similar trend was observed for albumin. Protein depletion in experimental animals (including fish) has been reported to be a physiological strategy in the animals to adapt to alterations in their metabolic systems. This leads to degradative processes such as proteolysis and utilization of degraded products for increased metabolism Yadav *et al.,* (2003); Adeyemo, (2005). In the present study, the slight decrease in the serum total protein and albumin levels might be due to their degradation and utilization for metabolic purposes.

The protein contain was high compared to the value reported by Abalaka (2013) for reared and wild C*larias gariepinus* respectively. Glucose was in line with the report of Abalaka (2013) for reared and wild C*larias gariepinus*. Albumin was higher compared with the report of Olanrewaju *et al.,* (2018) for *Heterotis niloticus*. Urea was also higher compared with the report of Olanrewaju *et al.,* (2018). Creatinine was lower compared to the report of Olanrewaju *et al.,* (2018).
Jawad *et al.,* (2004) opined that serum biochemistry varies from species to species and can be influenced by many biotic and abiotic factors such as water temperature, seasonal pattern, food, age and sex of the fish.

## CONCLUSION

Inclusion of watermelon peel meal at 100% in the two culture systems demonstrated the best growth parameters such as mean final weight 33.23g and 43.30g, mean weight gain 26.79g and 36.75g, specific growth rate 2.17g and 2.56g, protein efficiency ratio 0.92% and 0.92% and feed conversion ratio 2.33% and 2.11%. Best growth performance and nutrients utilization was observed in the fish raised in hapas nets while optimum survival rate was observed in the concrete pond culture system.

## RECOMMENDATIONS

Based on the findings of this study, it is therefore recommended that:

i. Inclusion of watermelon peel meal at 100% in the diet of C*larias gariepinus* fingerlings demonstrated the better growth in the mean final weight, mean weight gain, specific growth rate and protein efficiency ratio.
ii. Watermelon peel meal could be used to replace maize as an energy source in the diet of C*larias gariepinus* fingerlings without adverse effect.

The outdoor hapas net culture system remain the optimum system for enhanced growth of C*larias gariepinus* fingerlings while the concrete ponds remain the best in times of survival of C*larias gariepinus* fingerlings.

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# GROWTH PERFORMANCE OF *Coptodon zillii* FED OIL-BASED DIETS

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**ABSTRACT**
*Tilapia is an important aquaculture species in Nigeria, providing nutritional security and employment through various fisheries activities. However, high feed production costs hinder its large-scale cultivation. Fish oil (FO), rich in essential fatty acids and a key feed ingredient, is often wasted during fish processing. This study evaluated the effect of FO extracted from the fatty tissue of Clarias gariepinus on the growth performance of Coptodon zillii. Fingerlings of 180 C. zillii were reared in happa nets placed in an earthen pond. Four experimental diets containing 40% crude protein and varying FO inclusion levels (0%, 3%, 6%, and 9%) were fed at 5% body weight for 12 weeks. Growth parameters measured included mean weight gain (MWG), specific growth rate (SGR), and feed conversion ratio (FCR). Data were analysed using descriptive statistics and ANOVA at $p<0.05$. Results showed the highest MWG (41.50 ± 2.42 g) and SGR (0.85 ± 0.03%) in fish fed 3% FO, while the lowest values occurred at 9% FO. FCR was best (2.16 ± 0.20) in 3% FO and poorest (2.51 ± 0.04) in 9% FO. The study concludes that 3% FO inclusion optimizes the growth of C. zillii and is recommended for fish farmers.*

**Keywords:** Fish nutrition, aquaculture indices, fish feed, fatty tissue

## INTRODUCTION

Aquaculture is an important sector of food production. It provides nutritional security to the food basket, contributes to the agricultural exports and engages about 40 million people in different activities (Yadav *et al.*, 2019). The main goals of the aquaculture industry are to optimize growth and to produce high-quality fish (Bello *et al.*, 2012). Aquaculture has evolved as the fastest-growing food-producing sector, and developed as an important component in food security (Ibrahem *et al.*, 2010).
One major constraint of aquaculture production has been the cost of feed ingredients (Bbole *et al.*, 2-16). High cost of fish feed was observed as one of the problems hampering aquaculture development in Nigeria and fish feed account for at least 60% of the total cost of production (Gabreil *et al.*, 2007). This has motivated the research for alternative sources of fish feed ingredients for fishes that aim to reduce the cost of production without compromising fish quality.

Fish growth is considered as an integrated physiological response encompassing external environmental conditions (food quality and quantity, temperature, water quality) and internal physiological status (health, stress, reproductive state) (Sunam *et al.*, 2017). The growth trend in aquaculture production observed worldwide in recent years requires the development of affordable feeds that support fish growth and sustainable aquaculture production (Troell *et al.*, 2014).

Fish oil plays a major role in providing a source of concentrated energy, essential fatty acids, phospholipids, sterols, and fat-soluble vitamins, especially for fish, as they may have a limited ability to utilize carbohydrates as an energy source (Wang *et al.*, 2014).
In view of the above, the present research was set up with the objective of determining the growth performance of C*optodon zillii* fed oil-based diet. This research work is therefore carried out to evaluate the effect of fish oil extracted from fatty tissue of C*larias gariepinus* on C. *zillii* and also served as part of fish post-harvest effort of finding ways of utilizing a product that is considered as wasted.

## MATERIALS AND METHODS

### Fish oil Collection and Extraction

A total of 25kg of matured catfish (C*larias gariepinus*) was used. The fish were killed by percussive stunning (i.e hitting the fish head with a wooden club) according to Akinwumi (2023). Thereafter, their bodies were dissected and the fatty tissues were removed from their body. The fatty tissues of the fish were washed thoroughly, with tap water to remove the blood stain and then heated using a heating mantle (model: Electrothermal 300watt Cat No. EM1000/CE MK5) at $40^0$C for 25 minutes. The shafts were separated and the oil was decanted using mushing cloth. The oil was then put in a sterile bottle prior to use.

### Fish. feeding and sampling

Four diets containing varying levels of fish oil (0%, Control, 3% FO, 6% FO and 9% FO) as shown in table 1 were formulated. C*optodon zillii* fingerlings were acclimatized for 3 weeks to get them familiarized to the environment. After which a total of 180 pieces of C. *zillii* fingerlings of total weight 150.00±0.00 g were randomly allotted at 15 fingerlings per hapa in 12 sectional net of size $1.5m^2$ x $2m^2$ x $1m^2$ hapa, The four diets were fed to triplicate groups of fish at 5% body weight shared twice daily, in the morning and evening. The ration was adjusted bi-weekly when new mean weights of fish for the various experimental units were determined. The hapa were washed every week. Water quality parameters were monitored daily. The growth performance were determined according to Fasakin *et al.*, (2001); Aderolu *et al.*, (2009); Tiamiyu *et al.*, (2013); and Akinwumi and Eniade, 2014).

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### Water Quality

Water quality parameters were measured during the experiment. The temperature, dissolved oxygen, and the water pH were measured using the pH meter (pen-type pH meter pH-009 (I) A) and dissolved oxygen meter (Extech D0210), respectively.

### Statistical Analysis

Data was subjected to one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test for the separation of means at a significance level (P = 0.05) using Statistical Package for Social Science (SPSS version 23). The results were presented as mean ± SE (Standard error).

**Table 1:** Percentage composition of experimental diets.

| Ingredients | 0% Fish. Oil | 3% Fish Oil | 6% Fish Oil | 9%Fish Oil |
|---|---|---|---|---|
| Fish meal | 29.82 | 30.82 | 29.82 | 28.82 |
| Soya beans | 19.27 | 21.27 | 19.27 | 18.27 |
| Groundnut cake | 18.46 | 18.46 | 18.46 | 18.46 |
| Yellow maize | 11.44 | 11.44 | 11.44 | 10.44 |
| Rice bran | 9.51 | 9.51 | 9.51 | 9.51 |
| Vit/Min Premix | 1.50 | 1.50 | 1.50 | 1.50 |
| Starch | 2.50 | 2.50 | 2.50 | 2.50 |
| Salt | 0.50 | 0.50 | 0.50 | 0.50 |
| Bone meal | 1.00 | 1.00 | 1.00 | 1.00 |
| Vegetable Oil | 6.00 | - | - | - |
| Fish Oil | - | 3.00 | 6.00 | 9.00 |
| **TOTAL** | 100 | 100 | 100 | 100 |

## RESULTS

The data obtained on the growth performance of C*optodon zillii* fed fish oil-based feeds showed that the initial weights of the fish fed the experimental diets in all the groups were homogenous (Table 2).

**Table 2:** Growth Performance of *Coptodon zillii* fed experimental diets

| Growth parameter | 0% Fish Oil (0% FO)/Control | 3% Fish Oil (3% FO) | 6% Fish Oil (6% FO) | 9% Fish Oil (9% FO) | P value |
|---|---|---|---|---|---|
| Initial Weight (g) | 150.00±0.00$^a$ | 150.00±0.00$^a$ | 150.00±0.00$^a$ | 150.00±0.00$^a$ | - |
| Final Weight (g) | 555.45±0.94$^b$ | 618.00±29.10$^b$ | 443.82±16.04$^a$ | 418.52±19.35$^a$ | 0.000 |
| Initial Standard Length (cm) | 6.90±0.00$^a$ | 6.90±0.00$^a$ | 6.90±0.00$^a$ | 6.90±0.00$^a$ | 0.000 |
| Final Standard Length (cm) | 11.80±0.02$^b$ | 11.83±0.13$^b$ | 10.58±0.20$^a$ | 10.45±0.14$^a$ | 0.000 |
| Total Weight gain (g) | 435.45±13.94$^b$ | 498.00±29.10$^b$ | 323.82±16.04$^a$ | 298.52±19.35$^a$ | 0.000 |
| Mean Weight (g) | 37.85±0.26$^b$ | 41.50±2.42$^b$ | 26.99±1.34$^a$ | 25.88±1.03$^a$ | 0.000 |
| Mean daily Weight Gain (g) | 0.46±0.00$^b$ | 0.49±0.03$^b$ | 0.32±0.02$^a$ | 0.31±0.01$^a$ | 0.000 |
| Weekly Weight Gain (g) | 3.16±0.02$^b$ | 3.46±0.20$^b$ | 2.25±0.11$^a$ | 2.16±0.09$^a$ | 0.000 |
| Specific Growth rate (%) | 0.79±0.01$^b$ | 0.85±0.03$^b$ | 0.67±0.02$^a$ | 0.65±0.03$^a$ | 0.000 |
| Relative Growth rate (%) | 518.56±16.60$^b$ | 592.86±34.64$^b$ | 385.50±19.09$^a$ | 355.39±23.04$^a$ | 0.000 |
| Feed Conversion Ratio (%) | 2.40±0.09$^a$ | 2.16±0.20$^a$ | 2.45±0.17$^a$ | 2.51±0.04$^a$ | 0.365 |
| Number Stocked (n) | 15.00±0.00$^a$ | 15.00±0.00$^a$ | 15.00±0.00$^a$ | 15.00±0.00$^a$ | - |
| Number Harvested (n) | 14.00±0.33$^a$ | 12.00±0.00$^a$ | 12.00±0.00$^a$ | 14.00±033$^a$ | 0.596 |
| Survival Rate (%) | 97.23±2.77$^a$ | 100.00±0.00$^a$ | 100.00±0.00$^a$ | 97.23±2.77$^a$ | 0.596 |
| Initial Condition Factor (K) | 3.04±0.00$^a$ | 3.04±0.00$^a$ | 3.04±0.00$^a$ | 3.04±0.00$^a$ | - |
| Final Condition Factor (K) | 2.94±0.01$^a$ | 3.15±0.25$^a$ | 3.13±0.07$^a$ | 3.19±0.06$^a$ | 0.573 |
| Difference Condition factor (K) | -0.10±0.01$^a$ | 0.11±0.25$^a$ | 0.09±0.07$^a$ | 0.15±0.06$^a$ | 0.573 |

Value given in mean±standard error of triplicates. Figures in the same row having the same superscript are not significantly different (p>0.05)

However, the highest final weight was recorded in 3% FO (618g) while the lowest (418g) value was recorded in the 9% FO fish. There was no significant (p>0.05) difference in the mean weight gain in all the fish fed the fish oil-based diets. The specific growth rate and relative growth rate followed the same trend statistically. Feed Conversion Ratio showed no significant (p>0.05) difference in all the fish fed the experimental diets. There was no significant (p>0.05) difference in the survival rate of the experimental fishes. Nonetheless, the highest (100%) survival rates were obtained from 3% FO and 6% FO fed groups while the lowest (97.23%) values were recorded from 0% FO and 9% FO fed diets respectively. The initial and final condition factor showed no significant (p>0.05) differences in all the experimental fed fishes. There were significant (p<0.05) difference in the Dissolved Oxygen in all the fish fed the experimental diets except for 3% FO and 9% FO fed diets that showed no significant (p>0.05) difference for C. *zillii* (Table 3). The water Temperature in C. *zillii* showed no significant (p>0.05) difference between 6% FO and 9% FO fed diets but significantly different from 0% FO and 3% FO fed diets respectively. However, significant differences was observed in the pH of all the experimental fed diets except for 6% FO and 9% FO diets that showed no significant (p>0.05) different respectively.

**Table 3:** Physico-chemical in the culture system of *Coptodon zillii*

| Water Parameter | 0% Fish Oil (0% FO)/Control | 3% Fish Oil (3% FO) | 6% Fish Oil (6% FO) | 9% Fish Oil (9% FO) | P value |
|---|---|---|---|---|---|
| Dissolved Oxygen (mg/L) | 4.78+0.03$^a$ | 4.97+0.12$^{ab}$ | 5..32+0.18$^b$ | 5.05+0.03$^{ab}$ | 0.048 |
| Temperature ($^0$C) | 27.87+0.14$^b$ | 27.69+0.07$^{ab}$ | 27.57+0.04$^a$ | 27.44+0.04$^a$ | 0.022 |
| pH | 7.30+0.12$^c$ | 6.85+0.05$^b$ | 6.65+0.05$^a$ | 6.50+0.00$^a$ | 0.000 |

Value given in mean ±standard error of triplicates. Figures in the same row having the same superscript are not significantly different (p>0.05).

## DISCUSSION

The results obtained in this study showed that C*optodon zillii* was able to utilize the fish oil for growth. Significantly, better growths were achieved at relatively low inclusion level of fish oil compared to other

inclusion levels of fish oil. This observation contrasts with the findings of Vesal *et al.*, (2016) that recorded the highest growth at higher inclusion level of fish oil. The growth performance of C. *zillii* fed the experimental diets for 84 days as presented in Table 2 showed that there were significant differences ($p<0.05$) within the treatments with higher fish oil inclusion and low fish oil inclusion. In this experiment, the weight gain observed is in agreement with the work of Al-Souti *et al.* (2012) who recorded the lowest weight gain at higher inclusion level of fish oil. In terms of specific growth rate, the value recorded for this trial (0.65 – 0.85) are lower than those reported by several authors. Sagne *et al*. (2013) reported a value of 2.99 for 48% inclusion of fish oil in the diet of O*reochromis niloticus*. El-Tawil (2010) reported a SGR of 2.93 for 100% inclusion of fish oil in the diet of O*reochromis spp.* (Red tilapia). However, Al-Souti *et al.* (2012) reported SGR values ranging from 1.84 – 1.97 for O*reochromis spp.* (Hybrid Tilapia) fed 0-12% inclusion of fish oil. The highest feed conversion ratio recorded in this study was obtained from fish fed at highest inclusion level of fish oil. Al-Souti *et al.* (2012) reported that the highest feed conversion ratio in O. *niloticus* was observed at the lowest inclusion of fish oil, while Safamehr *et al*. (2008) recorded the highest feed conversion ratio at the lowest inclusion of fish oil.

## CONCLUSION

This study concluded that fatty tissues from C*larias gariepinus* generated as waste during fish processing can be turned into a valuable fish feed ingredient resource, while also reducing and recycling wastes. It is therefore, recommended that 3% FO containing diet is suitable for C. *zillii* without compromising growth rate.

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# BLACK SOLDIER FLY (*Hermetia illuciens*) FRASS: A POTENTIAL NUTRIENT SOURCE FOR FISH FEED

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**ABSTRACT**

*Feed remains the major cost component in fish production, creating the need for alternative, sustainable nutrient sources. Black soldier fly (Hermetia illucens, BSF) production generates a by-product known as frass, which may have potential as an animal feed ingredient. This study evaluated the proximate composition of BSF frass produced at the National Institute for Freshwater Fisheries Research (NIFFR), New Bussa, Nigeria. BSF larvae were reared on a substrate composed of a mixture of poultry manure and agro wastes (vegetable residues). Standard analytical procedures were used to determine crude protein, fat, fibre, ash, and carbohydrate contents. Proximate analysis revealed high crude protein (44.58 %), substantial fat content (22.83 %), moderate fibre (11.54 %), and low nitrogen-free extract (3.42 %). The results demonstrate that BSF frass can serve as an alternative nutrient source in livestock and aquaculture diets, thereby contributing to sustainable feed development and circular economy strategies.*

**Keywords**: Black Soldier Fly, Frass, Proximate composition, Animal feed

## INTRODUCTION

The rising cost of conventional feed ingredients remains a critical challenge to sustainable livestock and aquaculture production in Nigeria and globally. Feed accounts for up to 70% of the total cost of fish and poultry production, largely due to dependence on expensive protein sources such as soybean meal and fishmeal (Gabriel *et al.*, 2007). With increasing competition between humans, animals, and industry for these conventional ingredients, there is growing interest in identifying alternative, and sustainable nutrient sources that can reduce production costs without compromising animal performance. In this context, the black soldier fly (*Hermetia illucens*, BSF) and its by-products have attracted significant attention as viable solutions within the circular bioeconomy.

BSF larvae are widely recognized for their ability to efficiently convert organic waste into high-value biomass rich in protein and fat. In addition to larval biomass, the by-product of BSF production, commonly referred to as frass, consists of undigested feed residues, insect exuviae, and microbial biomass (Khusro *et al.*, 2012). Frass has traditionally been explored in soil amendment due to its nutrient and microbial content, but emerging evidence suggests that it may also serve as a valuable ingredient in animal feeds. Yildirim-Aksoy *et al.* (2022) reported frass containing approximately 21% crude protein.

Previous studies have shown that the nutrient composition of BSF frass varies significantly depending on the rearing substrate and processing conditions. For instance, a review by Gärttling & Schulz (2022) reported a wide variation in nutrient levels across frass products from different producers, particularly in macronutrient and micronutrient content (Salomon *et al.*, 2025).

Furthermore, BSF frass contains bioactive compounds such as chitin, which is derived from the exoskeletons and larval exuviae, and has been shown to stimulate immune responses in animals (Yildirim-Aksoy *et al.*, 2023).

Studies also indicate that frass harbours diverse and potentially beneficial microbial populations. For example, BSFL frass-based composts exhibit shifts in microbial community structure, likely due to its chitin-rich composition that supports chitin-degrading bacteria and fungi (Kenchanna *et al.*, 2024).

In Nigeria, studies on alternative feed ingredients have largely focused on plant-based proteins and BSF larvae meal, with limited attention given to frass as a potential feed resource. However, with the country facing rising demand for fish and livestock products amid persistent feed constraints, valorising frass could provide a low-cost, locally available, and sustainable solution. Internationally, the utilization of BSF frass has been linked to improvements in nutrient recycling, reductions in waste accumulation, and enhanced circularity in animal production systems (Müller *et al.*, 2019; Barragan-Fonseca *et al.*, 2020). These findings suggest that frass not only contributes nutritional value but also aligns with global goals for sustainable and climate-smart agriculture.

Despite these promising attributes, there remains limited empirical data on the nutritional potential of BSF frass in the Nigerian context. Most available reports focus on its agronomic benefits, leaving a knowledge gap on its suitability and variability as an animal feed resource. This study therefore seeks to characterize the proximate composition of BSF frass produced under local conditions at the National Institute for Freshwater Fisheries Research (NIFFR), New Bussa, Nigeria. By providing baseline data on its nutrient profile, this research aims to contribute evidence towards the inclusion of BSF frass in animal feed formulations, thereby promoting sustainable feed alternatives for aquaculture and livestock systems.

## MATERIALS AND METHODS

The study was carried out at the Black Soldier Fly (BSF) production facility of the National Institute for Freshwater Fisheries Research (NIFFR), New Bussa, Nigeria. BSF larvae were reared on a composite substrate consisting of poultry manure, maize bran, and vegetable residues, mixed in equal proportions by weight. The rearing process lasted ten days, after which the mature larvae were separated, and the frass was collected as residue from the rearing bins.

The samples were sieved to remove large substrate residues and air-dried before further processing. Proximate analysis of the samples was carried out at the NIFFR Central Laboratory, New Bussa, following the standard procedures of the Association of Official Analytical Chemists (AOAC, 2019). Moisture content was determined by oven-drying at 105 °C until a constant weight was obtained, while crude protein was estimated using the Kjeldahl method (N × 6.25). The fat content (ether extract) was analysed by Soxhlet extraction, and crude fibre was determined through sequential acid and alkali digestion. Ash content was obtained by incinerating samples in a muffle furnace at 550 °C. Nitrogen-free extract (NFE) was calculated by difference. All analyses were performed in triplicate, and the mean values were used for interpretation.

## RESULTS AND DISCUSSION

The proximate composition of the Black Soldier Fly frass is presented in Table 1. The frass was found to contain 44.58 % crude protein, 22.83 % fat, 11.54 % crude fibre, 1.20 % ash, and 3.42 % nitrogen-free extract, while the moisture content was 17.10 %.

**Table 1:** Proximate composition of *Hermetia illucens* frass

| Parameter | Composition (%) |
|---|---|
| Moisture | 17.10±0.33 |
| Crude Protein | 44.58±1.81 |
| Crude Fat (Ether Extract) | 22.83±0.04 |
| Crude Fibre | 11.54±0.43 |
| Ash | 1.20±0.02 |
| Nitrogen -Free Extract (Carbohydrate) | 3.42± 1.09 |

The results of this study demonstrate that BSF frass has considerable potential as an alternative nutrient source for animal feed. The crude protein value obtained (44.58 %) is notably higher than those reported in earlier studies, such as Yildirim-Aksoy *et al*. (2022), who found about 21 % protein in frass from BSF larvae reared on distillers' grains. Instead, the protein level in this study closely matches that reported by Romano *et al*. (2023), who observed crude protein values of approximately 45 % in frass samples. This finding highlights the strong influence of rearing substrate and management practices on the nutrient composition of BSF frass. Similarly, the fat content (22.83 %) is much higher than typical ranges (6–15 %) documented in literature, suggesting the presence of residual larval biomass or a nutrient-rich rearing substrate. The moderate fibre (11.54 %) provides functional dietary roughage, which is particularly valuable for ruminants but may restrict inclusion levels in monogastric diets if used excessively.

Beyond its proximate composition, frass also provides functional benefits such as chitin and beneficial microbial communities that can positively affect gut health and immunity in animals (Khusro *et al*., 2020). These attributes, together with its high protein and energy levels, position frass as more than just a waste by-product, but rather a valuable feed resource within the circular bioeconomy. In the Nigerian context, where feed constitutes the largest share of production costs in aquaculture and livestock farming, the valorisation of BSF frass as feed could provide significant cost savings and reduce reliance on conventional ingredients such as soybean meal and fishmeal (Gabriel *et al*., 2020). However, further work is needed to evaluate digestibility, amino acid composition, and animal performance when frass is included in diets, so as to establish safe and optimal inclusion levels across different livestock and aquaculture systems.

## CONCLUSION

This study has shown that BSF frass produced under Nigerian conditions contains appreciable levels of protein, fibre, minerals, and carbohydrates, underscoring its potential as a supplementary nutrient source in fish feeding. Incorporating BSF frass into feed systems aligns with the principles of sustainable and circular agriculture while offering cost-saving opportunities for livestock and aquaculture production.

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# EFFECT OF DIFFERENT INCLUSION LEVELS OF MAXIGRAIN® IN FORMULATED FEED ON NUTRIENT UTILIZATION OF AFRICAN CATFISH (*Clarias gariepinus*: Burchell, 1822) JUVENILES

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**ABSTRACT**
*The study on effect of different inclusion levels of Maxigrain® in formulated feed on nutrient utilization and percentage survival rate of Clarias gariepinus (burchell, 1822) juveniles was carried out at the Experimental Farm of the Department of Aquaculture and Fisheries Management of the Faculty of Agriculture, Nasarawa State University Keffi, Shabu-Lafia Campus. The experiment lasted for twelve weeks. Twenty (20) Clarias gariepinus of average weight of 10±0.25g were selected at random and placed in five treatments in three replicates in a Completely Randomized Design (CRD). A formulated basal diet of 40% Crude protein was supplemented with 0g/kg, 1.0g/kg, 1.50g/kg, 2.00g/kg and 2.50g/kg of Maxigrain® designated as T1, T2, T3, T4, and T5 respectively. Growth and nutrient utilization performance of fish were determined. The results showed that enzymes maxigrain at 2.5g/l inclusion in the diets of C. gariepinus improves growth and utilization of fish than other treatments including the control. The growth of C. gariepinus at 2.5g/kg was recorded highest weight gain (88.23g), Percentage Mean Weight Gain (999.07%), Specific Growth Rate (2.66), and condition factor (3.46). In terms of nutrient utilization, the fish fed with diets at 2.5g/kg enzymes inclusion had low feed intake (39.52g), low FCR (1.12), PER (0.024), and FER (89.23). The results of the study recommend that Clarias gariepinus diets should be formulated with 2.5g/kg of enzymes maxigrain for better feed efficiency, and better feed utilization. More research should be carried out on enzymes maxigrain inclusion in the diets of other fish species.*

**Keywords:** Enzymes, Feed, Utilization, Nutrient, Catfish

## INTRODUCTION

Aquaculture in developing countries like Nigeria is expanding, accompanied with supplementary feeding as an important part for higher productivity, and now accounts for at least 60%. The total cost of fish production in Africa, determines the viability and profitability of fish farming enterprise (Jimoh *et al.*, 2013). According to NRC (1993) fish feed constituents among which there is fish meal is about 40-60% of the recurrent cost of most intensive fish farming ventures, and can sometimes negate the economic viability of a farm if suitable alternative feed are not used (Bello *et al.*, 2014). As a result, there is a need to look resourcefully, outwards to explore, identify and utilize other resources which are cheaper and less competitive. Various attempts have been made to reduce this high cost of fish by introducing bio-substances into unconventional fish feed stuffs. Enzymes play a key role in the food industry, responsible for desirable and undesirable chemical reactions. These compounds can occur spontaneously in food products or even be incorporated on purpose.

Majority of feed ingredients contains high fibre and antinutritional factors which when enzymes are added to them could make it palatable and consumable to fish. Some of the enzymes that have been used and found beneficial include glycanases, xylases, phytase, cellulolase, protease, Maxigrain enzymes, hemi-cellulose (Sabo *et al.*, 2017). Kehinde *et al.* (2013) reported better performance for broilers fed fermented rice offal supplemented with Maxigrain® enzyme compared with the un-processed, reground and cooked rice offal. The aim of the study is to determine the effect of different inclusion levels of maxigrain on formulated feed for utilization of C*larias gariepinus* juveniles.

## MATERIALS AND METHODS

### Description of Study Area

The experiment was carried out at the Experimental Farm of the Department of Aquaculture and Fisheries Management of the Faculty of Agriculture, Nasarawa State University Keffi, Shabu-Lafia Campus.

### Experimental Design

Three hundred juveniles of C*larias gariepinus* were purchased from Odys fish farm at Danka Sarki along Kwandere road, Lafia. The fish were acclimatized for one week prior to the day of starting the experiment. Twenty fish of average weight of 10±0.25g were selected at random and placed in five treatments in three replicates in a Completely Randomized Design (CRD). Data were collected every week for the period of twelve weeks. Weight and length of fish were taken and recorded with a meter rule and weigh balance before and after the experiment. Water quality check was regularly checked during the feeding period.

### Preparation of Experimental Diet

A formulated diet of 40%CP was prepared at 0g/kg, 0.1g/kg, 0.15g/kg, 0.20g/kg and 0.25g/kg inclusion level of maxigrain representing T1, T2, T3, T4, and T5 respectively. The feed contain other ingredients as fish meal, GNS, SBC, maize, blood meal, palm oil, vitamin premix, and cassava as binder. All ingredients were milled into small particle size and weighed with a sensitive weighing balance (Metler Toledo PB 8001 London). The ingredients were thoroughly mixed to obtain a homogeneous mass and extruded with the aid of extruder machine. The pellets were dried and stored in air-tight polythene bags to avoid rancidity. The bags were labeled and stored prior to the commencement of the experiment.

**Table 1:** Experimental Diet using Different Inclusion of Maxigrain Enzymes

| S/N | Ingredients | Inclusion level | | | | |
|---|---|---|---|---|---|---|
| | | T1 | T2 | T3 | T4 | T5 |
| 1 | SBC | 30 | 30 | 30 | 30 | 30 |
| 2 | GNC | 27 | 27 | 27 | 27 | 27 |
| 3 | Fishmeal | 15 | 15 | 15 | 15 | 15 |
| 4 | Blood meal | 05 | 05 | 05 | 05 | 05 |
| 5 | Maize bran | 10 | 10 | 10 | 10 | 10 |
| 6 | Cassava | 12 | 12 | 12 | 12 | 12 |
| 7 | Bone meal | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 8 | Methionine | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 9 | Vitamin C | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 10 | Lysine | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 11 | Salt | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 12 | Oil | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 13 | Ingredient Weight (Kg) | 100 | 100 | 100 | 100 | 100 |
| 14 | Maxigrain (Enzymes) | 0g/kg | 1.0g/kg | 1.50g/kg | 2.00g/kg | 2.50g/kg |

### Determination of Growth Parameter

Growth performance indices were evaluated as shown below:

a) Weight gain: Final weight ($W_2$) – initial weight ($W_1$)

b) Percentage Weight Gain (PWG): $[(W_2 - W_1)/ W_1)] \times 100$

c) Feed Conversion (FC) = $\frac{\text{Weight of feed consumed}}{\text{Weight gain of fish}}$

d) Feed Efficiency = 1/FC X 100

e) Protein Intake (PI) = %CP in diet X Feed intake

f) Protein Efficiency (PE) = $\frac{\text{Weight Gain}}{\text{Protein Intake}}$

g) Specific Growth Rate (SGR) = $\frac{\text{Log}W_2 - \text{Log}W_1}{\text{Time (days)}}$

h) Survival Rate (%): Survival rate (%) was calculated as total fish number harvested and divided by total fish number stocked, expressed in percentage as follows:

i) Survival (%) = $\frac{\text{Total fish no. harvested}}{\text{Total fish number stocked}}$ X 100

j) Condition Factor = $\frac{\text{Weight of Fish}}{L^3}$ X 100

Where L = Length of fish

**Statistical Analysis**

The data collected was subjected Analysis of Variances (ANOVA) using STAR (Statistical Tool for Agricultural Research) package and the significance means were separated at 5% confidence level.

## RESULTS

**Proximate Composition of Experimental Diets treated with different inclusion of maxigarin**

The results in Table 1 present proximate composition of experimental diets formulated with treated Maxigrain enzymes at different level. The results showed significant differences in the values of proximate composition of the diets.

**Table 2:** Proximate Composition of Experimental Diets treated different level of maxigrain

| Parameters | T1 (0g/kg) | T2 (1g/kg) | T3 (1.5g/kg) | T4 (2.0g/k) | T5 (2.5g/kg) | SEM | P-value |
|---|---|---|---|---|---|---|---|
| **% Moisture** | 3.38±0.05 $^{c}$ | 3.28±0.04 $^{c}$ | 3.65±0.04 $^{b}$ | 3.33±0.04 $^{c}$ | 3.83±0.03 $^{a}$ | 0.21 | 0.000 |
| **%Ash** | 15.75±0.32 $^{a}$ | 13.5±0.21 $^{b}$ | 12.20±0.23 $^{b}$ | 11.70±0.25 $^{c}$ | 10.85±0.31 $^{c}$ | 1.71 | 0.001 |
| **%Fat** | 7.75± 0.23 $^{a}$ | 5.85±0.29 $^{b}$ | 5.75±0.11 $^{b}$ | 5.52±0.17 $^{b}$ | 5.21±0.21 $^{c}$ | 0.89 | 0.001 |
| **% C.P** | 37.63±1.21 $^{e}$ | 39.78±1.22 $^{d}$ | 40.93±0.16 $^{c}$ | 42.2±0.21 $^{b}$ | 43.10±0.12 $^{a}$ | 1.91 | 0.001 |
| **%C.F** | 9.77±0.13 $^{a}$ | 8.20±0.31 $^{b}$ | 7.65±0.21 $^{c}$ | 6.01±0.22 $^{d}$ | 4.60±0.24 $^{e}$ | 1.79 | 0.000 |
| **%CHO** | 15.73±0.32 $^{d}$ | 29.83±0.25 $^{c}$ | 29.82±0.42 $^{c}$ | 31.24±0.32 $^{b}$ | 32.41±0.26 $^{a}$ | 6.12 | 0.001 |

Means with the same letter are not significantly different (P>0.0) from each other
C.P = Crude protein, C.F = crude fibre, CHO = Carbohydrate

**Percentage Mean Weight Gain of *Clarias gariepinus* fed Experimental Diets**

Figure 1 present the results of mean weight gain of fish fed diets treated enzymes Maxigrain. The results showed significant differences in values of percentage weight gain across treatments. The fish that were fed diets in T5 (999.07%) were recorded as the highest in %MWG, while the fish fed with 0% inclusion of enzymes were having the lowest %MWG (435,92%) respectively.

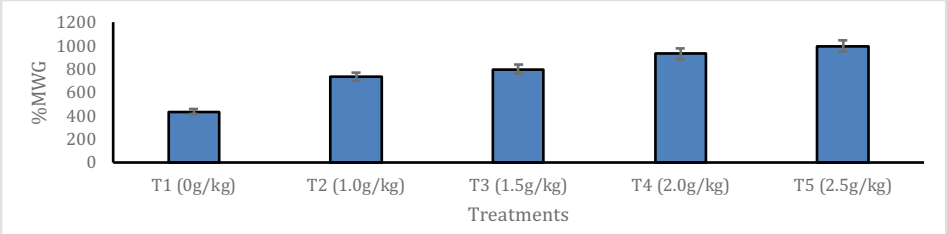



**Figure 1:** Percentage Mean Weight Gain of *Clarias gariepinus* fed Enzymes Maxigrain treated Diets

**The Condition Factor of *Clarias gariepinus* fed Experimental Diets treated with enzymes Maxigrain**

The figure 2 below showed the results of condition factor of fish recorded in the study. The results indicated significant differences (P<0.5) in the values of condition factor. Fish fed T5 (3.46) was recorded with the highest condition factor followed by T2 (2.78) while the control (1.91) was recorded with the lowest respectively. The fish fed with diets in T3 (2.51)

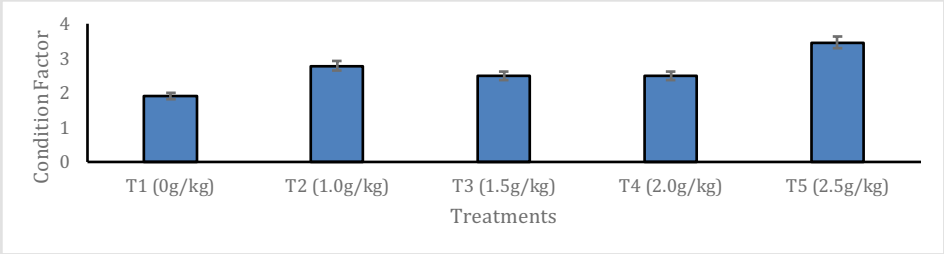



**Figure 2:** Condition Factor of *Clarias gariepinus* fed experimental diets containing maxigrain

**Specific Growth Rate of *Clarias gariepinus* fed Experimental Diets**

The results in Figure 3 below represent the results of specific growth rate of *Clarias gariepinus* juveniles fed with enzymes maxigrain treated diets. There were significant variations (P<0.05) in the specific growth rate of fish. The fish in T5 (2.66%) were recorded highest in SGR followed by T4 (2.59%), T3 (2.44%), T2 (2.36%) while T1 (1.86%) was recorded as the lowest respectively. the results of specific growth rate of fish increase with increase in inclusion level of enzymes maxigrain in the diets of the experimental fish.

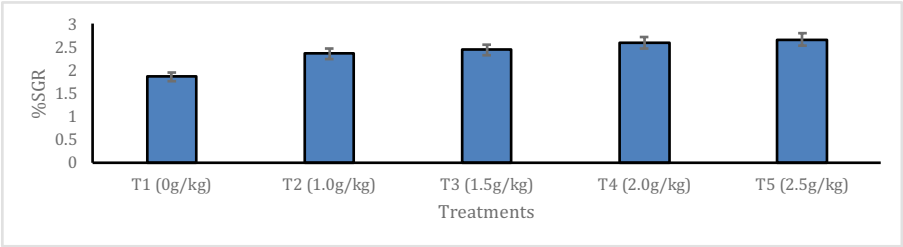



**Figure 3:** Specific Growth Rate of *Clarias gariepinus* fed Experimental Diets containing enzymes maxigrain

**Growth Performance of *Clarias gariepinus* fed Enzymes treated Diets at varying inclusion level**

The table 2 below showed the growth performance of *Clarias gariepinus* fed experimental diets containing varying inclusion of enzymes maxigrain. The initial weight of fish used in the study were not significantly different (P>0.05 from each other. but at the end of the study period, the final weight of fish showed significant differences (P<0.05) across treatments where by fish fed T5 (97.97g) had the highest final weight than other treatments including the control (43.48g) respectively. The fish fed T2, T3 and T4 obtained 64.47g, 76.71g and 80.49g respectively with significant variation (P<0.05) from each other. The weight gain of fish was recorded highest in T5 (88.23g) followed by T4 (72.69g) while the lowest was observed in T1 (35.37g) respectively. In terms of initial length of fish, no significant differences was observed across treatments. Final length of fish showed significant differences (P<0.5) in which the highest length was recorded in T5 (21.03cm) while the lowest (19.37cm) respectively. The fish feed T4 (2.36cm) had the highest increase in length followed by T3 (2.19cm) while the lowest was recorded in T1 (1.74cm) respectively.

**Table 2:** Growth Performance of C*larias gariepinus* fed Enzymes treated Diets at varying inclusion level

| Parameters | T1 | T2 | T3 | T4 | T5 | SEM | Pvalue |
|---|---|---|---|---|---|---|---|
| **Initial Weight** | 8.11±0.10 [a] | 7.71±0.11 [a] | 8.52±0.12 [a] | 7.80±0.11 [a] | 8.83±0.13 [a] | 3.33 | 0.190 |
| **Final Weight** | 43.48±1.83 [d] | 64.47±1.22 [c] | 76.71±1.04 [b] | 80.49±1.96 [b] | 97.07 ±1.99 [a] | 0.116 | 0.000 |
| **Weight Gain** | 35.37±1.03 [d] | 56.76±0.99 [c] | 68.19±0.12 [b] | 72.69 ±0.16 [b] | 88.23±0.11 [a] | 3.24 | 0.000 |
| **Initial Length** | 7.07±0.11 [a] | 7.01±0.12 [a] | 6.39±0.98 [a] | 6.07±0.11 [a] | 7.36±.11 [a] | 0.3081 | 0.200 |
| **Final Length** | 19.37±0.86 [c] | 19.7±0.95 [bc] | 20.35±0.67 [ab] | 20.34±0.97 [ab] | 21.03±0.73 [a] | 0.367 | 0.000 |
| **Increase in Length** | 1.74±0.00 [b] | 1.81±0.05 [b] | 2.19±0.09 [a] | 2.35±0.05 [a] | 1.87±0.03 [b] | 0.125 | 0.000 |

Means with the same letter are not significantly different (P>0.0) from each other

**Feed Utilization of *Clarias gariepinus* fed enzymes treated Diets**

The results in Table 3 showed the utilization of feed given to C*larias gariepinus* juveniles. The results showed significant differences (P<0.05) in the values of feed intake, feed conversion, protein efficiency and feed efficiency ratio. Fish fed T2, T3 and T4 also showed significant differences (P<0.05) and the intake were 63.22g, 78.35g and 88.74g respectively. Feed conversion of fish showed significant differences (P<0.05) among treatments. The FCR of fish in the control (1.65) was higher than fish feed diets with enzymes supplemented diets and the lowest FCR was recorded in T5 (1.12) respectively. PER was observed highest in T5 (0.024) and lowest T1 (0.01) respectively with significant differences (P<0.05) from each other. Other treatments showed slight differences in the values of PER. The fish in T2 (89.86) had the highest FER followed by T5 (89.23) with no significant differences (P>0.05) from each other and the lowest was recorded in fish fed diets without enzymes inclusion.

**Table 3:** Feed Utilization of C*larias gariepinus* fed Experimental Diets at varying inclusion of maxigrain

| **Parameters** | **T1** | **T2** | **T3** | **T4** | **T5** | **SEM** | **P-value** |
|---|---|---|---|---|---|---|---|
| **Feed Intake (g)** | 145.45±3.24 [a] | 63.22±1.41 [d] | 78.35±0 .99[c] | 88.74±1.54 [b] | 39.75±1.32 [e] | 2.86 | 0.000 |
| **FCR** | 1.65±0.06 [a] | 1.12±0.07 [b] | 1.15±0.04 [b] | 1.22±0.04 [b] | 1.12±0.06 [b] | 0.057 | 0.001 |
| **PER** | 0.01±0.00 [d] | 0.023±0.00 [ab] | 0.021±0.00 [bc] | 0.020±0.00 [c] | 0.024±0.00 [a] | 0.001 | 0.003 |
| **FER** | 60.66±1.78 [b] | 89.86±1.89 [a] | 87.24±2.07 [a] | 82.32±2.06 [a] | 89.23±2.83 [a] | 3.92 | 0.001 |

Means with the same letter are not significantly different (P>0.0) from each other

## DISCUSSION

Moisture content is the total amount water present in a food material usually expressed in percentage. When a sample moisture is low, it extends the shelf life of the product. This study revealed an amount lower than the research conducted by Sadiq *et al.* (2021) who reported 11.50%. Higher moisture content leads to microbial growth, and accelerate chemical reaction or degradation process. The differences obtained in the results compared could be attributed to methods of processing. The ash content is the inorganic content of mineral that does not volatize after subjecting the sample to high temperature. The ash content in the study decreased as the inclusion of enzymes increase, and the results of the study is similar to the report Sadiq *et al.* (2021). The value of ash content in the study suggests that the enzymes had effect in diets constituents for fish. Crude fibre determined the non-digestible plant cell wall component usually cellulose, hemicellulose and lignin, it is important for fish health and gut function. Recent study conducted by Adesina *et al.* (2020) made it clear that any ingredient with a low fibrous feed can affect digestion and cause reduction in the number of undigested materials in the digestive tract. The amount of crude fibre in the study was as low as 4.60% in treatments containing the highest inclusion level of enzymes compared to the control which is significant enough to improve the digestion in *Clarias gariepinus* according to Sadiq *et al.* (2021). The NFE represent non-fibrous carbohydrate, primarily sugars and starches as well as non- nitrogeneous, digestible organic substances in food. With the content of

fibre recorded in the study, it's an indication of high proportion of digestible carbohydrate and sugars in fish feed (Salua *et al.*, 2024).

In this study, there was an increase in final mean and body weight gain with an increased level of enzymes maxigrain. In term of length, the highest percentage of length increase were observed in fish fed treated diets and the fish grow in proportion to the weight of fish. The fact that weight gain was reported in all the treatments was an indication that the fish responded positively to all the diets and that the protein content of the experimental diets adequately provided for growth and dietary energy supply of the fish (Dambatta *et al.*, 2022).

Feed intake is important in the sense that it is the determinant of its performance. The feed conversion ratio was better in fish fed enzyme treated diets, in contrast to the finding in Oladipupo and Salami (2020) who reported that fish show better feed conversion ratio in the control diets. The study shows that there is increase in the PER as the inclusion of enzymes increases in the diet. This result agrees with the report of Olaniyi *et al.* (2009) who indicated that the higher the SGR the smaller the FCR values, the better the feed quality on C*larias gariepinus* fed different inclusion levels of mucuna seed meal. The SGR of C*larias gariepnius* in the study was higher in enzymes treated diets than values recorded in the control diets. There was an increase in SGR as the inclusion level of enzymes increases in the diets. The highest condition factor of the diets showed that fish fed highest enzymes inclusion was the best and this observation showed that the presence of enzymes improve nutrient digestibility leading to netter growth and over all well-being.

## CONCLUSION

The results obtained in the growth performance of fish showed that enzymes improves digestion, nutrient utilization and feed efficiency of fish. Fish fed the highest inclusion level of enzymes had the best growth performance compared to other treatments and control. The result of the study showed that enzymes inclusion in the diets of C*larias gariepinus* improves the feed efficiency and nutrient utilization. The result of the water quality parameters recorded at the end of the study indicated that the water quality parameters were at recommended levels.

## RECOMMENDATION

The results of the study recommend that C*larias gariepinus* diets should be formulated with 2.5g/kg of enzymes maxigrain for better feed efficiency, better feed utilization and digestibility. More research should be carried out on enzymes maxigrain inclusion in the diets of other fish species.

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# SURVIVAL AND GROWTH PERFORMANCE OF *Oreochromis niloticus* FED DIETS SUPPLEMENTED WITH DIFFERENT LEVELS OF METHYL TESTOSTERONE AND *Aloe vera* GEL

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**ABSTRACT**
*This study investigated the effects of dietary supplementation with methyl testosterone (MT) and Aloe vera gel on the growth performance and survival of Oreochromis niloticus fingerlings. A total of (420) fingerlings with an average initial weight of (2 grams) were stocked into (21) experimental tanks and reared for (6 months) under controlled conditions. Aloe vera gel 2.5mls,3.75mls and 5.0mls\250g), diets were formulated with graded levels of MT (25mls,50mls and 75mls /250g) and while a basal diet without supplementation served as the control. Growth parameters including weight gain, specific growth rate (SGR) and feed conversion ratio (FCR) were assessed, while survival was monitored throughout the trial. The results revealed that MT supplementation significantly ($p \leq 0.05$) enhanced survival rate at (75mls) concentration level with highest survival of (93.3%) and growth performance, with the best results obtained at (75ml (MTH) diet group's, final weight (275.14g), weight gain (268.34g) and feed conversion ratio of (1.60). Aloe vera gel 2.5mls (ALV) in tilapia diet gave the best growth and feed utilization as observed final weight gain (234.48g), weight gain (227.58g) and feed conversion ratio (1.81), and also highest survival rate (95%) compared to the control. Excessive MT supplementation, however, reduced survival. The findings suggest that the use of Aloe vera gel can enhance both growth and survival of O. niloticus, contributing to sustainable tilapia aquaculture.*

**Keywords:** *Oreochromis niloticus, Methyl testosterone, Aloe vera gel, Growth performance, Survival, Aquaculture.*

## INTRODUCTION

Tilapia (*Oreochromis niloticus*) is one of the most important species in global aquaculture due to its rapid growth, adaptability, and consumer acceptance. High yields potentials, resistance to diseases, are among the many reasons for their acceptability and widespread culture (El-Sayed, 2006). However, challenges such as poor growth efficiency, stress, and mortality limit production. To overcome these challenges, synthetic hormones and natural plant extracts have been explored as feed additives. Methyl testosterone (MT) is commonly used in tilapia farming to promote sex reversal and enhance growth performance. Despite its benefits, concerns exist regarding its effect on fish health and survival when administered at excessive levels. Methyl testosterone hormone (MTH) is reported to cause gonadal malformation when administered at high doses or over a prolonged period (Zaki *et al.*, 2021).

On the other hand, *Aloe vera*, a natural medicinal plant rich in bioactive compounds, has shown potential as an immunostimulant and growth promoter in aquaculture. Substitution of synthetic steroids with locally available natural hormones may give a better solution to dangers associated to using synthetic steroids. This study aimed to evaluate the effects of MT and *Aloe vera* gel supplementation on survival and growth performance of O. *niloticus* fingerlings, with a view to determining their optimal inclusion levels for sustainable aquaculture.

## MATERIALS AND METHODS

### Source, Collection and extraction of *Aloe vera* gel and phytochemical Screening

*Aloe vera* leaves (i.e *Aloe barbadensis*) were obtained from National Agricultural Extension Research and

Liaison services (NEARLS) garden Ahmadu Bello University Zaria (ABU ZARIA). The leaves were taken to Herbarium lab at the department of botany (ABU ZARIA) for identification. Phytochemical screening was carried at Kaduna State University.

**Hatchery Management of Fry**

A total of 420 Newly hatched fry of tilapia were obtained from Bagauda farm Kano and transported to fisheries and Aquaculture unit, National Agricultural Extension Research and Liaison services, Ahmadu Bello University Zaria, Nigeria. Twenty-one (21) plastic containers of twenty (20) liters were used to divide the Four hundred and twenty (420) Nile tilapia hatchlings (fry) randomly into six (6) treatment groups and a control.

**Experimental Feed Formulation:**

**Experimental Feed Containing 17-αMethyl testosterone Hormone (Treatment A):**

3grams of 17-αMethyl testosterone Hormone was dissolved in 2 liters of 95% ethyl Alcohol. 25mls,50mls and 75mls from the stock solution was use to mix 250gram each of commercial fry feed (0.1mm) and sprayed for the Alcohol to evaporate (Fuentes Silva *et al*.,2013).

**Experimental Feed Containing *Aloe vera* gel (ALV) (Treatment B):**

*Aloe vera* gel was scrapped and blended for a homogenous liquid, a measuring cylinder was used to measured 2.5mls,3.75mls and 5mls of the gel and mixed each with 250g of commercial feed (Prasad,2013).

**Ethical clearance and approval**

Ethical clearance was obtained from Ahmadu Bello University Committee on animal Use and Care (ABUCAUC) for permission.

**Experimental set-up**

The fry was divided into two experimental group. 17-αMethyl testosterone hormone diet (MTH) and *Aloe vera* (ALV) diet with a control. Each of the group were sub-divided into three and triplicated following their experimental feed 's concentration for two (2) month and commercial diets for four (4) month. All water quality parameters, and growth were monitored using standard methods. The research lasted for a period of six (6) months.

**Survival and Growth measurements**

Percentage survival was determined as cumulative survival divided by total number of fish stocked multiply by hundred.

$$\text{Survival (\%)} = \frac{\text{(fish stocked) - (mortality)}}{\text{fish stocked}} \times 100$$ Yisa *et al*. (2010).

Growth performance was assessed through weight gain, specific growth rate (SGR) and feed conversion ratio (FCR). Standard procedures were employed during measurements of fish.

**Statistical analysis**

Data were subjected to one-way ANOVA, and treatment means were separated using Duncan's multiple range test. Significance was accepted at ($p \leq 0.05$).

**RESULTS**

**Mean Percentage Survivability of Masculinized O. *niloticus***

The percentage survival of O. *niloticus* fed diet supplemented diets with different level of methyl testosterone (MTH) and *Aloe vera* (ALV) is presented in figure 1.1. Diet supplemented with 75 ml

(MTH) induced the highest percentage of survival (93.3%) amongst the methyl testosterone groups. Diet supplemented with 2.5ml (ALV) had 95% survival rate. There was significant difference in percentage survival ($p<0.05$).

**Growth Response and Feed Utilization of Methyl Testosterone and *Aloe vera* gel Meals of Masculinized O.*niloticus***

The growth and feed utilization parameters of O.*niloticus* fed different diets supplemented with different Methyl testosterone and *Aloe vera* gel levels is presented in Table 1.1. The final weight, weight gain, and feed conversion ratio of experimental fish were significantly ($p\leq0.05$) influenced by different levels of Methyl testosterone and *Aloe vera* gel diets.

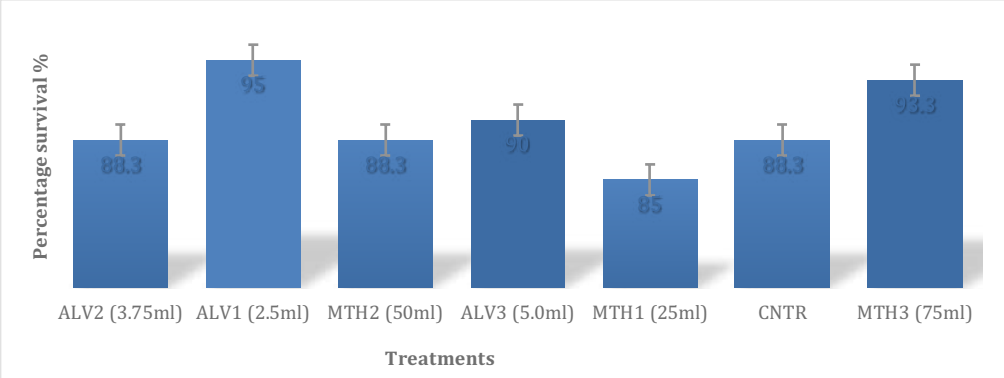



**Figure 1:** Percentage Survival of O*reochromis niloticus* fed Diet Supplemented with Different Levels of Methyl testosterone and *Aloe vera* gel

**Key:** ALV=*Aloe vera*, MTH=Methyltestosterone, S. R=Survival rate

**Table 1:** Growth response and feed utilization of O*reochromis niloticus* fed Diet Supplemented with Different Levels of Methyl testosterone and *Aloe vera* gel

| Parameters | MTH1 | MTH2 | MTH3 | ALV1 | ALV2 | ALV3 | Control | SEM | p-values |
|---|---|---|---|---|---|---|---|---|---|
| IL (cm) | 2.50 | 2.93 | 2.93 | 2.63 | 2.60 | 2.50 | 2.83 | 0.05 | 0.10 |
| FL (cm) | 12.47 | 12.85 | 13.34 | 12.76 | 12.33 | 12.65 | 13.01 | 0.19 | 0.84 |
| LG (cm) | 9.97 | 9.92 | 10.41 | 10.13 | 9.73 | 10.15 | 10.18 | 0.18 | 0.10 |
| IW (g) | 6.90 | 6.63 | 6.80 | 6.90 | 7.07 | 6.90 | 6.57 | 0.07 | 0.55 |
| FW (g) | $209.12^{b}$ | $241.11^{ab}$ | $275.14^{ab}$ | $234.48^{ab}$ | $222.18^{b}$ | $231.53^{ab}$ | $232.45^{ab}$ | 5.16 | 0.01 |
| WG (g) | $202.22^{b}$ | $234.48^{ab}$ | $268.34^{ab}$ | $227.58^{ab}$ | $215.11^{b}$ | $224.63^{ab}$ | $225.88^{ab}$ | 5.16 | 0.01 |
| FCR (g) | $2.11^{a}$ | $1.86^{ab}$ | $1.60^{ab}$ | $1.81^{ab}$ | $1.87^{ab}$ | $1.86^{ab}$ | $1.87^{ab}$ | 0.04 | 0.01 |
| PWG (%) | 2934.21 | 3567.57 | 3950.88 | 3299.50 | 3044.83 | 3257.45 | 3467.35 | 97.14 | 0.07 |

Values with different superscripts along rows are significantly different ($p< 0.05$)
IL= Initial length, FL = Final length, LG = Length gain, IW = Initial weight, FW = Final weight, WG = Weight gain, FCR =Feed conversion ratio, PWG =Percentage weight gain MTH=Methyl testosterone, ALV=*Aloe vera*

## DISCUSSION

The present study demonstrated that dietary supplementation of *Aloe vera* gel and methyl testosterone (MT) significantly improved the growth performance and survival of Oreochromis niloticus fingerlings compared to the control diet. The results showed that fish fed with 75 ml MT diet (MTH3) achieved the highest final weight (275.14 g) and weight gain (268.34 g), while those fed with 2.5 ml *Aloe vera* diet (ALV1) recorded the best survival rate (95%) and high growth performance. These findings indicate that both natural and synthetic additives can enhance growth and survival when applied at appropriate levels.

The superior growth performance observed in the MT treated groups aligns with previous findings that anabolic steroids, particularly methyl testosterone, promote protein synthesis and muscle development in fish by increasing androgenic activity (Fuentes Silva et al., 2013; Zaki et al., 2021). However, excessive inclusion of MT has been associated with gonadal malformation, stress, and reduced survival, emphasizing the need for optimal dosage to balance growth and safety. The present results confirm that 75 ml MT/250 g feed can enhance performance without compromising survival.

On the other hand, *Aloe vera* gel supplementation also produced significant improvements in growth and survival, especially at 2.5 ml inclusion level. This agrees with earlier reports that *Aloe vera* contains bioactive compounds such as polysaccharides, saponins, and anthraquinones, which possess immunostimulant and antioxidant properties that enhance feed utilization and disease resistance (Prasad, 2013; Gabriel et al., 2015). The immunostimulant effect of *Aloe vera* may have improved gut health and nutrient absorption, leading to better growth and lower mortality. Similar results were reported by Dawood et al. (2018), who observed improved hematological parameters and feed conversion efficiency in O*reochromis niloticus* fed diets supplemented with *Aloe vera* extract.

The enhanced feed conversion ratio (FCR) in both MTH3 and ALV1 groups suggests that supplementation promoted efficient nutrient utilization and metabolic activity. This observation supports the findings of Eyo et al. (2016), who reported improved growth indices and reduced FCR in fish diets enriched with natural phytogenic additives. Furthermore, the improved survival rate in the *Aloe vera* group could be attributed to its antimicrobial and anti-stress properties, which have been shown to strengthen the immune response and tolerance to environmental stressors (Sahu et al., 2007; Gabriel et al., 2015).

Interestingly, while both MT and *Aloe vera* improved growth, the *Aloe vera* based diets achieved comparable results without the potential risks associated with hormonal treatments. This suggests that natural plant-based supplements could serve as safer and more sustainable alternatives to synthetic hormones in aquaculture. As consumer demand for hormone free fish increases, the use of phytogenic additives like *Aloe vera* becomes increasingly relevant for ecofriendly and health-conscious aquaculture practices.

## CONCLUSION

The findings of this study reinforce the growing evidence that dietary inclusion of *Aloe vera* gel can improve growth performance, feed efficiency, and survival in O. *niloticus*. However, the response appears to be dose dependent, with excessive inclusion potentially leading to reduced feed palatability and metabolic imbalance. Further studies should explore long term effects, histological responses, and economic implications of integrating *Aloe vera* into commercial aquafeeds.

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# EFFECT OF ZOBO PLANT (*Hibiscus sabdariffa*) AS ADDITIVE IN THE PRACTICAL DIETS OF *Clarias gariepinus* FINGERLINGS

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**ABSTRACT**
*The high cost of feed additives used to provide essential vitamins and minerals absent in conventional fish feeds has placed a financial strain on fish farmers. This study evaluated the effects of Hibiscus sabdariffa (Zobo plant) on the performance of Clarias gariepinus fingerlings. A total of 300 fingerlings (3.3 g) were acclimatized and stocked in aquaria (20 litres) and fed six iso-proteinous (40% crude protein) diets containing 0%, 1%, 2%, 3%, 4%, and 5% inclusion levels of H. sabdariffa powder for eight weeks. Growth performance indices, feed utilization, survival, and carcass composition were assessed. The results revealed that Diet 2 (2% inclusion) produced the highest mean weight gain (16.29 g), specific growth rate (3.20%/day), and favorable feed conversion ratio (0.71). The highest survival rate was recorded in Diets 5 (93.3%). Carcass composition showed significantly higher crude protein (64.6%) in fish fed Diet 4, while Diet 2 recorded the highest lipid content (19.83%). The findings indicate that moderate inclusion diets 2 &3 (2-3 % inclusion) of H. sabdariffa enhances growth, survival, and nutrient utilization in C. gariepinus fingerlings, confirming its potential as a functional feed additive. However, excessive inclusion levels resulted in reduced performance. The study demonstrates the potential of H. sabdariffa as a safe, sustainable, and cost-effective partial substitute for commercial vitamin premix in aquaculture.*

**Keywords:** *Hibiscus sabdariffa, Clarias gariepinus, feed additive, growth performance, aquaculture sustainability*

## INTRODUCTION

Aquaculture is one of the fastest emerging food-producing sectors globally and is flourishing day by day (Habib *et al.*, 2020). *Clarias gariepinus* is widely considered to be one of the most important tropical catfish species for aquaculture, due to its hardiness and adaptability to varying environmental conditions. It has Pan-African distribution, from the Nile to West Africa and from Algeria to Southern Africa. There are over 60 species in the genus *Clarias* found throughout Africa. *Clarias gariepinus* holds high economic importance in many countries of the world. It can tolerate adverse water quality conditions, it grows fast and feeds on a large variety of agricultural by- products and can be raised in high densities (Abdurrazzaq *et al.*, 2024). Catfish are characterized based on their cylindrical body with a flattened ventral and prominent barbell(s), mostly scale-less compared to other teleost fishes. Catfishes are energetic bottom-dwelling fishes and opportunistic feeders that actively search for food, especially at night. They are distributed worldwide, except in the Antarctic. They are also one of the most diverse groups of ray-finned fish globally, containing both highly endangered and some of the world's most notorious invasive alien species (Thirukanthan *et al.*, 2023).

Considering the increase in need for natural and cost-effective feed additives in aquaculture plant that contain bioactive property *Hibiscus sabdariffa* (Zobo plant) have gained increasing research interest. *Hibiscus sabdariffa* (commonly known as Zobo) is one of the most widely cultivated flowering plants in the world. Extracts from *Hibiscus sabdariffa* have been reported to act as an immune-stimulating agent in animals and humans (Portillo *et al.*, 2021). In addition, *Hibiscus sabdariffa* has demonstrated multiple beneficial effects, functioning as a stress reliever, anti-inflammatory agent, immune-stimulator, antioxidant, and growth promoter in various fish species such as Rainbow trout (*Oncorhynchus mykiss*)

(Yousefi *et al*., 2021), Nile tilapia (O*reochromis niloticus)*, and Common carp (C*yprinus carpio*) (Yin *et al*., 2011).

The high cost of feed additives used to provide essential vitamins and minerals absent in conventional fish feeds has placed a financial strain on fish farmers.as a result, many are unable to afford them, leading to reduced productivity and profitabilty.in an attempt to meet production targets quickly, some farmers have fallen victim to fraud, purchasing unverified and sometimes toxic substances falsely marketed as fish growth boosters. These unsafe practices not only endanger fish health but also reduced the chances for Nigeria and other African countries to export processed fish products to international markets due to concerns over quality and safety standards.
The present study was designed to evaluate the potential of *Hibiscus sabdariffa* (Zobo plant) as a natural dietary additive in the nutrition of C*larias gariepinus* fingerlings specifically.

## MATERIALS AND METHODS

The experiment was conducted at the Old Teaching and Research Farm, Bosso Campus Department of Water Resources, Aquaculture and Fisheries Technology of Federal University of Technology Minna, Niger State. Three hundred fingerlings (average weight 3.5 g) were randomly distributed into 18 aquaria in a completely randomized design (15 fish per tank, triplicates per treatment). Six experimental diets containing (40% crude protein) were formulated with graded inclusion of *H. sabdariffa* powder (0–5%). Fish were fed at 3% body weight, three times daily, for eight weeks. Growth performance indices (mean weight gain, specific growth rate, feed conversion ratio, protein efficiency ratio), survival, and carcass proximate composition were determined following standard procedures (AOAC, 2017). Six (6) iso-proteinous experimental diets, each containing 40% crude protein, were formulated for C*larias gariepinus* fingerlings in accordance with NRC (1993) nutrient requirements. The diets were developed using linear programming on Microsoft Excel to achieve the targeted protein level. The diets were designated as follows:

1) Control: 0% Hibiscus powder (Control)
2) Diet 1: 1% Hibiscus powder
3) Diet 2: 2% Hibiscus powder
4) Diet 3: 3% Hibiscus powder
5) Diet 4: 4% Hibiscus powder
6) Diet 5: 5% Hibiscus powder

Feed ingredients were accurately weighed using a Golden Mettler 2000L model balance. The weighed ingredients were homogenized in a plastic bowl, and steam was applied to facilitate gelatinization, forming a moist dough. The dough was subsequently pelletized using a manual pelletizer with a 2 mm die and sun-dried to obtain the final experimental feeds. Water quality parameters (temperature, pH, DO, alkalinity, ammonia) were monitored fortnightly. Data were analyzed using one-way ANOVA, with significance set at $p<0.05$.

## RESULTS AND DISCUSSION

**Table 1:** Growth performance of C*larias gariepinus* fingerlings fed varying inclusion levels of *Hibiscus* as an Additive

| Tank | MIW | MFW | MWG | SGR | FCR | PER | ANPU | SR (%) |
|---|---|---|---|---|---|---|---|---|
| Control | $3.64 \pm 0.37^{a}$ | $19.04 \pm 0.94^{c}$ | $15.61 \pm 0.96^{c}$ | $3.06 \pm 0.095^{b}$ | $0.55 \pm 0.01^{a}$ | $4.52 \pm 0.12^{a}$ | $235.00 \pm 61.94^{a}$ | $86.67 \pm 0.00^{bc}$ |
| Diet 1 | $3.68 \pm 0.73^{a}$ | $13.15 \pm 0.99^{a}$ | $9.05 \pm 1.00^{a}$ | $2.08 \pm 0.14^{a}$ | $0.79 \pm 0.11^{a}$ | $3.20 \pm 0.46^{a}$ | $200.60 \pm 32.00^{a}$ | $80.00 \pm 0.00^{b}$ |
| Diet 2 | $3.47 \pm 0.43^{a}$ | $19.57 \pm 0.45^{c}$ | $16.29 \pm 0.08^{c}$ | $3..20 \pm 0.16^{b}$ | $0.71 \pm 0.03^{a}$ | $3.51 \pm 0.15^{a}$ | $224.10 \pm 11.31^{a}$ | $90.00 \pm 4.71^{bc}$ |
| Diet 3 | $3.39 \pm 0.33^{a}$ | $14.94 \pm 0.68^{b}$ | $11.65 \pm 0.28^{b}$ | $2.71 \pm 0.14^{ab}$ | $0.70 \pm 0.16^{a}$ | $3.69 \pm 0.83^{a}$ | $226.75 \pm 48.44^{a}$ | $66.68 \pm 0.02^{a}$ |
| Diet 4 | $3.19 \pm 0.11^{a}$ | $16.67 \pm 1.63^{bc}$ | $13.55 \pm 1.71^{bc}$ | $2.98 \pm 0.22^{ab}$ | $0.75 \pm 0.07^{a}$ | $3.34 \pm 0.33^{a}$ | $248.15 \pm 20.15^{a}$ | $83.34 \pm 4.72^{b}$ |
| Diet 5 | $3.58 \pm 0.21^{a}$ | $17.20 \pm 0.76b^{c}$ | $13.73. \pm 0.91^{bc}$ | $2.86 \pm 0.15^{ab}$ | $0.68 \pm 0.005^{a}$ | $3.66 \pm 0.03^{a}$ | $216.10 \pm 0.57^{a}$ | $93.33 \pm 0.00^{c}$ |

*Means along the column with the same superscript are not significantly different (p>0.05)*
*Key: MIW=mean initial weight, MFW=mean final weight, MWG=mean weight gain, SGR=specific growth rate, FCR= feed conversion ratio, PER=protein efficiency ratio, ANPU= apparent net protein utilization, SR= survival rate*

**Table 2:** Carcass proximate composition of C*larias gariepinus* fed with different inclusion levels of *Hibiscus sabdariffa*

| Tank | Crude Protein | Crude Lipid | Crude Fibre | Ash | Moisture |
|---|---|---|---|---|---|
| Control | $56.40\pm1.34^{b}$ | $16.91\pm0.00^{b}$ | $1.30\pm0.14^{a}$ | $17.16\pm0.07^{b}$ | $8.56\pm0.07^{a}$ |
| Diet 1 | $52.15\pm1.34^{b}$ | $18.40\pm0.00^{d}$ | $1.10\pm0.14^{a}$ | $18.35\pm0.46^{c}$ | $8.43\pm0.11^{a}$ |
| Diet 2 | $57.90\pm1.00^{b}$ | $19.83\pm0.00^{e}$ | $1.50\pm0.42^{a}$ | $15.03\pm0.00^{a}$ | $8.86\pm0.12^{a}$ |
| Diet 3 | $52.65\pm3.47^{ab}$ | $16.61\pm0.29^{b}$ | $1.80\pm0.00^{a}$ | $17.45\pm0.00^{b}$ | $9.21\pm1.11^{a}$ |
| Diet 4 | $64.60\pm2.55^{c}$ | $16.17\pm0.00^{a}$ | $1.65\pm0.71^{a}$ | $17.72\pm0.00^{bc}$ | $10.19\pm0.09^{a}$ |
| Diet 5 | $50.40\pm4.53^{a}$ | $17.77\pm0.00^{c}$ | $1.35\pm0.071^{a}$ | $18.30\pm0.19^{c}$ | $10.92\pm020^{a}$ |

*Means along the column with the same superscript are not significantly different*

Growth performance varied significantly across treatments. Diet 2 (2% *Hibiscus*) produced the highest final weight (19.57 g), mean weight gain (16.29 g), and SGR (3.20%/day), comparable to the control diet. Survival was highest in Diet 5 (93.3%), while Diet 1 showed the poorest growth performance. Carcass composition revealed increased crude protein in Diet 4 (64.6%) and highest lipid content in Diet 2 (19.83%). These results support earlier findings that moderate inclusion of medicinal plants enhances growth and immunity in fish (Enyidi & Ayogu, 2023). The improved growth may be attributed to phytochemicals such as anthocyanins and flavonoids, which reduce oxidative stress and enhance feed utilization. However, excessive inclusion may introduce anti-nutritional factors, reducing nutrient digestibility and performance.

## CONCLUSION

Moderate inclusion (2–3%) of *Hibiscus sabdariffa* in the diet of C*larias gariepinus* fingerlings improved growth performance, nutrient utilization, and survival rate. The plant shows potential as a safe, sustainable, and cost-effective functional feed additive that can partially substitute synthetic vitamin premixes in aquaculture.

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# EFFICACY OF FEED SUPPLEMENTED WITH AIR-DRIED *Garcinia kola* (HECKEL) SEEDS ON GUT MORPHOMETRY OF *Clarias gariepinus* (BURCHELL 1822)

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**ABSTRACT**

*Medicinal plants are affordable, with little or no risk of environmental pollution and the emergence of antibiotic-resistant bacteria. They are renowned as potential replacements for antibiotics and serve as additives that promote growth and gut health of fish. Hence, this study evaluated the effects of diet fortified with air-dried seeds of Garcinia kola (ADGK). This was carried out in triplicate in a Completely Randomized Design. Diets fortified with varying inclusions of ADGK were used as treatments at 0 (positive control, T1); 1g (T2); 2g (T3); 3g (T4); of ADGK and 0.2g (T5); of Oxtetracyline (OTC) per 100g of diet respectively. The growth performance parameters, gut microbiota and gut histomorphometry were recorded after 12 weeks of feeding trial. Weight gain increased significantly ($P < 0.05$) with increasing levels of GK, highest WG (105.94±1.70g) and best FCR (1.31±0.03) were recorded in group fed T4. The LAB and TVC were significantly more in the gut of fish fed T4 (8.29±0.26$log_{10}$cfu/g and 8.84±0.25$log_{10}$cfu/g) respectively. Longest VH (1.33±1.22) fed T4. T3 and T4 had the shallowest CD (0.12±0.00), while the thickest muscle (0.25±0.10) was found in fish fed T5. Conclusively, the presence of high level of LAB and TVC are indicators of more beneficial microbes that can modulate gut and enhance growth, while the longer VH and shallower CD signified structure that can enhance effective digestion and nutrient utilization. Conclusively, addition of 3g of Air-dried G. kola in 100g of feed of C. gariepinus is hereby recommended in for healthy growth and efficient production.*

**Keywords**: Aquaculture, Bitter kola, Catfish, Cryptal depth, Fish health, Phytochemicals

## INTRODUCTION

Fish is a cheap source of animal protein, which has been contributing tremendously to human's nutritional needs and provides means of livelihood to thousands. Production from the wild could no longer keep pace with the demand for fish because of overfishing, climate change and the likes. However, aquaculture, which is commonly seen as a production mechanism that will keep pace with increased demands, is confronted with its own set of hindrances with regards to sustainability such as; high costs of production, lack of technical capacity, disease outbreaks and environmental pollution (Kaleem and Sabi, 2021). Nevertheless, intensification of aquaculture to meet demand-supply gap of an ever-increasing population, has led to increase in the use of various drugs and chemicals in enhancing growth and disease treatment, and eventually transcend into detrimental effects to aquatic ecosystems.

Application of antimicrobials in aquaculture provides a potentially wider environmental exposure pathway for drug distribution through water with important ecosystem health implications (Lulijwa *et al.*, 2020). Phytogenic plants with traditional medicinal usage have been identified as potential feed additives for increasing resistance to pathogens, improving feed efficiency and growth performance subsequently (Abdel-Tawwab *et al.*,2018). Antimicrobial potential of bitter kola is based mainly on the phytochemical components of the plant: tannins, saponins, alkaloids, glycosides, terpenonids and flavonoids found in its stem bark, roots, fruits, seeds and flowers (Akoro *et al.*, 2020). The

phytochemicals present it the plant has made it a choice additives that could have beneficial effects on stimulation of appetite, enhancement feed conversion, stimulation of immune system, and regulation of gut microflora of cultivated fish. Nyadjeu *et al.* (2019) reported that supplementation of *G. kola* seeds in diets of young Tilapia improved growth performance and impaired gonadal development in females. Result of a research carried out by Dada (2012) suggest that dietary supplementation with *G. kola* seed powder improved fecundity, hatchability and survival of *C. gariepinus* larval and has a potential pro-fertility property which can be exploited in fish seed production.

Information on the effects of Air-dried *G. kola* seed on gut microflora, gut morphometry and their correlation with feed utilization in *Clarias gariepinus* is scarce. Hence, the present study aimed to examine the effect of dietary Air-dried *G. kola* seed (ADGK) meal on the population of some microflora and gut morphometry and their relationship with feed efficiency in *C. gariepinus*.

## MATERIALS AND METHODS

### Collection and Preparation of Feed Additives

Fresh seeds of bitter kola were sourced from a reputable farm in Ondo Township, Ondo State, Nigeria. Ondo About 2kg of seeds of bitter kola were peeled, washed with distilled water, drained with a plastic sieve and chop into smaller pieces using mortar and pestle; evenly spread on a mosquito net-size mesh at a room temperature (25-30$^0$C) to air dry under shade for two weeks (Isitua *et al.*, 2015).

### Diets formulation and preparation

Five isonitrogenous diets with similar diet were formulated with 40% crude protein. The concentrated *G. kola* extract were included in the diets as phytogenic additives at 1.0, 2.0 and 3.0% inclusion levels while the negative (i.e. unfortified) control diet that contained no test ingredient, and the negative (which is fortified) control contained 0.2% oxytetracyline according to the manufacturer's recommendation. Feed ingredients were purchased from a reputable feed store in Ibadan; grinded to fine powder, cassava starch was added as binder and mixed gradually with the mixed feed until it was evenly distributed. The resultant dough was pelletized with 2mm die sized pelletizing machine, sun-dried mildly, then crumbled into smaller sizes manually and then packed in well labeled airtight polythene bags and stored in dry environment at room temperature (27$^0$C) throughout the experimental period.

### Stocking and feeding of experimental fish

Healthy *Clarias gariepinus* fingerlings (mean weight 10.7±0.5g; n = 300) were purchased from a reputable fish farm in Ibadan for the experiment. These fish were conditioned for fourteen days (2 weeks) and fed *ad libtum*, twenty acclimatized fingerlings were randomly selected and distributed into 3 experimental treatments with 2 controls (positive and negative) in triplicates, and fed at 3% body weight for twelve weeks. The experimental diets were weigh and dived into two equal parts and fed to fish in the morning and evening between 8:30-9:30am and 3:30-4:30pm Nigerian time respectively.

### Growth performance and feed utilization parameters

The following parameters were estimated after the feeding trial:

$$\text{Weight gain (WG, \%)} = \frac{\text{Weight gain (g) )}}{Initialweight\ (g)} x\ 100$$

$$\text{FCR} = \frac{\text{Dry weight of feed fed (g)}}{Fishweightgain\ (g)}$$

**Survival Rate Percentage**

$$\text{SR (\%)} = \frac{\text{Initial number of fish stocked} - \text{Mortality}}{Initialnumberof fishstocked} \text{ x 100 (Nyadjeu, } et\ al.\text{, 2019).}$$

**Morphometric Evaluation**

Five fish samples were randomly collected from each replicate of the different treatments gut morphometry evaluation at the end of the experiment. Morphometric measurements of the fish were measured using electronic sensitive scale. The guts were obtained by dissecting the fish under aseptic conditions with sterile scalpels and forceps. The guts were scooped into appropriately labeled plain bottles containing 10% buffered formalin solution until analysis was done. Each gut was subdivided into three sections (proximal, middle and distal) to measure the villi length, villi width and cryptal depth using a microscope with a micrometer rule as described by (Bello *et al.*, 2012).

**Statistical analysis**

The data were analyzed using one-way analysis of variance (ANOVA) while Duncan multiple range test was used to compare differences among means at 5% probability level.

## RESULTS AND DISCUSSION

**Effects of fortifying diets with air-dried G. *kola* seeds on the growth performance, nutrient utilization of C. *gariepinus*.**

Fish fed T4 diet had the significantly higher final weight (116.02±1.71g), weight gain (105.94±1.70g), and Survival Rate (95.00±5.00) at ($P<0.05$), while the least FWG (74.77±4.22g), WG (64.69±4.25g) were found in group fed OTC-treated diets. Highest Survival Rate was recorded in T4 (95.00±5.00) without any significant different from others, however, the least SR was recorded in fish fed the control feed (85.00±5.00). The best FCR (1.31±0.03) was found in the group of fish fed T4, the highest FCR was found in those fed with T5 (1.99±0.26) and there is significant difference in the recorded FCR.

**Table 1:** Growth Performance of C. *gariepinus* fed with diets fortified with Air-dried G. *kola* meal

| Diet (g/100g) | IW (g) | FW (g) | WG (g) | SR (%) | FCR |
|---|---|---|---|---|---|
| T1(0g) | 10.02±0.02$^{a}$ | 85.78±0.91$^{b}$ | 75.54±0.89$^{b}$ | 85.00±5.00$^{a}$ | 1.75±0.00$^{bc}$ |
| T2 (1g) | 10.02±0.02$^{a}$ | 87.59±1.02$^{b}$ | 77.52±1.04$^{b}$ | 88.33±2.89$^{ab}$ | 1.74±0.18$^{bc}$ |
| T3 (2g) | 10.02±0.02$^{a}$ | 108.56±6.55$^{c}$ | 98.51±6.55$^{c}$ | 91.67±2.89$^{ab}$ | 1.41±0.21$^{ab}$ |
| T4 (3g) | 10.02±0.02$^{a}$ | 116.02±1.71$^{d}$ | 105.94±1.70$^{d}$ | 95.00±5.00$^{b}$ | 1.31±0.03$^{a}$ |
| T5 (OTC) | 10.04±0.02$^{a}$ | 74.767±4.22$^{a}$ | 64.69±4.25$^{a}$ | 88.33±2.89$^{ab}$ | 1.99±0.26$^{c}$ |

**The efficacy of dietary intake of different inclusions of G. *kola* seeds on population of Gut Microbiota**

Largest numbers of Lactic acid bacteria (8.29±0.26) were found in T4 which was significance at ($P<0.05$), while the lowest (4.44±1.07) was found in the group fed the positive control. Lactic Acid Bacteria (LAB) is known to provide substrate in fish gut to stimulate the growth of the fish and enhance the activities of the resident helpful microorganisms in the guts of the fish and also heighten their health. Fish fed T4 also had the highest number of Total Viable Count (TVC) (8.84±0.25), while the least TVC (7.32±0.45) was discovered positive control group. *E.coli* (3.30±0.32) was only found in the gut of the positively controlled group, this is an indicator that G. *kola* extract might have the capacity to produce bacteriocins that could have hindered the growth of *E. coli*. There is absence of Salmonella and *Staphylococcus* species in group fed T5. Furthermore, the numbers of *Staphylococcus* species found in the gut of the fish fed ADGK-treated diets reduced with increasing levels of inclusion, however, highest significant number of this microflora (3.93±0.82) was observed in the gut of fish fed positive control diet at ($P>0.05$).

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| Diet (g/100g) | LAB ($log_{10}$cfu/g) | T.V.C ($log_{10}$cfu/g) | *E. coli* | Salmonella | Vibro spp | Staphy. |
|---|---|---|---|---|---|---|
| T1(0g) | $4.44\pm1.07^{a}$ | $7.32\pm0.45^{a}$ | $3.30\pm0.32^{b}$ | $3.00\pm0.45^{c}$ | $4.66\pm1.03^{c}$ | $3.93\pm0.82^{d}$ |
| T2 (1g) | $7.00\pm0.36^{b}$ | $8.17\pm0.02^{b}$ | $0.00\pm0.00^{a}$ | $1.85\pm0.68^{b}$ | $3.24\pm0.88^{b}$ | $2.07\pm0.55^{c}$ |
| T3 (2g) | $7.94\pm0.40^{bc}$ | $8.44\pm0.13^{bc}$ | $0.00\pm0.00^{a}$ | $1.46\pm0.61^{b}$ | $2.94\pm0.96^{b}$ | $1.23\pm0.89^{b}$ |
| T4 (3g) | $8.29\pm0.26^{d}$ | $8.84\pm0.25^{c}$ | $0.00\pm0.00^{a}$ | $1.35\pm0.60^{b}$ | $0.00\pm0.00^{a}$ | $0.00\pm0.00^{a}$ |
| T5 (OTC) | $7.23\pm0.11^{b}$ | $7.44\pm0.03^{a}$ | $0.00\pm0.00^{a}$ | $0.00\pm0.00^{a}$ | $0.00\pm0.00^{a}$ | $0.00\pm0.00^{a}$ |

**Effects of dietary Air-dried *G. kola* seeds on the gut morphometrics of *C. garipinus***

Villi Height (VH) of *C. gariepinus* fed diet containing T4 (1.33±1.22) was significantly higher (P<0.05) than the VH of the groups of fish fed with other diets with the least (0.72±0.06) found in group fed the OTC-treated diet and the VH increases with inclusion of the experimental extracts as shown in Table 3. The Villus Width (VW) of the group of fish fed T4 (0.27±0.02) was significantly higher than that of all the experimental groups at (P<0.05). The propria width of the experimental fish were not significantly different from one another, although, the highest was found in fish on diets containing T4 (0.22±0.04) than those on others at (P>0.05, while lowest was found in OTC-treated group (0.14±0.03). The fish fed with T4 had significantly shallow cryptal depth (0.12±0.01) than fish from other groups at ($p < 0.05$) when compared to the control groups. Fish fed T1 had the highest value of muscle thickness (0.25±0.10), while the highest absorption area was found in T4 (0.34±0.6) and the least was recorded in T1 (0.11±0.04).

**Table 3:** Effects of dietary Air-dried *G. kola* seeds on the gut morphometrics of *C. garipinus*

| Diet (%) | Villi height | Villi width | Propria width | Cryptal depth | Area of Absorption ($cm^3$) | Muscle thickness |
|---|---|---|---|---|---|---|
| T1(0g) | $0.72\pm0.06^{a}$ | $0.16\pm0.05^{a}$ | $0.14\pm0.03^{a}$ | $0.17\pm0.02^{c}$ | $0.11\pm0.04^{a}$ | $0.25\pm0.10^{a}$ |
| T2 (1g) | $0.83\pm0.12^{a}$ | $0.20\pm0.04^{a}$ | $0.19\pm0.01^{ab}$ | $0.14\pm0.02^{ab}$ | $0.14\pm0.04^{ab}$ | $0.20\pm0.07^{a}$ |
| T3 (2g) | $1.04\pm0.06$ | $0.23\pm.0.02$ | $0.20\pm0.41^{b}$ | $0.12\pm0.02^{a}$ | $0.22\pm0.03^{a}$ | $0.17\pm0.02^{a}$ |
| T4 (3g) | $1.33\pm1.22$ | $0.27\pm0.02$ | $0.22\pm0.04^{b}$ | $0.12\pm0.00^{a}$ | $0.34\pm0.6^{a}$ | $0.20\pm0.08^{a}$ |
| T5 (OTC) | $0.82\pm0.06^{a}$ | $0.18\pm0.02^{a}$ | $0.16\pm0.02^{b}$ | $0.15\pm0.02^{bc}$ | $0.15\pm0.03^{ab}$ | $0.21\pm0.06^{a}$ |

## DISCUSSION

Growth parameters such as the FW, WG, and the SR and the FCR of the experimental fish improve with an increment in the level of the additives. The improved growth might be as a result the presence of phytochemicals such as flavonoids, alkaloids and phenols in the plant which helps in increasing feed acceptability, enhancing feed digestibility and ingestion of nutrient for leading to conversion of consumed feed to flesh. This result is in alignment with the findings of some researchers who reported that supplementing fish feed with beneficial plants helps in improving their growth. Some scholars, such as

Adeniyi *et al*,(2018) and Brum *et al.* (2025) opined that some medicinal additives helps in improving feed digestibility, leading to better nutrient absorption and reduced feed requirements in fish culturing. Ajadi *et al.* (2022) added 0.5%, 1% and 1.5% of *Alstonia boonei* and *Mitracarpus scaber* respectively to experimental fish diet and reported that indicated that the plants enhanced growth performance in fish with little or no deleterious effects. Adeniyi *et al.* (2020) conducted a research to examined the effects of tamarind pulp (TP) meal and OTC on the growth of C*larias gariepinus* and reported that the fish fed tamarind pulp (TP) meal performed better than the group fed OTC-treated feed (the antibiotic).

The result of the gut microflora reviewed the presence of LAB which was more in fish fed air-dried *G. kola* seeds than those fed control diets. The presence of LAB in the gut of the fish is an indicator that it might have acted as the substrate to stimulate the growth of the fish and improve the activities of the resident beneficial microbes in the guts of the fish and also boost their health. Ekelemu *et al.* (2025) reported that the harmful bacteria load in the gut of fish fed powdered *Moringa oleifera* leave was significantly reduced ($P < 0.05$) as inclusion of additive increased. According to Kang Yang *et al.* (2020), gallic acid influences the gut microbiome and modulates the immune response to maintain intestinal health. The improvement of intestinal health reduced the animal's exposure to microbial toxins and other undesired. This result indicates that increasing *A. lepidophyllus* level in C. *gariepinus* diet increases the presence of bioactive compounds present in the phyto-additive such as flavonoids and phenolics compounds. Hence, Yemdjie *et al.* (2023) opined that they help the animals to grow better within the framework of their genetic potential

Fortifying the feed of C. gariepinus with ADGK helped in improving the structures of the gut, increase in the aadition of the additive aided the elongation of VH and the reduced CD. These features helped in increasing the surface area of absorption and give room for proper digestion and nutrient utilization. Sadiq *et al.* (2025) evaluated the gut histomorphometry of juvenile (C*larias gariepinus*) fed diets fortified with varying inclusion levels of ginger and garlic and reported that gut morphometry results in this study emphasized the benefits of these phytogenic additives, indicating enhanced nutrient absorption. The work aligned with the report of Butt and Volkoff (2019) who reported that, a longer villus length will leads to increased surface area for nutrient uptake, enhancing absorption. The present work is in consistency with results of Wei *et al.* (2025) who achieved improved gut health in fish supplemented with ginger, attributing the effects to its bioactive compounds, which enhance gut epithelial reliability.

## CONCLUSION

This study underscores the competency of Air-dried *G. kola* seeds in the feed of juvenile of C. *gariepinus*, and discovered that diets fortified with 30g of *G. kola* seeds yielded the most favourable growth and gut microbiota and morphometry outcomes. This performance could be attributed to the presence of beneficial bioactive components of the selected plants which could help in sustainable aquaculture practices. Nonetheless, further research is encouraged to help in understanding the impact of habitual usage of the plant on fish health and yield.

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# BLOOD CHEMISTRY OF AFRICAN CATFISH (*Clarias gareipinus*) FED SUBSTITUTION LEVELS OF TREATED AFRICAN ELEMI (*Canarium schweinfurthii*) SEED MEAL

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**ABSTRACT**
*The experiment was conducted at the Teaching and Research Farm of the Faculty of Agriculture Shabu, Lafia Campus, Nasarawa State University Keffi, Nasarawa State Nigeria for twelve (12) weeks. The experimental seeds were collected from Jiplik in Pankshin Local Government Area of Plateau state. The seeds were toasted at 120°C for 15 minutes and were crushed using hammer mill with 0.01g of enzymes before analysis in the laboratory. Five treatments were used in three replicates and each replicate tank contained 20 fingerlings of the experimental fish in a Completely Randomized Design. The serum and haematology were examined. All data obtained from the study were subjected to analysis of variance using STAR 2.0.1 window and significant means separated by Duncan multiple range test at 0.05 level of significance. The findings revealed significant increase in PCV, Hb, RBC, WBC, PLt, N MCV and MCH without adverse effect on the fingerlings. Farmers are advised to incorporate enzymes (maxigtrain) in Catfish feed formulation where African elemi seed is used as source of feed ingredient.*

**Keywords**:
Haematology, serum, substitution, African elemi and catfish

## INTRODUCTION

Catfish is valuable by fish consumers because of its excellent taste and meat quality especially when presented in smoked, fried or dried form (Ekanem *et al.*, 2017). Apart from its acceptability and affordability, the African Catfish is rich in omega-3- fatty acid, thiamine, riboflavin, phosphorus, vitamins A, vitamin D, iron and calcium which is required for good health and tissue development (Awom and Eyo, 2016). Haematological and serum biochemical parameters are key clinical tools required for the diagnosis and prognostication of health statuses under culture or natural conditions (Adeyemo and Enefe, 2021).

Haematological assessment is a rapid approach for the determination of the fish homeostasis, while serum biochemical assessments provide information on physio-pathological changes in the organs and or systems of the fish. However, for these tools to be effective there is a need to have a reliable set of reference values (obtained from healthy specimens) upon which results can be compared (Adeyemo and Enefe, 2021). The haematological and serum biochemistry reference intervals have been established for some fish species under intensive culture and a few others under natural conditions including *Clarias gariepinius* (Adeyemo *et al.*, 2014).

A biochemical test known as serum total protein, or plasma total protein, determines the total protein content of blood plasma or serum. Albumin and globulin are the two types of protein found in plasma. Together with protein in the blood plasma, albumin and globulin are necessary for the proper functioning of fish physiology. Albumin is essential for the movement of organic compounds, while globulin is needed for immunity. Their presence provides normal physiology and health condition of the fish. (Kulkarni, 2021).

According to Kulkarni (2021) serum protein concentration in fish ranged from 4.6 g/dl to 7.8 g/dl, serum albumin from 1.0 g/dl to 1.9 g/dl and serum globulin from 3.3 g/dl to 6.6 g/dl. According to the author, albumin plays significant role in the transportation of various metabolites, hormones, metals, vitamins, and drugs.

African elemi seeds are embedded in a delicious, oily, purplish green pulp that tastes sweet but not overly sweet, like avocado and pear. It can be eaten raw or softened in warm water to improve palatability (Maduelosi and Anyaye, 2015). African elemi (C*anarium schweinfurthii*) has long been used in traditional medicine to cure a variety of human diseases (Komakech, 2021). The seed contains reasonable amounts of potassium, sodium, phosphorus, iron, zinc, calcium, copper as well as magnesium, which can serve as an additional promising source of protein, carbohydrate and mineral contents for human and animal feeds formulations (Adegboyega *et al.*, 2015; Ayoade *et al.*, 2017).

According to Delbert (2010), cellulose and other fibrous carbohydrates are found in the structural components of plants and are indigestible to monogastric (simple-stomach) animals, including fish. Typically, fish feeds include less than 7% crude fibre by weight in order to minimise the quantity of undigested material that enters the culture system.

All animals need digestive enzymes to break down food, and their bodies either create these enzymes naturally or through the help of bacteria that live in their gastrointestinal tracts. Animals are not able to digest about 15-25 % of the feed they eat, because the feed contain some indigestible components and or the animal bodies lack the specific enzyme which is required for the digestion of those specific feed nutrients (Konietzny and Greiner, 2002). Supplementation of the specific digestive enzymes in feed improves its nutritional value by increasing its digestion efficiency and enzymes help in the breakdown of anti-nutritional factors which are present in feed ingredients. Enzymes enhance feed consistency, supporting gut health and preventing the formation of pathogenic microorganisms during the digestive process. Beta glucanase breaks down fibre in non-starch polysaccharides while phytases operate on phytate to extract phosphorus from it (Muhammad *et al.*, 2016). The study is therefore aimed at determining the haematology and serum biochemistry of fish fed treated African elemi seed meal.

## MATERIALS AND METHODS

### Collection of African Elemi Seeds and the Processing Method

The African elemi seeds were collected at Jiplik in Pankshin Local Government Area of Plateau State. Sand and toasting pan were used for the toasting to about $120^0$C thereafter it was stirred continually to enhance uniform heating and to prevent denaturing of the nutrient content of the experimental material. Subsequently, toasted African elemi (C*anarium schweinfurthii)* seeds were crushed using hammer mill, following the methods of (Anyalogbu *et al.*, 2017) at feed mill of the Faculty of Agriculture Shabu Lafia Campus of Nasarawa state.

### Experimental Design and statistical analysis

The experiment consists of five (5) treatments replicated three times in a completely randomized design (CRD). The seed meal was processed with 0.01g of enzymes (*maxigrain*) to break down the fibre content of African elemi seed meal for easy digestion by the fish. The results obtained were statistically analysed using One Way Analysis of Variance (ANOVA). STAR statistical software was used to analyse the data.

## RESULTS AND DISCUSSION

**Table 1:** Haematological Parameters of Catfish (*Clarias gariepinus*) Fed treated African Elemi (*Canarium schweinfurthii*) Seed Meal

| Parameters | AESM1 00% | AESM2 1.5% | AESM3 3% | AESM4 4.5% | AESM5 6% | SEM | P-value |
|---|---|---|---|---|---|---|---|
| PCV (%) | $27.00^{b}$ | $26.00^{b}$ | $30.00^{a}$ | $24.00^{c}$ | $23.00^{c}$ | 0.75 | $0.00^{*}$ |
| Hb (g/dl) | $9.35^{b}$ | $8.90^{c}$ | $10.60^{a}$ | $8.20^{d}$ | $7.80^{d}$ | 0.33 | $0.00^{*}$ |
| RBC(X10cell/ul | $2.81^{b}$ | $2.00^{d}$ | $3.16^{a}$ | $2.57^{c}$ | $2.47^{c}$ | 0.13 | $0.00^{*}$ |
| WBC($10^{3}$/cell/ul | $116.00^{a}$ | $77.10^{d}$ | $69.50^{e}$ | $82.10^{c}$ | $85.70^{b}$ | 5.31 | $0.00^{*}$ |
| Plt | $25.00a^{b}$ | $28.00^{ab}$ | $15.00^{d}$ | $19.00^{c}$ | $31.00^{a}$ | 1.00 | $0.00^{*}$ |
| N (%) | $3.00^{b}$ | $2.00^{b}$ | $5.00^{ab}$ | $3.00^{b}$ | $8.00^{a}$ | 0.77 | $0.03^{*}$ |
| L (%) | 97.00 | 93.00 | 95.00 | 95.00 | 92.00 | 0.67 | $0.09^{NS}$ |
| MCV(fl)/cell | $129.00^{bc}$ | $130.00^{bc}$ | $127.00^{c}$ | $132.00^{ab}$ | $134.00^{a}$ | 0.87 | $0.03^{*}$ |
| MCH(pg/cell) | $40.00b^{c}$ | $42.00^{ab}$ | $38.00^{c}$ | $43.00^{ab}$ | $44.00^{a}$ | 0.79 | $0.03^{*}$ |
| MCHC(g/dl) | 31.00 | 32.00 | 30.00 | 33.00 | 34.00 | 0.58 | $0.17^{NS}$ |

AESM =African elemi Seed Meal; PCV = Packed Cell Volume; Hb = Haemoglobin; RBC = Red Blood Cell; WBC = White Blood Cell; Plt=Platelets MCV = Mean Corpuscular Volume; MCH = Mean Corpuscular Haemoglobin; MCHC = Mean Corpuscular Haemoglobin Concentration; N = Neutrophils; L = Lymphocytes; Fl = fentolitre; pg = picogram; g/d = gram per deciliter, %= Percent

### Haematological parameters of Catfish (*Clarias gariepinus)* fed treated African elemi (*Canarium schweinfurthii*) seed meal

The substitute for maize with African elemi seed meal significantly ($p<0.05$) influenced the haemoglobin level of African catfish. The significant difference ($p<0.05$) that was observed in PCV, Hb, RBC, WBC, Plt, N, MCV, and MCH in this study may be as a result of stress in handling the fish as reported by (Guluwa, 2014).

**Table 2:** Serum Biochemical Parameters of Catfish Fed treated African Elemi *(Canarium schweinfurthii*) Seed Meal

| Serum Parameters | AESM1 00% | AESM 1.5% | AESM3 3% | AESM 4.5% | AESM 6% | SEM | P-value |
|---|---|---|---|---|---|---|---|
| Creatinine (mmol/l) | $28.00^{b}$ | $28.00^{b}$ | $28.00^{b}$ | $38.00^{a}$ | $38.00^{a}$ | 2.16 | $0.01^{*}$ |
| Total Protein (g/l) | 30.00 | 29.00 | 29.00 | 27.00 | 27.00 | 0.71 | $0.25^{NS}$ |
| Albumin (g/l) | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 0.04 | $1.00^{NS}$ |
| Globulin (mmol/l) | 9.00 | 10.00 | 11.00 | 15.00 | 16.00 | 1.06 | $0.08^{NS}$ |
| Urea (mmol/l) | $1.30^{b}$ | $1.6^{a}$ | $1.70^{a}$ | $2.00^{a}$ | $2.00^{a}$ | 0.13 | $0.02^{*}$ |

Means on the same row with different superscripts are significantly different ($p<0.05$). NS=no significant difference. AESM= African elemi seed meal, SEM= Standard error of mean, %= Percent

The value PCV count in the study could be the consequence of anaemia brought on by erythrocyte loss, erythrocyte breakdown, or insufficient erythrocyte synthesis by the bone marrow. Haemoglobin (Hb) is essential for transferring oxygen in the blood from the lungs of the fish to the tissues. The RBC play a role in delivering oxygen and removing waste from the fish. Toasting as a processing method was able to minimize the quantities of saponin that causes haemolysis of red blood cell as reported by (Ehirim *et al.*, 2015). The value of RBC in the study may indicate a vitamin B6, B12 or folate deficiency in the diet as reported by (Keri *et al.*, 2012). High value of RBC implies that the fish was able to fight against infection. The displacement in WBC may be as a result of disease condition or low production of WBC from bone marrow (Ganomg, 1991).

### Serum biochemical constituents of Catfish (*Clarias gariepinus)* fed treated African elemi

**(*Canarium schweinfurthii*) seed meal**

For albumin, globulin, and total protein, there was no significant change ($p>0.05$). It indicates that the addition of treated African elemi to the experimental diet had no effect on renal functioning. Considerable ($p<0.05$) variations were observed in urea and creatinine across all treatments. Protein and nitrogen metabolism result in the production of urea, a metabolic byproduct, in the liver.

Urea was significantly ($p<0.05$) higher in treatment 4 (2.00 mmol/l), this is in line with the value of 1.8-2.04mmol/l as reported by Alabi *et al*., (2008). This may be as a result of the kidney's inability to remove urea from the blood, however, not at a level of causing deleterious effect on the fish as reported by (Ajeniyi and Solomon, 2014). Treatment 1(1.30mmol/l) the control showed the lowest level of urea. This shows that the kidneys were able to remove urea from the blood normally (Madero *et al.*, 2017). In the study, Creatinine level increased with increase in the substitution level of African elemi. At the substitution level of 4.5% and 6 % African elemi, creatinine showed an important disparity ($p<0.05$) (38.00mmol/l) though lower than the value 52.50-58.50 mmol/l value reported by (Kwari *et al.*, 2008). This suggests that the fish in all the treatments were in normal state of health as observed by (Ajeniyi and Solomon, 2014) who confirmed that Creatinine increases as kidney function decreases.

## CONCLUSION

The inclusion of African Elemi in the diet of C*larias gariepinus* showed significant effect on the haematology and serum biochemistry parameters without adverse effect on the fish. The concentrations of haematological and serum biochemistry in the study were within the normal range recommended for African catfish.

## RECOMMENDATION

African elemi (C*anarium schweinfurthii)* seed meal should be incorporated in formulating C*larias gariepinus* diet for maximal feed utilization and growth. Utilizing African elemi seed will reduce the cost of purchasing maize in the diet of fish.

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# SUNDRIED MAGGOT (*Musca domestica*) MEAL AS A REPLACEMENT FOR FISH MEAL IN THE DIET OFAFRICAN catfish (*Clarias gariepinus*) FINGERLINGS

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**ABSTRACT**
*This study was conducted to determine the effect of sundried maggot (Musca domestica) meal on growth performance and survival of African catfish (Clarias gariepinus) fingerlings. The varying levels of sundried maggot meal in the different experimental diets were 0, 25, 50, 75, and 100% (all diets were iso-nitrogenous of 42.43±0.61 crude protein).Ten fingerlings of the experimental fish (25.58±0.05 g) were fed the different diets for a period of 42 days in triplicates. The greatest increase in body weight (30.18±0.03 g) of the fish was achieved with diet 3 ($p<0.05$), this was followed by the fish fed with 25% of the sundried maggot meal (27.90±0.44 g) while the least increase in body weight (13.71±0.46 g) was obtained in the fish fed with 100% of the sundried maggot meal. Similarly, the best specific growth rate (SGR) and food conversion ratio (FCR) values of 1.86±0.00 %/day and 2.59respectively were obtained in the fish fed with diet 3 while the fish fed with diet containing the sundried maggot meal recorded the least specific growth rate (SGR) and food conversion ratio (FCR).Based on the analysis of the results, African Catfish(C gariepinus) fingerlings could tolerate up to 50% level of inclusion of sundried maggot meal in practice without adverse effect on growth of the fish.*

**Keywords**: African Catfish (*Clarias gariepinus*), sundried maggot (*Musca domestica*) meal, growth performance

## INTRODUCTION

In the development and management of an aquaculture enterprise, fish feed plays a vital role in its growth and expansion (Gabriel *et al*., 2007) and constitutes 40 - 50% of the operational cost in the intensive and semi-intensive aquaculture system (Jabir *et al*., 2012). Since fish meal is getting more and more expensive as a feed ingredient, it has been found that using unconventional feedstuffs results in good growth and superior cost benefit ratios. The aquaculture industry is working to meet the world's rapidly growing demand for fish in order to reduce hunger and improve food and nutritional security (FAO, 2018).

Recently, the increasing cost of feed has been at alarming rate and this has been affecting the development and expansion of aquaculture in African countries particularly Nigeria (Soybean *et al*., 2006). Fish meal been the major protein source in the fish diet constitutes the highest cost thereby making the price of the feed to rise exponentially. Therefore, several attempts have been made to substitute fish meal with other animal protein sources such as earth worm, shrimp waste, insect and plant protein sources such as sun flower, rape seed, soyabean meal and cottonseed meal.
However, they cannot replace fish meal wholly but partially due to the presence of chitin in their

exoskeleton. Ng *et al*. (2001) reported that chitin found in the exoskeletons is a polymer of glucosamine insoluble in common solvents and the presence of chitin do leads to depression of growth performance and protein utilization in catfish fed high levels. In the same vein, problem of anti-nutritional factor in tropical legumes have limited their usage and direct incorporation into animal feeds (Ogun and Wrath, 2001).

Maggot is the larva form of the housefly, *Musa domestica* and it is not edible by man. It can be produced from chicken manure, cow dung, pig dung and other moist, rotting plant and animal remains including human faeces. Maggot meal is an animal protein source produced from waste, it has been reported to be highly nutritive with crude protein ranging between 43.9 and 62.4%, lipid 12.5 and 21%, and crude fibre 5.8 and 8.2% (Awoniyi *et al*., 2003; Fasakin *et al*., 2003a, b; Ajani *et al*., 2004). Maggot meal is also rich in phosphorus, trace elements and B complex, vitamins (Teotis and Milles, 1973).
According to Fashina-Bombata and Balogun (1997), the cost of harvesting and processing one kilogram of maggot meal is smaller compared to the cost of 1kg of fish meal, thereby showing the cost effectiveness of using maggot meal in the diet of African catfish. This study therefore evaluates the nutritive value and growth performance of C*larias gariepinus* fed with maggot meal.

## MATERIALS AND METHODS

### Experimental site

The experiment was carried out at the Feed mill complex of the Federal College of Freshwater Fisheries Technology, New Bussa, Niger State.

### Maggot production

25 kg of chicken manure, 5 kg of cow dung (7:3 respectively) were mixed together to a thickness of 5 cm to constitute substrate using the sack method. The mixture was soaked in water, tied in fertilizer or jute bags and kept outside in a shade to allow maggot develop. The sacks were watered twice daily morning and evening to maintain the constant moisture required foe maggot development. The eggs laid by the female flies on the substrate hatched into larvae within two days, maggots start appearing on the second day with a peak on the 4$^{th}$ and 5$^{th}$ day after which the larval matured and was totally harvested by washing and sieving out through a 3mm wire mesh. The larvae were harvested and sundried to a constant weight, after which the dried maggots were milled into a meal and kept in an air tight container at room temperature (37°C).

### Experimental Fish

One hundred and fifty (150) fingerlings of African catfish (C*larias gariepinus*) with average weight and uniform size (25.58±0.05 g) were obtained from A and B fish Hatchery Complex, New Bussa, Niger State. The fish were acclimatized for three (3) days in the bowls during which they were fed on 40% crude protein feed before the commencement of the experiment.

### Experiment Diet

The maggots (*Musca domestica*) were produced and harvested from chicken and cow dung manure. The other feed ingredients which include fish meal, soyabean meal, groundnut cake and maize meal as well as vitamin premix, bone meal, vegetable oil, methionine, lysine, starch and salt were bought from the Jasope feed depot, New Bussa. Five isonitrogenous diets of 40% crude protein were formulated: Treatment 1 (DT 1) contained 0% of maggot meal (control), DT 2 (25%maggot meal), DT 3 (50% maggot meal), DT 4 (75% maggot meal) and DT5 (100% maggot meal), with these ratios of maggot meal to fish meal 0, 1:4, 1:2. 3:4. 1:1 respectively. The diets were made into dough and pelleted with a flat die pelleting machine (OHAS 200 g model) and then sun-dried for one day to reduce the moisture content and to prevent deterioration. The diets were packaged in an air tight polythene bag at room temperature (37°C) and

labelled before administered to the fish.

**Experimental design**
25L cylindrical plastic bowls were used for this study which were consist of five treatments replicated twice in a completely randomized design (CRD). Ten fingerlings of C*larias gariepinus* of equal size were stocked in each bowl. Fish were fed twice per day at 5% body weight for a period of eight weeks. The fish were weighed with an electronic sensitive weighing balance (OHAUS-LS-200 model). The plastic bowls were washed, thoroughly rinsed and filled with water to 16cm high.

**Statistical Analysis**
All value collected were subjected to one-way analysis of variance (ANOVA) using statistical software SPSS version 20 to determine significance difference among treatments and the treatment means would be separated by Duncan's multiple range test at 95%.

## RESULTS AND DISCUSSION
The percentage composition of the maggot meal-based diets is presented in Table 1.

**Table 1:** Percentage composition of the maggot meal-based diets

| Ingredients | DT1 (0%MM) | DT2 (25%MM) | DT3 (50%MM) | DT4 (75%MM) | DT5 (100%MM) |
|---|---|---|---|---|---|
| Dried maggot meal | 0.0 | 5.25 | 10.50 | 15.75 | 21.00 |
| Fish meal | 21.00 | 15.75 | 10.50 | 5.25 | 14.80 |
| Soyabean meal | 42.00 | 42.00 | 42.00 | 42.00 | 42.00 |
| Yellow Maize | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 |
| Guinea corn | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 |
| Groundnut cake | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| Vitamin premix | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Vegetable oil | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Bone meal | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| Methionine | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Lysine | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Starch | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| Salt | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| TOTAL | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

**Hi-Nutrients Vitamins/ Minerals premix supplies 100g Diet. Palmat A: 1000IU; Cholecalceferol (D): 1000IU; G-Tocopherolacetate (E): 1.1mg; Menacilione (K): 0.02mg; Thiamine B1: 0.63mg; Riboflavin (B12): 0.001mg; Nicotinic Acid: 3.0mg; Folic Acid: 0.1mg; Choline: 31.3mg; Ascobic Acid©: 0.1mg; Iron (Fe): 0.05mg; Cu: 0.25mg; Mn: 6.00mg; Co: 0.5mg; Zn: 5.0mg; Sn: 0.02mg*

The proximate and energy composition of maggotmeal and fish meal are presented in Table2.

**Table 2:** Proximate and energy composition (% dry matter) of maggotmeal and fish meal

| Nutrients | Maggot meal | Fish meal |
|---|---|---|
| Moisture content (%) | 9.80 | 9.80 |
| Crude protein (%) | 51.78 | 65.75 |
| Crude fat (%) | 20.92 | 9.26 |
| Crude ash (%) | 11.56 | 5.67 |
| Crude fibre (%) | 1.65 | 0.91 |
| NFE (%) | 4.29 | 9.61 |
| GE (Kcal/100g) | 507.84 | 430.53 |
| ME (Kcal/100g) | 4125.6 | 4505.30 |

Nitrogen Free Extract = 100 – (Moisture content + Crude protein + Crude fat + Crude ash + Crude fibre).

Gross energy and Metabolizable energy = Caloric value of protein 4.0, NFE 4.0 and fat 9 kcal/g (Atwater's calculation as described by Foster and Smith (1997). The proximate composition of the experimental diets of *Clarias gariepinus* fingerlings dried maggot meal-based diets is presented in Table 3.

**Table 3:** Proximate composition of the maggot meal-based diets

| Chemical Components | Control Diet (0%MM) | Diet 2 (25%MM) | Diet 3 (50%MM) | Diet 4 (75%MM) | Diet 5 (100%MM) |
|---|---|---|---|---|---|
| Moisture content (%) | $12.60\pm0.55^{ab}$ | $12.62\pm0.59^{ab}$ | $11.96\pm0.06^{c}$ | $13.01\pm0.05^{a}$ | $13.05\pm0.06^{a}$ |
| Crude protein (%) | $42.17\pm0.88^{a}$ | $42.12\pm0.60^{a}$ | $42.55\pm0.73^{a}$ | $42.48\pm0.43^{a}$ | $42.84\pm0.51^{a}$ |
| Crude fat (%) | $12.78\pm0.31^{a}$ | $12.74\pm0.15^{a}$ | $12.61\pm0.04^{a}$ | $12.72\pm0.06^{a}$ | $12.63\pm0.01^{a}$ |
| Total ash (%) | $8.55\pm0.03^{d}$ | $11.36\pm0.02^{b}$ | $11.43\pm0.02^{a}$ | $10.42\pm0.02^{c}$ | $10.41\pm0.02^{c}$ |
| Crude fibre (%) | $3.84\pm0.09^{b}$ | $3.88\pm0.04^{b}$ | $3.93\pm0.02^{b}$ | $4.10\pm0.10^{a}$ | $3.91\pm0.02^{b}$ |
| NFE (%) | $20.05\pm1.86^{a}$ | $16.94\pm1.63^{b}$ | $17.55\pm0.89^{b}$ | $17.27\pm0.66^{b}$ | $17.16\pm0.60^{b}$ |
| Gross energy (kcal/g) | $362.57\pm2.37^{a}$ | $334.94\pm16.62^{b}$ | $353.87\pm0.28^{a}$ | $353.45\pm0.387^{a}$ | $353.49\pm0.20^{a}$ |
| Metabolizable energy (kcal/g) | $4726.70\pm592.01^{a}$ | $4278.77\pm18.65^{a}$ | $4363.70\pm50.58^{a}$ | $4309.99\pm2.94^{a}$ | $4315.23\pm6.87^{a}$ |

Values are means±standard deviation of triplicate samples abc±SD with similar superscript in the same column are not significantly different (P>0.05).

The growth performance and survival of *Clarias gariepinus* fingerlings fed maggot meal-based diets for 42 days is shown in Table 4.

**Table 4:** Growth performance and survival of *Clarias gariepinus* fingerlings fed maggot meal-based diets for 42 days

| Parameters | Diet 1 (0%MM) | Diet 2 (25%MM) | Diet 3 (50%MM) | Diet 4 (75%MM) | Diet 5 (100%MM) |
|---|---|---|---|---|---|
| Initial mean weight (g) | $25.55\pm0.08^{bc}$ | $25.59\pm0.02^{abc}$ | $25.53\pm0.01^{c}$ | $25.61\pm0.01^{ab}$ | $25.63\pm0.01^{a}$ |
| Final mean weight (g) | $51.42\pm0.59^{c}$ | $53.49\pm0.46^{b}$ | $55.71\pm0.02^{a}$ | $40.54\pm0.65^{d}$ | $39.35\pm0.47^{e}$ |
| Mean weight gain (g) | $25.87\pm0.68^{c}$ | $27.90\pm0.44^{b}$ | $30.18\pm0.03^{a}$ | $14.93\pm0.66^{d}$ | $13.71\pm0.46^{e}$ |
| Relative weight gain (%) | $101.27\pm2.96^{c}$ | $109.01\pm1.64^{b}$ | $118.19\pm0.17^{a}$ | $58.29\pm2.60^{d}$ | $53.49\pm1.78^{e}$ |
| Daily growth rate (g/day) | $0.62\pm0.02^{c}$ | $0.66\pm0.01^{b}$ | $0.72\pm0.00^{a}$ | $0.34\pm0.01^{d}$ | $0.32\pm0.01^{e}$ |
| Specific growth rate (%/day) | $1.67\pm0.04^{c}$ | $1.75\pm0.02^{b}$ | $1.86\pm0.00^{a}$ | $1.09\pm0.04^{d}$ | $1.02\pm0.03^{e}$ |
| Feed intake (g) | $74.00\pm0.74^{a}$ | $75.24\pm0.21^{a}$ | $78.21\pm0.95^{a}$ | $67.96\pm0.97^{b}$ | $62.27\pm5.77^{d}$ |
| Food conversion ratio (FCR) | $2.86\pm0.05^{b}$ | $2.70\pm0.05^{bc}$ | $2.59\pm0.03^{c}$ | $4.55\pm0.13^{a}$ | $4.53\pm0.27^{a}$ |
| Protein fed (%) | $31.22\pm0.96^{a}$ | $31.69\pm0.36^{a}$ | $33.27\pm0.17^{a}$ | $31.79\pm2.41^{b}$ | $26.70\pm2.77^{a}$ |
| Protein efficiency ratio (PER) | $0.83\pm0.00^{a}$ | $0.88\pm0.00^{ab}$ | $0.90\pm0.01^{a}$ | $0.47\pm0.06^{c}$ | $0.51\pm0.04^{c}$ |
| Survival rate (%) | $100.00\pm0.00^{a}$ | $96.67\pm2.89^{ab}$ | $100.00\pm0.00^{a}$ | $96.67\pm2.89^{ab}$ | $93.33\pm2.89^{b}$ |
| Culture period (days) | 42 | 42 | 42 | 42 | 42 |

Values are means±standard deviation of triplicate samples abc±SD with similar superscript in the same column are not significantly different (P>0.05).

The mean weekly weight changes of *Clarias gariepinus* fingerlings fed maggot meal-based diets is presented in Figure 1.

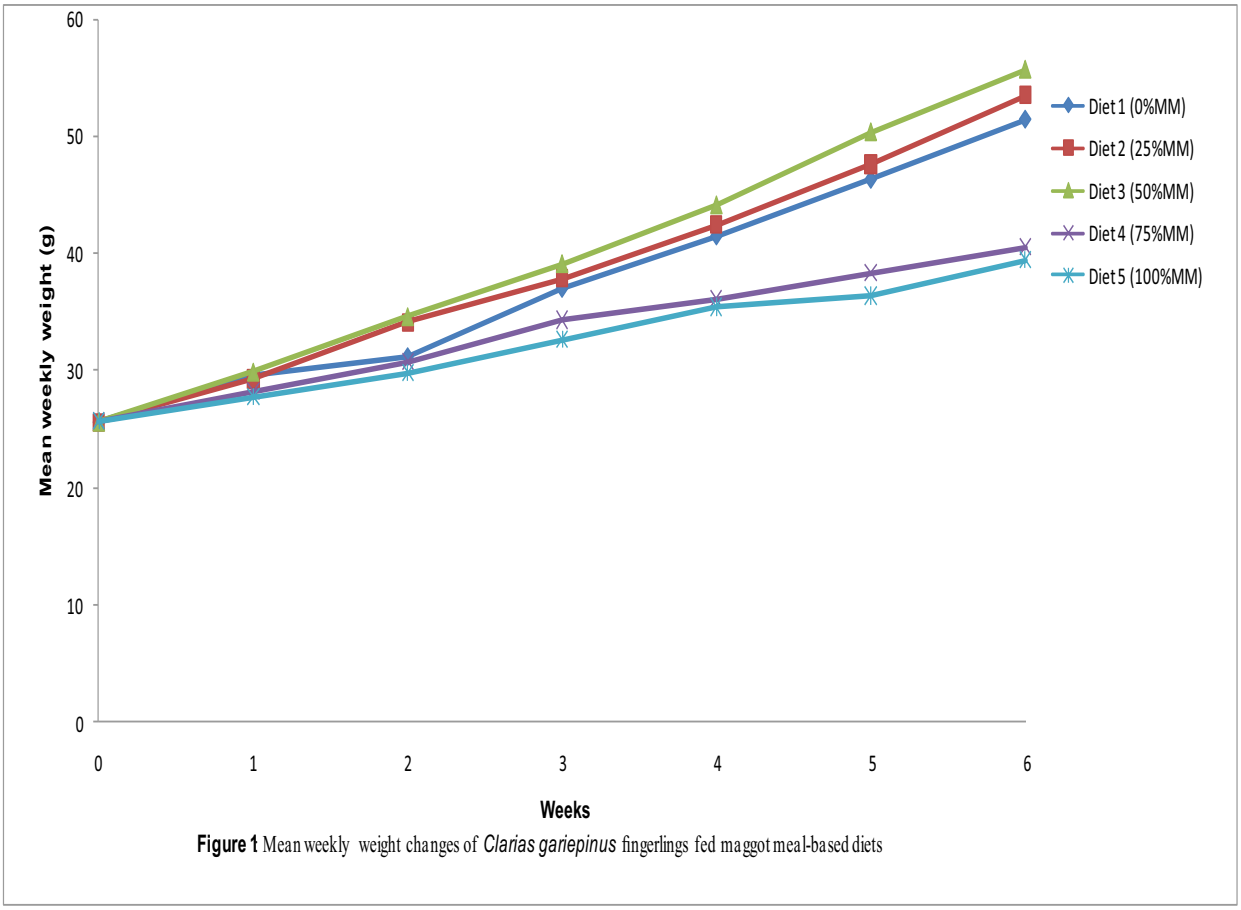



**Figure 1** Mean weekly weight changes of *Clarias gariepinus* fingerlings fed maggot meal-based diets

## DISCUSSION

The moisture content of the maggot meal was moisture content 9.80%, crude protein 51.78%, crude fat 23.92%, ash 11.56%, crude fibre 1.65 and NFE 4.29%.Protein levels of maggot meal in this study were in accord with Sogbesan *et al.*, (2006) who reported protein levels of 50.42g/100g. However, the crude protein of maggot meal was comparably with that published by (Adetarami and Akinlade, 2013).

The result revealed that diets were iso-nitrogenous. The protein content ranged from 42.12 to 42.84% and was not significantly different ($p>0.05$) and conforms to the recommendation of optimum dietary protein of fish (Sogbesan and Ugwumba, 2008). he results also showed that there is a significant difference ($p>0.05$) in moisture content and carbohydrates of the different diets. Crude fat was highest in diet 1 (12.78%), followed by diet 2 (12.74%), followed by diet 4 (12.72%) and diet 5 (12.63%) while diet 3 had the lowest value (12.61%) of crude fat. Total ash was highest in diet 3 (11.43%), followed by diets 2 (11.36%), followed by diet 4 (10.42%) and 5 (10.41%) while diets 1 had the lowest value (8.55%) of total ash. Diets 4 had the highest crude fibre value of 4.10%, followed by diet 3 (3.93%), followed by diet 5 (3.91%) and diet 2 (3.88%) while diet 1 had the lowest value (3.84%) of crude fibre. The nitrogen free extract (NFE) was highest in diet 1 (20.05%), followed by diet 3 (17.55%), followed by diet 4 (17.27%) and diet 5 (17.16%) while diet 2 had the lowest value (16.94%) of NFE.

In the present study, there was a general increase in weight gain in all treatments, thus indicating that the fish were able to convert feed protein in extra muscles. Weight gain and specific growth rate are usually considered as the most important measurement of productivity of diets (Ogunji *et. al.*, 2008). Growth performance and survival by C. *gariepinus* fed sundried maggot meal-based diets in Table 4 showed that an increase in the maggot meal in the diets gave growth, development in and feed conversion efficiency. A decrement in mean weight gain (MWG) and specific growth rate (SGR) were observed with increasing

levels of sundried maggot meal. The best growth for all treatments was observed in African catfish, C. *gariepinus* fingerlings fed 50% sundried maggot meal-based diet (Diet 3). The improving growth response observed with increasing levels of sundried maggot meal, may be caused by the high level of crude protein in maggot leaf meal. This agreed with (Fantatto *et al*., 2024) who observed a better performance by exploring maggot as sustainable alternatives in aquaculture feeding. Fish fed 100% sundried maggot meal inclusion level (Diet 5) recorded the least FCR (4.53), this is an indication that it has lower feed to flesh conversion. The lowest growth rate was noticed in the Diet 5, this may be attributed to the low feed conversion efficiency. All the five treatments were accepted and utilized by the fingerlings with the highest total feed intake observed in Diet 3 (50%SMM) while Diet 5 showed the lowest value, this is in agreement with Madu and Ufodike (2003) that worked on growth and survival of catfish (*Clarias anguillaris*) juveniles fed tilapia and maggot as unconventional diets. The significantly ($P>0.05$) higher protein efficiency ratio (PER) of fish fed 25% and 50% sundried maggot meal based diets compare to others, attests to the fact that maximum utilisation of nutrients was obtained at the higher levels of sundried maggot meal in the diet.

## CONCLUSION AND RECOMMENDATION

In this study, sundried maggot (SMM) meal was incorporated at different levels into the diets of fingerlings of C*larias gariepinus*. Analyses of the maggot meal indicate that the proximate composition is comparable with those of animal protein sources. The formulated diets were nutritionally acceptable and biological available to fingerlings of C. *gariepinus* in indoor condition. The dried maggot meal can be included in the diet of C. *gariepinus* without compromising fish growth and nutrient utilization. Based on the results of the study, moderate replacement of fish meal with sundried maggot meal at 50% inclusion level in the diets of African catfish,C. *gariepinus* is recommended.

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# EFFECT OF ORGANIC MANURE ON ZOOPLANKTON DYNAMICS IN AQUACULTURE IN NASARAWA STATE, NIGERIA

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**ABSTRACT**
*The study investigated the effect of different organic manures poultry droppings, cow dung, and their combination on zooplankton abundance in aquaculture tanks. Twelve plastic tanks (50 L) were filled with 30 L of borehole water and fertilized with respective treatments in a completely randomized design with three replicates. Zooplankton samples were collected from River Shabu and Ombi 2 and monitored over 20 days. Moina micrura thrived best in poultry droppings, reaching a peak population of 55.33 ± 2.95 at day 12, while Cyclops nauplii and Brachionus calyciflorus peaked in cow dung and mixed manure treatments. Water quality parameters remained within acceptable ranges for aquaculture, although dissolved oxygen was slightly lower in manured treatments. Poultry manure was most effective in promoting cladocerans, while cow dung favored copepods and rotifers. Organic manure application is recommended as a low-cost strategy for enhancing live feed production, fish survival, and overall pond productivity.*

**Keywords**: Zooplankton, Poultry Manure, Cow Dung, Aquaculture, Live Feed.

## INTRODUCTION

The use of manure in aquaculture supports the production of protein using inputs of little nutrient value to man or livestock. In organic fertilizers are expensive and their use by small holder farmers may be limited. Animal manures have a long history of use as a source of soluble phosphorus, nitrogen and carbon for algal growth and natural food production. Animal manure is often used in semi-intensive systems to improve the primary production of the ponds and fish growth (*Justine*, 2012).

Fish farming provides both food and income in many communities (Brummett, 1995; Brummett and Noble, 1995). Successful aquaculture relies on proper feeding of fish larvae, fry, and fingerlings, which require adequate lipids, proteins, carbohydrates, vitamins, and minerals (Watanabe and Kiron, 1994; Kanazawa, 2003). Poor nutrient availability can result in low growth, poor feed efficiency, and high mortality (Sargent *et al.*, 1999; Olivotto *et al.*, 2003).

Organic manures are a cost-effective alternative to artificial feeds. Animal manures provide nitrogen, phosphorus, and carbon, stimulating algal growth and natural food production for fish (Justine, 2012). Poultry manure has been shown to trigger more phytoplankton production than other organic or chemical fertilizers (Boyd, 1982). Cow dung and mixtures of manures can enhance different types of zooplankton, contributing to larval survival and growth (Rath and Rajendra, 2011; Palanichamy, 1996).

The larval fishes are often fed with rotifers and cladocera at first followed by artificial pelleted feeds later. The fry and spawn prefer live feed though formulated feeds are sufficiently rich in protein. The requirements of the minerals and micronutrient for spawn and fry are still little understood to be incorporated formulated feeds (Rath and Rajendra, 2011).

This study aims to determine the effect of different organic manures on zooplankton abundance and assess the implications for small-scale aquaculture in Nasarawa State, Nigeria.

## MATERIALS AND METHODS

### Study Area

The experiment was conducted at the Department of Aquaculture and Fisheries Management, Nasarawa State University, Lafia (Latitude 8°35′N, Longitude 8°32′E), altitude 181.53 m, mean temperature 34°C, relative humidity 40–80%, daylight 9–12 hours.

### Experimental Design

Twelve plastic tanks (50 L) were filled with 30 L borehole water and fertilized with:
T1: Poultry droppings (10 L filtrate).
T2: Cow dung (10 L filtrate).
T3: Poultry + Cow dung (5 L each).
T0: Control (no manure).
The design was completely randomized with three replicates per treatment.

### Zooplankton Collection

Zooplankton were collected from River Shabu using 100 $\mu$m mesh plankton nets, pooled, and introduced into each tank at 0.3 L per tank.

### Data Collection

Zooplankton Abundance: 2 mL samples were preserved with 4% formalin, mounted on slides, and counted under × 40 magnifications.
Water Quality: Temperature (°C) and dissolved oxygen (mg/L) were measured every 4 days at 07:00 am using a digital thermometer and Winkler titration method.

### Statistical Analysis

Data were analyzed using Analysis of Variance (ANOVA) in SPSS; significance was set at $p < 0.05$

## RESULTS

### Zooplankton population at four days (4) intervals in organic manure

Table 1 shows high value of 8.67±0.84 population of *Moina micrura* and low population of *Branchionus calyciflorus* value is 1.66±0.42 was recorded in poultry droppings. The value of 6.33±0.21 poulation of *Moina micrura*, 5.33±0.84 of *Cyclop nauplii* and 1±0 of *Branchionus calyciflorus* were record in cow dung. The value of 6.67±2.32 population of *M. micrura*, 5±0 for C. *nauplii* and 1.67±0 *B. calyciflorus* were recorded in poultry + cow dung. The value of 3±0 population of *Moina micrura, Cyclops nauplii* 4±0.63 and *Branchionus calyciflorus* 1.33±0.21 were recorded at day 4 in control respectively. Table 1 shows that the population of *Moina micrura* value is 55.33±2.95 while *Cyclop nauplii* 13.67±2.32 and *Banchionus calyciflorus* 3.33±0.84 in poultry droppings at day 12. Table 1 shows the value 20±3.16 for *M. micrura*, 24.33±2.73 for C. *nauplii* and 6.67±1.05 for *B. calyciflorus* at day 12 in cow dung. Table 1 shows the value 33.33±2.10 for *M. micrura*, 17.66±4.84 for C. *nauplii* and 2±0 for *B. calyciflorus* in poultry + cow dung at day 12 and the value 5.33±0.21 for *M. micrura*, 5.67±0.21 for C. *nauplii* and 1.67±0.42 for *B. calyciflorus* in the control at day 12 respectively. Table 1 show the population value 6±0 for *M. micrura*, 5.33±0.21 for *Cyclops nauplii* and 0.67±0.21 *B. calyciflorus* in poultry droppings at day 20. The value 7±0.63 for *M. micrura*, 5±0.63 for C. *nauplii*, 1.33±0.21 for *B. calyciflorus* in cow dung at day 20. The value 15.33±0.21 for *M. micrura*, 16.33±2.32 for C. *nauplii* and 1.67±0.21 for *B. calyciflorus* in poultry + cow dung at day 20. The value 6.67±1.06 for *M. micrura*, 7±0.63 for C. *nauplii* and 0.33±0 for *B. calyciflorus* at day 20 in control.

**Table 1:** Zooplankton population at four days (4) intervals in organic manure

| Treatments | | Day 4 | Day 8 | Day 12 | Day 16 | Day 20 |
|---|---|---|---|---|---|---|
| Poultry dropping | *Moina micrura* | 8.67±0.84c | 37.00±1.89b | 55.33±2.95a | 35.33±2.95b | 6.00±0.00c |
| | *Cyclops nauplii* | 5.33±0.21c | 17.00±1.89a | 13.67±2.32b | 8.00±0.00c | 5.33±0.21c |
| | *Branchionus calyciflorus* | 1.66±0.42c | 6.00±3.15a | 3.33±0.84b | 1.33±0.00c | 0.67±0.21d |
| Cow dung | *Moina micrura* | 6.33±0.21d | 27.67±1.68a | 20.00±3.16b | 17.00±1.89c | 7.00±0.63d |
| | *Cyclops nauplii* | 5.33±0.84d | 22.00±1.89b | 24.33±2.73a | 18.00±1.26c | 5.00±0.63d |
| | *Branchionus calyciflorus* | 1.00±0.00d | 4.33±0.21b | 6.67±1.05a | 2.00±0.00c | 1.33±0.21d |
| Poultry+Cow dung | *Moina micrura* | 6.67±2.32e | 31.33±0.84b | 33.33±2.10a | 24.33±2.32c | 15.33±0.21d |
| | *Cyclops nauplii* | 5.00±0.00b | 17.00±1.89a | 17.66±4.84a | 18.00±1.26a | 16.33±2.32a |
| | *Branchionus calyciflorus* | 1.67±0.00e | 4.33±2.08a | 2.00±0.00c | 2.33±0.21b | 1.67±0.21d |
| Control | *Moina micrura* | 3.00±0.00d | 2.67±0.42d | 5.33±0.21c | 7.33±1.68a | 6.67±1.06b |
| | *Cyclops nauplii* | 4.00±0.63d | 3.67±0.42d | 5.67±0.21c | 8.33±1.06a | 7.00±0.63b |
| | *Branchionus calyciflorus* | 1.33±0.21b | 2.00±0.00a | 1.67±0.42b | 1.00±0.00c | 0.33±0.00d |

**Water quality parameter used for culturing zooplankton**

Table 2 shows the result shows that poultry droppings had the high value of temperature 27.58+0.07°C, Poultry + cow dung has the temperature range value of 27.00+0.65°C which is significantly different from cow dung 26.23+0.22°C and control has the lowest temperature range 26.13+0.15°C. Dissolved oxygen was high value of 6.61mg/l in water with no manure i.e. control which is significantly different from other treatments cow dung with value of 5.76+0.44mg/l, poultry + cow dung with the value 5.04+0.11mg/l and the lowest dissolved oxygen was recorded in poultry droppings 4.81+0.13mg/l.

**Table 2:** Water quality parameter used for culturing zooplankton

| Treatment | Dissolved Oxygen (mg/l) | Temperature ($^0$C) |
|---|---|---|
| Poultry dropping | $4.81+0.13^c$ | $27.58+0.07^a$ |
| Cow dung | $5.76+0.44^b$ | $26.23+0.22^b$ |
| Poultry + Cow | $5.04+0.11^b$ | $27.00+0.65^a$ |
| Control | $6.65+0.04^a$ | $26.13+0.15^b$ |

## DISCUSSION

From the result of table 1, it shows that the population density of *Moina micrura* in poultry dropping reached its peak (55.33±2.95) at 12 days of culture then drops to 35.33±2.95 at 16 days of culture. Likewise *Moina micrura* production in cow dung was at its peak at 8 days of culture before dropping at 16 days and 12 days in combination of poultry and cow dung. There was a fall in the population after 12 days of culture. C*yclops nauplii* was also at its peak of production at 8 days in poultry dropping, 12 days in cow dung and 16 days in combination of poultry dropping and cow dung while the control was at its peak of production at 16 days before crashing. *Brachionus calyciflorus* culture in poultry dropping was at its peak of production at 8 days and day 12 in cow dung while in combination of poultry and cow dung, the peak of production was recorded at day 8. Production and population were at its peak in the control at day 8. From the result in table 1, it shows that *Moina micrura* thrive better in poultry dropping and combination of poultry dropping and cow dung at 12 days and 8 days in cow dung only. Whereas, C*yclops nauplii* thrive better in poultry dropping at day 8 and 12 days in cow dung and combination of cow dung and poultry dropping. *Brachionus calyciflorus* was able to thrive well in poultry dropping at day 8 and day 12 in cow

dung and combination of poultry dropping and cow dung. This points to the fact that using any of the three organic fertilizers will give varying population of zooplankton over an 20 days culture period. This is in agreements with the findings of Rottmann *et al*. (2003) on the use of cow dung and swine faeces as fertilizers in zooplankton culture. These high percentages which the days accounted for, among other factors, is in tandem with the submission of Ovie *et al*. (2000), that organic manures are used to provide suitable nutrients for the culture of moinids and other zooplanktonic assemblages. Similarly, Morris (1995) reveals that organic fertilizers have low carbon to nitrogen (C:N) ratios, with fine particle sizes which allow rapid decomposition. Zooplanktons consume and utilize the fungi and bacteria associated with the decaying organic materials to achieve body and population growth.

However, the use of heavy doses of organic manures may cause dissolved oxygen and ammonia problems during the initial decomposition, which could result in poor zooplankton growth and survival. This confirms the need for application of appropriate quantities. From the result Poultry droppings shows to be more effective in term of zooplankton population, which was in agreement with Boyd (1982) who reported that poultry manure triggers more production of phytoplankton in ponds than any organic fertilizers including chemical fertilizer. The favourable temperature condition and unlimited supply of nutrients, mainly nitrogen (N), phosphorus (P), and potassium (K), from the manures allowed increase in zooplankton population as the number of days increased till the populations reached their peaks. This is in consonance with Morris (1995) view on the use of organic fertilizers to promote desirable zooplankton species, such as rotifers, copepods, moina and daphnia. This result also follows the submission of Wurts (2004) that organic fertilizers are effective in zooplankton production in particular copepods, as well as cladocerans, especially *Moina micrura* and *Daphnia spp* in the tropical African region. Water quality parameters including water temperature and dissolved oxygen were within the acceptable range for optimal fish growth and health as recommended by Boyd (1979) and Viveen *et al*. (1986).

## CONCLUSION

Poultry droppings are most effective for *Moina micrura*. Cow dung favors C*yclops nauplii* and *Branchionus calyciflorus*. Mixed manure produces moderate populations. Organic manures are viable, low-cost alternatives to artificial feeds.

## RECOMMENDATIONS

Apply poultry droppings to boost *Moina micrura* for larval feed. Use cow dung or mixed manure for balanced populations of copepods and rotifers. Apply manure moderately to prevent oxygen depletion. Conduct further studies on other local manures and long-term pond effects.

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# POTENTIAL OF MARKET DEGRADABLE WASTE IN FISH FEED PRODUCTION

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**ABSTRACT**
*Proximate analysis of different market waste purchased from Sapele market shows as follows: A (fish waste) is composed of 12.40% moisture, 47.11% CP, 7.65% fats, 7.55% fibre, 23.02% ash, 2.27% CHO (carbohydrate) and 2635.45 Kcal metabolizable energy. B (vegetable waste) was composed of 11.10% moisture, 13.81% CP, 2.10% fat, 19.41% fibre, 19.97% ash, 33.61% CHO and 2075.3 Kcal metabolizable energy. While C (waste from grains) was composed of 9.10 moisture, 10.66% CP, 2.86% fat, 6.45% fibre, 7.54% ash. 54.39% CHO and 2834.85 Kcal metabolizable energy. This indicates that market waste can be a good source of ingredient for the production of feed for Clarias gariepinus if well investigated.*

**Keywords**: Fish Feed, Market Degradable Waste, Proximate Analysis

## INTRODUCTION

Fish and fish products are known worldwide as very important diet to humans because of their high nutrient quality and significance in improving human health (Amao *et al.*, 2006). Fish is lower in fat compared to any other source of animal protein. Oily fish are high in omega-3-fatty acids commonly called "the good fats". Since the human body cannot make significant amount of these essential nutrients, fish consumption becomes an important part of the human diet (Edwin *et al.*, 2001; Oyewole and Amosu, 2012; Uchechukwu *et al.*, 2014). Catfishes of the family *Clariidae* are the most commonly cultivated fishes (Chris *et al.*, 2011; Adewumi and Oluleye, 2011). However, cost of fish feed has been reported by many researchers to be a major limiting factor in the production of catfish in Nigeria (Ohen and Abang, 2009; Nwosu and Onyeneke, 2013). Fishmeal is an excellent protein source in fish diet due to its balanced amino acid profile and high digestibility by fish. Traditionally, fishmeal is the main dietary protein source in fish feed formulation. But the cost of fish meal has been reported to be the major contributor to high cost of feed which has resulted to the close down of many farms in the country. Without quality feed, fish production in Nigeria will drastically reduce which will in turn increase food insecurity, loss of jobs and also increase insecurity in the country. As a result, it become very important for Nigeria Institute for Oceanography and Marine Research having been in the forefront in the fight against food insecurity to urgently carry out research to reduce this high cost of feed using renewable waste. This will not only provide cheap feed for farmers but will also reduce waste generated from our markets.

## MATERIALS AND METHODS

The study was conducted at the Nigerian Institute for Oceanography and Marine Research Sapele out station Sapele Local Government Area of Delta State, Nigeria (N50 54´.5´´E005°39´56.4´´). Two main markets were visited around Sapele local government. The market waste was purchased from these two markets. All the wastes were processed separately by drying under the sun. The dried wastes were taken for crushing into fine particles separately using local grinding machine. The crushed samples were taken for proximate analysis and results recorded.



**Figure 1:** Vegetable waste



**Figure 2:** Waste from fish



**Figure 3:** Waste from grains

## RESULTS AND DISCUSSION

The percentage moisture, crude protein, crude fat, fibre, ash, and CHO as well as metabolizable energy in Kcal/kg are show in the table below.

**Table 1:** Proximate Analysis of different market waste purchased from Sapele market

| Parameter | A | B | C |
|---|---|---|---|
| **Moisture%** | 12.40 | 11.10 | 9.10 |
| **CP %** | 47.11 | 13.81 | 19.66 |
| **Fat %** | 7.65 | 2.10 | 2.86 |
| **Fibre %** | 7.55 | 19.41 | 6.45 |
| **Ash %** | 23.02 | 19.97 | 7.54 |
| **CHO %** | 2.27 | 33.61 | 54.39 |
| **Met. Energy Kcal/kg** | 2625.45 | 2075.3 | 2834.85 |

**A = fish waste, B = Vegetable waste, C = Waste from grains**

Proximate analysis of different market waste purchased from Sapele market shows as follows: A (fish waste) is composed of 12.40% moisture, 47.11% CP, 7.65% fats, 7.55% fibre, 23.02% ash, 2.27% CHO (carbohydrate) and 2635.45 Kcal metabolizable energy. B (vegetable waste) was composed of 11.10% moisture, 13.81% CP, 2.10% fat, 19.41% fibre, 19.97% ash, 33.61% CHO and 2075.3 Kcal metabolizable energy. C (water hyacinth) was composed of 10,60% moisture, 16.06% CP, 4.21% fat, 27.97% fubre, 16.45% ash, 24.74% CHO and 1989.85% Kcal metabolizable energy. While D (waste from grains) was composed of 9.10 moisture, 10.66% CP, 2.86% fat, 6.45% fibre, 7.54% ash. 54.39% CHO and 2834.85 Kcal metabolizable energy.

According to Maranga, et al (2023), the proximate analysis of some feed ingredients showed that the CP of fish meal was 48.80% while the fish waste recorded 47.11%. The wheat brain was reported to have CP of 17.10% while waste from grains recorded 19.66% CP. Udo and Ozor (2022) reported the proximate analysis some feed ingredients of fish meal CP of 52.89%, yellow maize meal (cereal) with CP of 7.31% and Fermented Bambara nut meal having CP of 21.92% which is relatively close to the result of the market waste recorded in this study. Comparing the proximate composition of waste analysed in this study with that recorded by Maranga, et al (2023), and Udo and Ozor (2022), it becomes very important to carry out more research on market waste as a way of reducing cost of fish production in Nigeria.

## CONCLUSION

This study is ongoing; feed will be formulated using the investigated market waste, proximate of the feed carried as well as feeding trials. We are determined in bring down the coat of feed.

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# GROWTH PERFORMANCE AND OXIDATIVE STRESS RESPONSE OF *Clarias gariepinus* (Burchell, 1822) FED GRADED DIETS WITH *Zingiber officinale* R. AND *Allium sativum* L.

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**ABSTRACT**
*Stress and diseases are one of the leading causes of economic loss in aquaculture and one of the ways to mitigate against these is by use of antibiotics during production. In order to cut back on the use of synthetic antibiotics, there is a need to explore other natural alternatives. Therefore, the present study investigated the effect of Zingiber officinale (ZO) and Allium sativum (AS) mixtures on growth and oxidative stress response of Clarias gariepinus juveniles (n= 540). A basal diet amended with varying ratios of ZO to AS in g per 1kg of diet were used as treatments; T1 (control) 0:0, while T1, T2, T3, T4, T5 and T6 contained 100:0; 75:25; 50:50; 25:75 and 0:100 respectively for 56 days. Growth parameters, including weight gain, feed conversion ratio (FCR), protein efficiency ratio (PER), and feed efficiency (FE), were recorded. Tissue samples from the liver and intestines were analysed for oxidative stress markers and antioxidant enzyme activities following standard procedures. Results of fish fed diet 100g/kg AS showed improved growth performance with highest weight gain of 93.02±2.27g and FCR of 0.83. Antioxidant tests showed less oxidative stress, with decreased lipid peroxidation and improved enzyme activity present in supplemented treatments. These results indicate that garlic and ginger improved growth performance and decreased oxidative stress in C. gariepinus, suggesting a natural substitute to artificial feed additives.*

**Keywords:** Antioxidant enzymes, Aquaculture, Feed additives, Oxidative stress

## INTRODUCTION

Nigeria is the most populous nation in Africa and with the growing population of an estimated 239 million people (Worldometers, 2025) there is an increasingly growing demand for protein especially fish, estimated at 3.2m metric ton and a production of 1.1m metric tonnes (FAO, 2025) which has been reported to be a cheap source of protein (Liverpool-Tasie *et al.*, 2021). Aquaculture as one of the fastest growing food-producing sectors has contributed in meeting growing demand for aquatic food species, reducing pressures on capture fisheries and improving economic growth (Sadiq *et al.*, 2025).

*Clarias gariepinus* is a key species in African aquaculture due to its adaptability, fast growth, and resilience. However, oxidative stress and diseases remain significant threats to its production which is often managed with antibiotics; these have raised concerns about residual effect, resistance, and costs. Adding phytogenic feed additives to fish diets has been reported to show great potentials in improving antioxidant status and reducing stress response of fish (Serradell *et al.*, 2023). Phytogenic such as ginger and garlic are useful in preventing and treating fish diseases in aquaculture, promoting growth and influencing immune responses (Fei, 2020; Osama *et al.*, 2022; Mehri *et al.*, 2014; Rania *et al.*, 2019). This has necessitated the need to explore other natural alternatives with antioxidative stress properties to be used as feed additives in aquaculture.

Ginger (*Zingiber officinale* Roscoe), mostly cultivated in the Southern region of North Nigeria (Ayodele

and Sambo, 2014), provide resources for use in medicine, food and nutrition and supplements. Recent researches have focused on improving its productivity and agronomic qualities overtime particularly for its medicinal value amongst others (Adiele and Ezeokwelume, 2022). Garlic, a member of the *Liliaceae* family, is a globally cultivated bulbous plant, capped at hundreds of in vitro/ in vivo and therapeutic testing for its medicinal effect and phytochemical properties (Yusuf *et al.*, 2018).

Although previous studies have investigated phytogenic additives, limited research exists on the combined effect of ginger (*Z. officinale*) and garlic (*A. sativum*) on oxidative stress markers and growth in C. *gariepinus*. These additives when administered to fish in small amounts can act to improve fish growth performance such as feed intake, weight gain and as organic additives, they are less harmful to the aquatic environment (Alemayehu *et al.*, 2018). This study therefore, aims to investigate the effects of dietary mixtures of *Z. officinale* and *A. sativum* on the oxidative stress response and growth performance of C. *gariepinus* juveniles.

## MATERIALS AND METHODS

This study was carried out at the Faculty of Agriculture Teaching and Research Farm, University of Abuja Main Campus, along airport Road, Gwagwalada, Abuja, Nigeria.

### Experimental fish and diets

Five hundred and forty (540) disease-free C*larias gariepinus* (15.0±2.0g) were acclimatize for 14 days and randomly assigned to six treatments with three replicates each. Diets were prepared with ginger and garlic mixtures at ratios of 0:0 (control); 100g:0g; 75g:25g; 50g:50g; 25g:75g; and 0g:100g and bound with corn starch to 1kg of commercial feed. The feed were air-dried and fed twice daily to the experimental fish for 56 days.

### Parameters measured

Growth parameters such as weight gain, percentage weight gain, Feed conversion ratio (FCR, PER, FE, SGR were monitored using the following formulas

$$MWG\ (g) = W_2 - W_1$$

$$PWG\ = \frac{Weight\ gain\ (g)}{Final\ weight}\ x\ 100$$

$$SGR = \frac{lnW_2 - lnW_1}{T_2 - T_1} \times 100$$

$$PER = \frac{Body\ weight\ gain}{Protein\ intake}$$

$$Survival\ Rate\ (\%) = \frac{Number\ of\ fish\ that\ survived}{Total\ number\ of\ fish\ stocked} x\ 100$$

Where;
$W_1$ = initia1 weight of fish,
$W_2$ = fina1 weight 0f fish and
T = duration of experiment (day).
Serum, liver, and intestinal tissues were analysed for oxidative stress markers such as; malondialdehyde (MDA), hydrogen peroxide ($H_2O_2$), Hydroxyl Radical Scavenging Activity (HRSA) Lipid peroxidation (LPO) and antioxidant enzymes such as; superoxide dismutase (SOD), catalase (CAT), glutathione reductase (GR), glutathione peroxidase (GSH-Px), reduced glutathione (GSH) and total antioxidant capacity (T-AOC).

### Statistical analysis

Data generated were subjected to one-way analysis of variance (ANOVA) followed by Tukey HSD post-

hoc test using SPSS version 21 at 5% level of significance ($p<0.05$).

## RESULTS AND DISCUSSION

### Growth Performance of C. *gariepinus* fed graded levels of *Z. officinale* and *A. sativum*

The data presented in figure 1 shows the results of fish fed diets with *Z. officinale* and *A. sativum*. The growth performance of *Clarias gariepinus* fed diets with ginger (*Zingiber officinale*) and garlic (*Allium sativum*) mixtures shows the potentials of these natural herbs as replacements for synthetic antibiotics and as additives in aquaculture (Jahanjoo *et al.*, 2018; Korni *et al.*, 2021).

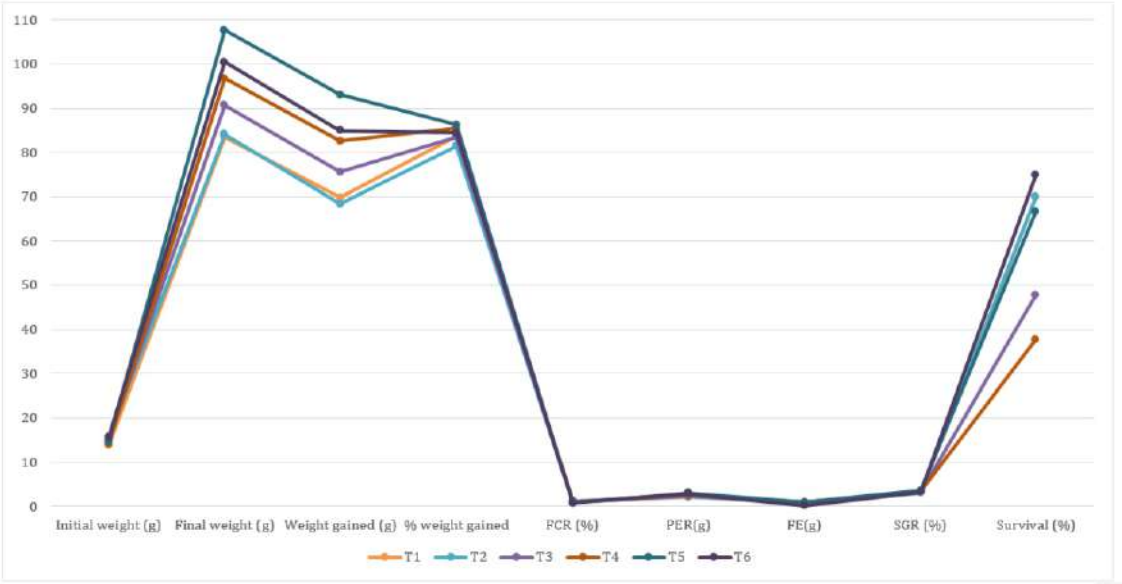



**Figure 1:** Growth Performance of *C. gariepinus* fed diets with *Z. officinale* and *A. **sativum***

The results obtained from the present study showed significant variations in growth parameters and oxidative stress responses influenced by the specific combinations of these additives indicating the possible coactive or additive effects of combining ginger and garlic. *Clarias gariepinus* fed diets with varying inclusion levels of ginger-garlic mixtures exhibited significantly higher growth than the control. Final weights ranged from 83.44±24.71g in C. *gariepinus* fed control diet, 0g:0g ($T_1$) to 107.80±24.66g in fish fed diets 25g:75g ($T_5$) followed by fish fed $T_6$ (100.44±32.92g). The highest mean weight gain (93.02±2.27g) and lowest FCR (0.83) was recorded in fish fed diets containing 25g:75g ($T_5$). Similarly, feed efficiency (FE) and protein efficiency ratio (PER) were higher in fish fed ginger-garlic amended diets with fish fed 25g:75g ginger to garlic recording 1.03 and 3.00 FE and PER respectively. Survival was highest (75±5.78%) in fish fed the highest garlic concentration 0g:100g ($T_6$) but not significantly different ($p>0.05$) from fed T5 (66.7±7.28%), however, it differed ($p<0.05$) from those fed T4 (37.8±5.92%). These results are in tandem with the findings of Mehri *et al.* (2014), Adewole (2021) and Amulejoye *et al.* (2024), who reported improved growth in catfish fed diets supplemented with phytogenic additives. The weight gain observed in the current study suggests that garlic, when combined with ginger, enhances nutrient assimilation and feed efficiency.

### Oxidative stress markers in liver of C. *gariepinus* fed diets with *Z. officinale* and *A. sativum*

Results of oxidative stress markers and antioxidant enzymes in tissues of C. *gariepinus* fed diets with *Z. officinale* and *A. sativum* are presented in table 1. Oxidative stress markers in the liver and intestines showed that fish fed the control diets ($T_1$) and 0g:100g ginger to garlic (T5) had lower hydrogen peroxide ($H_2O_2$), malondialdehyde (MDA) and lipid peroxidation (LPO) values.

**Table 1:** Oxidative stress markers in liver of C. *gariepinus* fed diets with *Z. officinale* and *A. sativum*

| Parameter | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ |
|---|---|---|---|---|---|---|
| $H_2O_2$ (mmol/g protein) | $9.2\pm0.09^{a}$ | $11.48\pm0.42^{b}$ | $11.20\pm0.51^{bcf}$ | $11.07\pm0.72^{dcf}$ | $10.69\pm0.64^{e}$ | $11.12\pm0.15^{f}$ |
| HRSA (U/g protein) | $2.67\pm0.13^{a}$ | $1.09\pm0.10^{b}$ | $1.34\pm0.12^{c}$ | $1.58\pm0.13^{d}$ | $2.26\pm0.11^{e}$ | $1.42\pm0.10^{c}$ |
| MDA (nmol/g protein) | $2.59\pm0.06^{a}$ | $4.27\pm0.10^{b}$ | $3.83\pm0.10^{c}$ | $3.65\pm0.11^{d}$ | $3.23\pm0.09^{e}$ | $2.37\pm0.03^{f}$ |
| LPO (μmol/g protein) | $1.75\pm0.02^{a}$ | $2.86\pm0.14^{b}$ | $2.66\pm0.11^{c}$ | $1.09\pm0.10^{d}$ | $1.00\pm0.13^{e}$ | $1.89\pm0.02^{f}$ |
| T-AOC (U/mg protein) | $2.41\pm0.03^{a}$ | $1.05\pm0.01^{b}$ | $1.40\pm0.01^{c}$ | $1.60\pm0.20^{d}$ | $1.81\pm0.03^{e}$ | $1.02\pm0.01^{b}$ |
| CAT (U/mg protein) | $11.13\pm2.41^{a}$ | $4.39\pm3.06^{b}$ | $6.09\pm2.77^{b}$ | $8.21\pm2.61^{bc}$ | $9.68\pm3.15^{ac}$ | $5.17\pm2.11^{bd}$ |
| T-SOD (U/mg protein) | $28.72\pm3.90^{a}$ | $20.04\pm4.19^{b}$ | $20.43\pm5.38^{b}$ | $20.66\pm5.00^{b}$ | $20.93\pm5.18^{b}$ | $20.10\pm3.21^{b}$ |
| GR (U/mg protein) | $6.10\pm1.04^{a}$ | $3.09\pm1.00^{b}$ | $4.22\pm0.96^{cd}$ | $4.37\pm1.03^{def}$ | $5.08\pm1.14^{ce}$ | $4.17\pm1.04^{cf}$ |
| GSH-Px (U/mg Protein) | $64.82\pm8.23^{a}$ | $57.01\pm6.09^{b}$ | $59.01\pm6.12^{b}$ | $59.44\pm5.73^{b}$ | $60.23\pm4.82^{ab}$ | $58.06\pm6.00^{b}$ |
| GSH (mg/ g protein) | $3.77\pm1.02^{a}$ | $1.08\pm0.04^{b}$ | $1.65\pm0.07^{c}$ | $2.30\pm0.55^{de}$ | $2.66\pm0.34^{e}$ | $1.21\pm0.10^{b}$ |

Mean with the same superscripts along the same rows differ significantly ($p < 0.05$)

Superoxide dismutase and other antioxidant enzymes were higher in fish fed the control diets followed by those fed diets with higher ginger concentrations; however, those fed diets with higher garlic inclusion had lower values, indicating that garlic provided some protective benefits to the fish. The results of this study are similar to those of Rania *et al.* (2019), Fazelan *et al.* (2020) and Olaniyi *et al.* (2020) who reported improved antioxidant status of tilapia, C*yprinus carpio* and C. *gariepinus* following feed supplementation with ginger and garlic.

## CONCLUSION

This study highlighted the antioxidant properties of ginger and garlic, as seen by the increased levels of antioxidant enzymes and reduced levels of oxidative stress markers in the liver of the fish fed diets with ginger and garlic mixtures. C*larias gariepinus* fed diets with ginger and garlic exhibited improved growth and reduced stress markers with no adverse effect to the health of the fish and can therefore serve as suitable natural feed additives in aquaculture.

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# GROWTH PERFORMANCE AND NUTRIENT UTILIZATION OF C*larias gariepinus* JUVENILE FED VARYING LEVELS OF CATTLE HOOF DIET

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**ABSTRACT**
*The study on the growth performance and nutrient utilization of African catfish (Clarias gariepinus) fed varying levels of cattle hoof meal was carried out for Twelve weeks (90 days). Diets containing 40% crude protein were formulated at 0, 25, 50, 75 and 100% for T1, T2, T3, T4 and T5 respectively. Twenty (20) juveniles of average weight of 10g were distributed five treatments in three replicates in a Randomized Complete Block Design (RCBD). The fish were fed at 5% body weight daily. The results of proximate composition show that cattle hoof meal contain 56.39%crude protein, 8.40% crude fibre, 7.20% crude lipid, 0.08%. Growth performance of Clarias gariepinus in the study showed significant differences (P<0.05) from each other. The fish fed the control diet (T1) had lower weight gain compared to fish fed in T5. The results indicated 100% cattle hoof meal had the highest (888.56%) while CHM1 (0%) had the lowest (668.90%) respectively. The results of specific growth of fish fed diet containing graded level of cattle hooves meal in the study showed T5 had highest (2.54) value followed by CHM2 (2.50) while CHM1 (2.27) was the lowest. Feed conversion of fish in treatment CHM1 was the highest (1.31) followed by CHM2 (1.28) which are significantly different (P<0.05) from other treatments. From the results of the study, Catfish (Clarias gariepinus) diets should be formulated with cattle hooves at 100% to replace fishmeal in order to reduce cost of production. Further studies on the best substitution level of fish meal with cattle hoof meal should be conducted using culturable indigenous species.*

**Keyword:** Nutrient, Utilization, Catfish, Cattle hoof.

## INTRODUCTION

C*larias gariepinus*, also known as African catfish, is widely cultured species in aquaculture due to its fast growth rate, highly yield potential and religious tolerance to various environmental conditions (Ojewole *et al*., 2022). However, the high cost of fish meal, a primary protein source in fish feed, poses a significant challenge to the sustainability of catfish farming (Nyadjeu *et al*., 2023).

Utilization of animal by-product protein in fish feed could be an alternative to expensive fishmeal to decrease production cost. Several animal by-products have been used to supplement/replace fish meal in the diet of C*larias gariepinus* at different inclusion level with each producing different results. Many studies have been conducted to determine the suitability of animal-based ingredients such as poultry by product (Gomaah and El Naggar, 2004), grasshopper meal (Olaleye, 2015), locust meal (Balogun, 2011), cricket meal (Taufek *et al*., 2016), recycled dead chicken meal (Agbabiaka *et al*., 2013), maggot meal (Ogunji *et al*., 2011). Chor *et al*. 2013 reported that 20% inclusion level of feather meal in the diet of C*larias gariepinus* produced the best promising result.

Cattle hoof meal (CHM) is rich in protein and essential amino acids, has been identified as a potential substitute for fish meal (Falaye and Sule, 2020). Recent studies have shown that C*larias gariepinus* juvenile fed with 25% cattle hoof meal had the best growth performance and feed utilization proficiency (Akinwole and Akinnuoye, 2012).

The high cost and increasing demand for fish meal in aquaculture feeds have led to a search for alternative protein sources. Fish meal is the major component of aquaculture feeds, but its high cost and limited availability have made it challenging for aquaculture farmers to maintain profitability (Omeru and Solomon, 2016). Cattle hoof meal, a by-product of cattle industry, has been identified as a potential substitute for fish meal due to its high protein content and availability (Umar *et al*., 2016). Therefore, this study investigates the growth performance and feed utilization of C*larias gariepinus* fed varying levels of cattle hoof diet.

## MATERIALS AND METHODS

### Study Area

This experiment was conducted in the Aquaculture Unit of Faculty Agriculture Shabu-Lafia Campus, Nasarawa State University, Keffi.

### Source of *Clarias gariepinus* Juveniles

A total number of 300 juveniles of C*larias gariepinus* were procured from Buka Sidi fish farm in Lafia and transported in 50-liter plastic container to the Aquaculture Unit of Faculty of Agriculture Shabu-Lafia Campus. The juveniles were fed with vital feed (commercial feed) during the two weeks period of acclimatization.

### Source of Cattle Hooves and Other Feed Ingredients

Cattle hooves were obtained from the abattoir at Zongo Area, Lafia, Nasarawa State. The other feed ingredients like fish meal, soybean meal, yellow maize, palm oil, salt, methionine, lysine, premix, were all obtained at Kasuwa Koro market, Lafia, Nasarawa State.

### Preparation of Cattle Hoof Meal

The Cattle hoof meal was prepared by soaking the hooves in 10 % sodium carbonate for sixty hours at room temperature. Thereafter it was boiled in a big pot (which contained 10% sodium carbonate) on a cooking gas for one hour. When boiling was completed, the hooves were oven dried at 80°C for 48 hours. This was done to aid the digestibility of the feed. On cooling, the hooves were pulverized into powder using pistil, mortar and a sieve and then stored in an air-tight polythene bag until required.

### Proximate Analysis of Cattle hoof Meal and Experimental diets

Proximate analysis of the prepared cattle hoof meal and experimental diets were carried out according to the Association of Official Analytical Chemist procedures (A.O.A.C., 2005) at Fertilizer Blending Plant Laboratory Lafia, Nasarawa State.

**Table 2.** Gross Composition of Experimental Diets Fed to C*larias gariepinus*

| Ingredients | Levels (%) of fishmeal replaced with CHM | | | | |
|---|---|---|---|---|---|
| | 0 | 25 | 50 | 75 | 100 |
| Cattle Hoof meal | 0 | 3.5 | 7 | 10.5 | 14 |
| Fish meal | 14 | 10.5 | 7 | 3.5 | 0 |
| Soya bean meal | 36 | 36 | 36 | 36 | 36 |
| Groundnut cake | 28 | 28 | 28 | 28 | 28 |
| Maize | 10 | 10 | 10 | 10 | 10 |
| Cassava flour (Binder) | 10 | 10 | 10 | 10 | 10 |
| Bone meal | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Lysine | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |

| | | | | | |
|---|---|---|---|---|---|
| Methionine | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Mineral-vitamin premix | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Salt | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Vegetable oil | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| **Total** | **100** | **100** | **100** | **100** | **100** |

**Experimental Setup**

The experiment was conducted in Completely Randomized Design using five treatments in three replicates. Twenty fish were stocked in each replicate, making a total of sixty fish per treatment. C*larias gariepinus* of uniform sizes were stocked in each tank to avoid cannibalism.

**Physicochemical Parameters of Water**

Water temperature and pH were measured with thermometer and pH meter weekly, before and after changing the water using clinical thermometer while dissolved oxygen (DO) was measured using DO meter.

**Growth Performance**

Growth performance of the fish after the 90 days of the feeding trial was determined using the following parameters:

**Mean weight gain (g) (MWG)**

$$MWG = Wt_2 - Wt_1$$ (Adikwu, 2003)

Where;

$Wt_1$ = Initial mean weight of fish at $T_1$

Wt2 = Final mean weight of fish at time T2

**Feed Conversion Ratio (g) (FCR)**

$$\text{Feed Conversion Ratio (g) (FCR)} = \frac{\text{Weight of feed given (g)}}{\text{Fish weight gain (g)}}$$

**Specific Growth Rate**

$$\text{Specific Growth Rate (SGR)} = \frac{\text{Log w2} - \text{Log w1} \times 100}{t}$$

$W_2$ = Final average weight at the end of the experiment

$W_1$ = Initial average weight at the beginning of the experiment

$Log_e$ = the base of natural logarithm (10)

t = Number of days for the experiment

**Relative Growth Rate (RGR)**

$$\text{Relative Growth Rate (RGR) (\%)} = \frac{(Wf - Wi) \times 100}{Wi}$$

Wf = Final average weight at the end of the experiment

Wi = Initial average weight at the beginning of the experiment

**Protein Efficiency Ratio**

$$\text{Protein Efficiency Ratio (PER)} = \frac{\text{Fish Weight Gain (g)}}{\text{Protein intake (g)}}$$

**Condition Factor (K)**

$$K = \frac{100 \times W}{L^3}$$

Where: K = Condition factor
L= Length (cm)
W = Body weight of fish (g)

**Survival Rate (%)**

$$(SR)\ (\%) = \frac{\text{Initial number of fish stocked} - \text{mortality} \times 100}{\text{Initial number of fish stocked}}$$ (Akinwole and Faturoti, 2006)

**Data Analysis**

Mean values of the water quality parameters measured was calculated. Mean values of the growth measurements and cost benefits were subjected to one way Analysis of variance (ANOVA) and tested for significant difference at 5% level of significance. Differences between Means were determined using Duncan's Multiple Range Test.

## Results

**Proximate Composition of Cattle hooves**

The result of proximate composition of cattle hooves in the study is presented in Figure 1. The content of moisture content was 6.05%, crude protein (56.39%), crude fibre (8.40%), crude lipids (7.20%), ash (11.90%) and carbohydrate (10.06%).

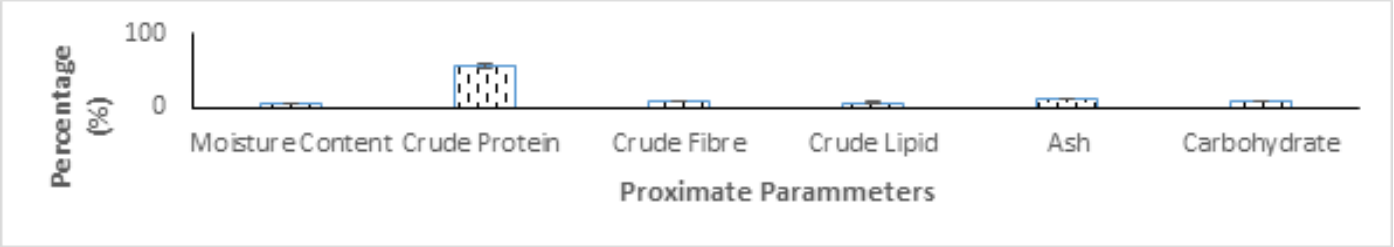



**Figure 1:** Proximate Composition of Cattle hooves Meal

**Proximate Composition of Experimental Diets**

The results of proximate composition of experimental diets are presented in Table 2 below. The results showed significant variation ($P<0.05$) in the parameters of Moisture Content, Crude Fibre, Ash, nitrogen free extract except nitrogen free extract. The mean values of moisture content of the diets ranged between 10.27±0.16 to 13.05±0.15, crude protein 40.38±2.33 to 41.09±2.43, crude fibre 1.92±0.05 to 3.47±0.68, crude lipid 12.11±0.65 to 12.54±0.19, ash 6.60±0.36 to 10.78±0.22, and nitrogen free extract 22.34±0.96to 28.25±0.16 respectively.

**Table 3:** Proximate Composition of Experimental Diets

| Parameters | CHM1 (0%) | CHM2 (25%) | CHM3 (50%) | CHM4 (75%) | CHM5 (100%) |
|---|---|---|---|---|---|
| **Moisture Content** | 10.84±0.21$^{b}$ | 10.36±0.33$^{b}$ | 11.37±0.11$^{b}$ | 13.05±0.15$^{a}$ | 10.27±0.16$^{b}$ |
| **Crude Protein** | 41.09±2.43$^{a}$ | 40.81±2.65$^{a}$ | 40.95±2.76$^{a}$ | 40.38±2.33$^{a}$ | 40.85±2.75$^{a}$ |
| **Crude Fibre** | 2.54±0.19$^{b}$ | 2.72±0.09$^{b}$ | 2.83±0.09$^{b}$ | 3.47±0.68$^{a}$ | 1.92±0.05$^{c}$ |
| **Crude Lipid** | 12.54±0.19$^{a}$ | 12.21±0.49$^{a}$ | 12.51±0.29$^{a}$ | 12.35±0.68$^{a}$ | 12.11±0.65$^{a}$ |
| **Ash** | 10.78±0.22$^{a}$ | 8.03±0.33$^{b}$ | 7.82±0.23$^{c}$ | 7.27±0.24$^{c}$ | 6.60±0.36$^{d}$ |
| **Nitrogen Free Extract** | 22.34±0.96$^{e}$ | 25.87±0.56$^{b}$ | 24.52±0.87$^{c}$ | 23.48±0.54$^{d}$ | 28.25±0.16$^{a}$ |
| **Gross energy** | 1874.33 | 1916.63 | 1908.16 | 1869.86 | 1955.49 |

Means with the same superscripts are not significantly different ($P>0.05$) from each other

**Condition Factor of Fish fed Cattle hooves Meal Diets**

The results in Figure 2 shows the condition factor of fish fed on experimental diets. The highest condition factor of fish was observed in CHM5 (2.77) indicating significant variation (P<0.5) from other treatments. The lowest value of condition factor was recorded in CHM2 (2.43) which showed no significant differences (P>0.05) from treatment CHM1 (2.49), CHM3 (2.49) and CHM4 (2.52) respectively.

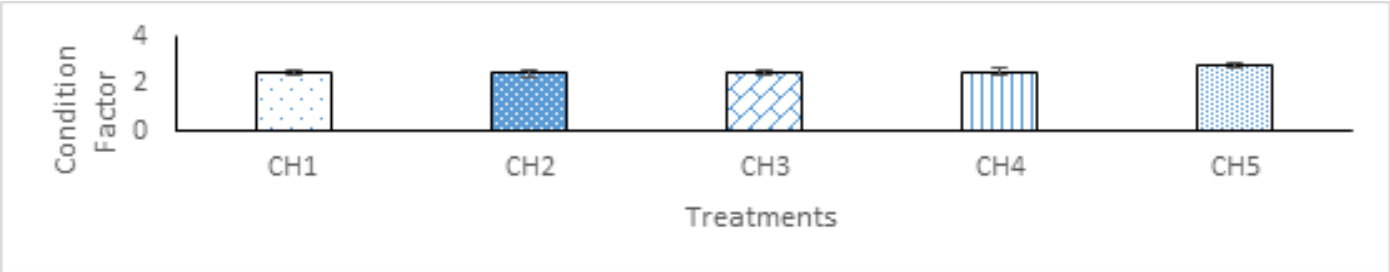



**Figure 2:** Condition Factor of Fish

**Survival rate of *Clarias gariepinus* fed with Cattle hooves Meal Diets**

The results in figure 3 showed the survival rate of *Clarias gariepinus* fed the experimental diets. There were significant differences (P<0.05) in the values of survival rate of fish obtained in the study. The results indicated that fish fed 75% (90%) and 100% (90%) inclusion of cattle hooves meals were the highest in terms of survival followed by fish fed with 50% (80%) of the hooves inclusion, 25% (75%) inclusion, while 0% (70%) inclusion was the lowest respectively.

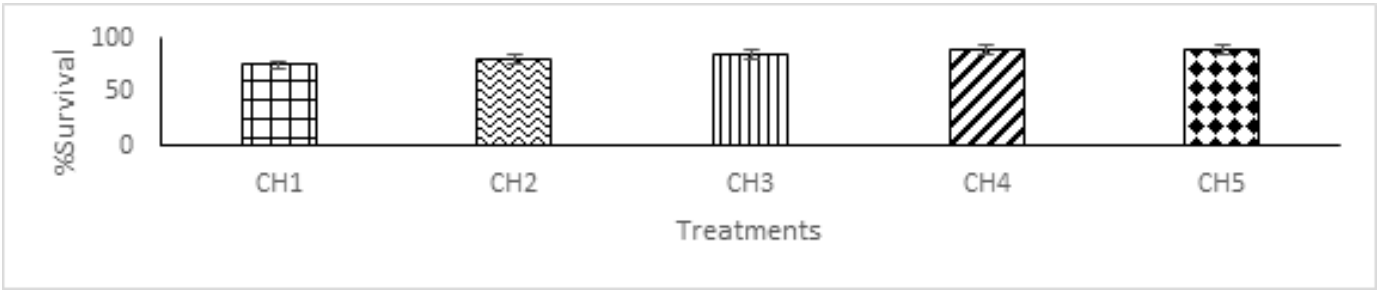



**Figure 3:** Survival rate of *Clarias gariepinus* fed Cattle hooves Meal Diets

**Growth Performance of Fish fed Cattle hooves Meal Diets**

The result of growth performance of *Clarias gariepinus* fed experimental diets is presented in Table 4. No significant differences (P>0.05) were observed in the initial growth of fish. The final weight of fish showed significant variations (P<0.05) indicating CHM5 (85.63g) as the highest followed by CHM4 (78.79g), CHM3 (77.38g), CHM2 (75.37g) while the lowest was recorded in CHM1 (62.05g). Similar trend was recorded in the weight gain of fish fed the experimental diets; CHM1 (53.98g), CHM2 (67.38g), CHM3 (68.96g) CHM4 (69.93g) and CHM5 (76.96g) respectively, showing significant differences (P<0.05) from each other. The initial length of fish was not significantly different (P>0.05) from each other. There was significant variation (P<0.05) in the final length of fish and the highest length was observed in CHM5 (22.9cm) while other treatments were not significantly different (P>0.05) from each other. All the fish that fed on the cattle hoof diets were not significantly different (P>0.05) from each other in terms of increase in length but showed significant differences (P<0.05) from the fish that fed on diets without cattle hoof. The result in table 4 shows the percentage weight gain of fish fed cattle hoof meal diets for 90 days. The results indicated CHM5 (100%) inclusion of the meal had the highest (888.56%) followed by CHM2 (851.40%) with a significant difference (P<0.05) from other treatments while CHM1 (0%) was the lowest (668.90%).

**Table 4:** Growth Performance of Fish fed Cattle hooves Meal Diets

| Parameters | CHM1 (0%) | CHM2 (25%) | CHM3 (50%) | CHM4 (75%) | CHM5 (100%) | SEM | Pvalue |
|---|---|---|---|---|---|---|---|
| Initial Weight | 8.07±0.11$^{a}$ | 7.99±0.13$^{a}$ | 8.42±0.10$^{a}$ | 8.86±0.11$^{a}$ | 8.67±0.11$^{a}$ | 0.3747 | 0.1904 |
| Final Weight | 62.05±2.43$^{d}$ | 75.37±2.33$^{c}$ | 77.38±2.15$^{b}$ | 78.79±2.76$^{b}$ | 85.63±3.24$^{a}$ | 1.0679 | 0.0000 |
| Weight Gain | 53.98±2.14$^{d}$ | 67.38±2.53$^{c}$ | 68.96±2.11$^{bc}$ | 69.93±2.61$^{b}$ | 76.96±2.76$^{a}$ | 1.3902 | 0.0000 |
| %MWG | 668.90±0.04$^{b}$ | 851.40±0.09$^{a}$ | 818.67±0.07$^{a}$ | 790.29±0.12$^{a}$ | 888.56±0.23$^{a}$ | 2.3505 | 0.0156 |
| Initial Length | 8.09±0.17$^{a}$ | 7.03±0.09$^{a}$ | 7.04±0.06$^{a}$ | 7.02±0.08$^{a}$ | 8.04±0.06$^{a}$ | 0.0603 | 0.0000 |
| Final Length | 21.03±0.11$^{c}$ | 21.08±0.11$^{b}$ | 21.08±0.12$^{b}$ | 21.07±0.11$^{b}$ | 22.09±0.12$^{a}$ | 0.0002 | 0.0000 |
| Increase in Length | 12.94±0.88$^{b}$ | 14.04±0.98$^{a}$ | 14.04±0.78$^{a}$ | 14.05±0.77$^{a}$ | 14.05±0.86$^{a}$ | 0.0008 | 0.000 |
| %Increase in length | 159.95±0.33$^{c}$ | 199.67±0.42$^{a}$ | 199.48±0.46$^{a}$ | 200.00±0.53$^{a}$ | 174.75±0.84$^{b}$ | 0.8174 | 0.0000 |
| SGR | 2.27±0.05$^{b}$ | 2.50±0.09$^{a}$ | 2.46±0.10$^{a}$ | 2.43±0.08$^{a}$ | 2.54±0.07$^{a}$ | 0.0046 | 0.0084 |

Means with the same superscripts are not significantly different (P>0.05) from each other

The values recorded were 159.95%, 199.67%, 199.48%, 200.00% and 174.75% for CHM1, CHM2, CHM3, CHM4 and CHM5 respectively. The highest fish length was recorded in CHM2, CHM3 and CHM4 showing no significant differences (P>0.05) from each other while the lowest fish length was recorded in CHM1. The results of specific growth of fish fed diet containing graded level of cattle hooves meal in the study showed that treatment (CHM5) was recorded as the highest (2.54) followed by CHM2 (2.50) while CHM1 (2.27) was the lowest. The results of specific growth rate of fish showed that CHM5 was significantly different (P<0.05) from other treatments. However, values of CHM1, CHM2, CHM3 and CHM4 were not significantly different (P>0.05) from each other.

**Feed Utilization of *Clarias gariepinus* fed Cattle hooves Meal Diets**

The results in Table 5 present the values of feed utilization of C*larias gariepinus* fed cattle hooves meal diets. The results showed significant differences (P<0.05) in the values of feed utilization whereby the fish in treatment CHM5 had the highest feed intake (97.86g) followed by CHM4 (88.49g), CH3 (87.34g), CHM2 (86.34g) while CHM1 (70.58g) was the lowest respectively. Feed conversion of fish in treatment CHM1 was the highest (1.31) followed by CHM2 (1.28) which are significantly different (P<0.05) from other treatments CHM3 (1.27), CHM4 (1.27) and CHM5 (1.27) respectively. The protein efficiency ratio of fish in treatment CHM5 (0.0199) was the highest while CHM1 (0.0181) was the lowest but they are significantly different (P<0.05) from other treatments. The highest feed efficiency of fish was observed in CHM3 (78.95), CHM4 (79.02) and CHM5 (78.64) respectively while the lowest was recorded in CHM1 (76.48)

**Table 5:** Feed Utilization of C*larias gariepinus* fed Cattle hooves Meal Diets

| Parameters | CHM1 (0%) | CHM2 (25%) | CHM3 (50%) | CHM4 (75%) | CHM5 (100%) | SEM | Pvalue |
|---|---|---|---|---|---|---|---|
| Feed Intake | 70.58±2.8 $^{c}$ | 86.34±2.8 $^{b}$ | 87.34±2.8 $^{b}$ | 88.49±2.8 $^{b}$ | 97.86±2. $^{a}$ | 2.505 | 0.000 |
| FCR | 1.31±0.06 $^{a}$ | 1.28±0.05 $^{b}$ | 1.27±0.06 $^{c}$ | 1.27±0.07 $^{c}$ | 1.27±0.0 $^{c}$ | 0.023 | 0.000 |
| PER | 0.02±0.00 $^{d}$ | 0.019±0.0 $^{c}$ | 0.0195±0.00 $^{b}$ | 0.0195±0.00 $^{b}$ | 0.0199±.00 $^{a}$ | 0.0104 | 0.0000 |
| FER | 76.48±2.16 $^{c}$ | 78.04±2.19 $^{b}$ | 78.95±2.21 $^{a}$ | 79.02±2.11 $^{a}$ | 78.64±2.17 $^{a}$ | 0.0492 | 0.000 |

Means with the same superscripts are not significantly different (P>0.05) from each other

**Water Quality Parameters of the Experiment**

Table 6 showed the result of water quality parameters recorded in the study. The result showed no significant differences (P>0.05) in the mean value of water temperature which range between 25.00 to 26.00°C. Similar observation was recorded in the value of dissolve oxygen which range from 4.46±0.11 to 4.56±0.11mg/l with no significant differences (P>0.05). The pH values ranged between 5.75±0.13

to 5.89±0.14.

**Table 6:** Water Quality Parameters of the Experiment

| Parameter | CHM1 (0%) | CHM2 (25%) | CHM3 (50%) | CHM4 (75%) | CHM5 (100%) |
|---|---|---|---|---|---|
| Temperature (°C) | 25.37±0.66[a] | 25.67±0.67[a] | 26.00±0.84[a] | 25.67±0.75[a] | 25.00±0.47[a] |
| Dissolved Oxygen (mg/l) | 4.50±0.12[a] | 4.46±0.10[a] | 4.46±0.11[a] | 4.56±0.11[a] | 4.46±0.16[a] |
| pH | 5.89±0.14[a] | 5.84±0.16[a] | 5.68±0.15[a] | 5.88±0.14[a] | 5.75±0.13[a] |

Means with the same superscripts are not significant different (P>0.05) from each other.

## DISCUSSION

### Proximate Composition of Cattle Hooves

The results recorded for proximate composition of cattle hoof indicates good nutritive constituents. This could be due to the amount of nutrient composed in hoof derived from intake of specific nutrients essential for keratinization. The crude protein value in the hoof was lower than 90.74% reported by Falaye and Sule (2020); feather meal 81.15 % and 93.3 % for Cattle horn and hoof (Assis *et al.*, 2017). The result could be attributed to increase in the synthesis of tissue protein in the feed consumed by the cattle.
The result for moisture content of cattle hoof in the study is higher than 0.85% reported by FAO according to Daniela *et al.* (2025) but lower than low moisture content in feed materials. Low moisture content is generally less vulnerable to microbial spoilage and growth of food borne pathogen. Cattle hooves in the study had a low fibre which is consistent with values reported for cray fish (6.07%) by Nasim *et al.* (2012), and 5.12% for fish reported by Nsa *et al.* (2009). The fibre content of cattle hooves composition in this study could be due to the present of collagen that contribute to the overall strength and flexibility of the hoof structures.

This study recorded a good amount of lipids in the cattle hooves. Lipids are fatty component organic compounds that are water insoluble. The contain fats, oils, waxes, and sterols (Nasim *et al.*, 2012). They play crucial roles in energy storage, structural components of cell membrane, hormones synthesis and insulation. They aid in the absorption of fat-soluble vitamins and can cushion vital organs. The ash content of the cattle hooves indicated that the hooves are rich in minerals and it application in fish diets will help in enzymes/hormones function, growth, Health, reproduction and diseases resistance in fish. The content of NFE% in the cattle hooves showed that the hooves are rich in protein components than energy (Nsa *et al.*, 2009).

### Growth Performance and Nutrient Utilization of C*larias gariepinus* fed Experimental Diets

The result of this study showed that fish fed with inclusion of cattle hoof performed better than those without cattle hoof. The best response of the diets in terms of weight gain, percentage of mean weight gain, specific growth rate, condition factor, feed conversion, and protein efficiency were observed in the highest inclusion level (100%) of cattle hoof. The result of the current study contradicts the report of Yusuf *et al.* (2022) at 25% inclusion of cattle hoof for growth performance of fish. It was observed in the study that fish fed with cattle hoof in CH2, CH3, CH4, and CH5 increased in weight as the inclusion level increase. Replacing fishmeal with cattle hoof at 100% indicated a better result than other diets without cattle hoof. The reason for the outstanding weight observed in the study could be as a result of the present of other component of ingredients couple with the cattle hoof could have direct influence on fish weight, by providing essential nutrients, energy and building block for growth. However, the amount and quality of the formulated diets along with feeding rate and frequency could impact weight gain in the experimental fish.

This study result at 100% cattle hoof is better than those conducted using other ingredients such as blood meal and fish waste to replace fishmeal; Obomunu *et al.* (2024) stated that blood meal can effectively substitute fish meal at a 25% inclusion level in fish feed production, potentially reducing costs without compromising fish growth or health; the growth performance of fish in this study was also better than the report of Benard *et al*. (2023) who used fishmeal at 25.3%. The experimental fish were observed with higher length than those that were fed without cattle hoof, the differences could be linked to the ease of digesting feed and the availability of nutrients. The fish in CHM5 were recorded with the highest (2.77) condition factor. Condition factor (K) of fish is used to compare the "condition" either by fatness or wellbeing of fish (Getso *et al.*, 2017), heavier fish of a particular length are in a better physiological condition. This observation was recorded in all the treatments of fish fed on cattle hoof diets.

The specific growth rate of fish in CHM5 showed good values of SGR in cattle hoof diets. The facts that cattle hoof meal crude protein is above 40% which is the lower than fishmeal, according to the result of this study, the meal is qualify and could substitute for fish meal in the diets of C*larias gariepinus*. The present of cattle hoof in fish diets in the study enhanced growth and nutrient utilization of C*larias gariepinus* in SGR, PER and FCR. Feed intake occurs due to feed acceptance by experimental fish showed that all diets used for the trials were accepted by C. *gariepinus* irrespective of the percentage of inclusion level, similar to the observation of Fawole *et al.* (2019) who substituted fishmeal with *Hermetia illucens* in diets of African catfish (C*larias gariepinus*). The higher the SGR and the lower the FCR value, the better the feed quality (Omeru and Solomon, 2014). Similarly, Adikwu (2003) also reported that the lower the FCR the better the feed utilization by the fish. The values of protein efficiency ratio in this study and in all the experimental feed were far below the value one (1.00). Protein efficiency ratio is a measurement of how well the protein sources in a diet could provide the essential amino acids requirement of the fish fed (Yusuf *et al.*, 2022), this comment is not the true reflection of the PER in this study. Instead, since all the fish grew, it is an indication that the experimental diets tested contained the required nutrients needed by the fish. The result of the growth parameters recorded at 100% inclusion was an indication that the fish responded positively to all the diets and that the protein content of the experimental diets adequately provided growth and dietary energy supply to the fish.

In terms of survival rate, all the fish in treatment tanks appeared healthy and there was no diseases outbreak throughout the trial period. The very few mortalities observed under the current study may have not been diet related but due to mishandling during water exchange and sampling time thus, a higher survival rate (SR) was reported among the trial diets. The survival rate observed for this study was similar to the research of Maina *et al.* (2020) on C*larias gariepinus* under semi-intensive culture system though higher than that reported by Nairuti *et al.* (2021) on O*reochromis niloticus*.

**Water Quality Parameter Recorded in the Study**

The physico chemical parameters of water recorded in the experimental tanks were within the optimum level required for the culture of C*larias gariepinus*. Catfish require optimum water temperature between 23-32°C, dissolve oxygen of ≥5mg/l, pH of 6-9, and Ammonia of <8.8mg/l. There were no significant differences ($P>0.05$) in the physico chemical parameters of the fish across the treatments because the five treatments were held in a large concrete tank in three replicates. The optimum physico chemical parameters of water in this study may have contributed to the growth rate and survival percentages in all treatments except for water pH which was slightly acidic but still fall within recommended range.

## CONCLUSION

1. The results recorded for proximate composition of cattle hoof indicates good nutritive constituents.
2. The best response of the diets in terms of weight gain, percentage of mean weight gain, specific

growth rate, condition factor, feed conversion, and protein efficiency were observed in the highest inclusion level (100%) of cattle hoof.

3. In terms of survival rate, all the fish in treatment tanks appeared healthy and there was no diseases outbreak throughout the trial period. This study showed that using cattle hoof to replace fishmeal at 100% is economical and less cost effective compared to other treatments including the control.
4. The physico chemical parameters of water recorded in the experimental tanks were within the optimum level required for the culture of C*larias gariepinus*. Catfish require optimum water temperature between 23-32°C, dissolve oxygen of ≥5mg/l, pH of 6-9.

**RECOMMENDATION**

1. From the results of the study, Catfish (C*larias gariepinus*) diets should be formulated with cattle hooves at 100% to replace fishmeal in order to reduce cost of production.
2. Studied should be carried out on some other unconventional protein sources of ingredients for fish feed to reduce dependent on commercial feed.
3. Further studies on the best substitution level of fish meal with cattle hoof meal should be conducted using culturable indigenous species.

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# EFFECT OF INGREDIENTS COMPOSITION ON FLOATABILITY AND STABILITY OF LOCAL FARM MADE FISH FEED

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**ABSTRACT**

*This study evaluated the effects of* Saccharomyces cerevisiae *(yeast) and sodium bicarbonate on the physical quality of catfish (*Clarias gariepinus*) diets, focusing on floatability, water absorption index (WAI), bulk density, and water stability. Eleven diets were formulated: a control (D1), five yeast-based diets (D2–D6), and five sodium bicarbonate–based diets (D7–D11). Results showed significant ($p < 0.05$) differences across treatments. Floatability was highest in sodium bicarbonate diets (up to 100% at 300 seconds), moderate in yeast diets, and absent in the control. WAI ranged from 0.55 to 2.30 g/g, with the control exhibiting the highest absorption, yeast diets showing intermediate values, and sodium bicarbonate diets recording the lowest, indicating an inverse relationship between floatability and water absorption. Bulk density varied from 0.32 to 0.39 g/cm$^3$, with lower densities corresponding to greater buoyancy. Water stability was greatest in sodium bicarbonate diets (90.67–96.37%), followed by yeast diets (81–85%) and the control (79.17%). Overall, sodium bicarbonate proved more effective in enhancing floatability and stability, while yeast inclusion balanced water absorption and pellet durability. These findings highlight the potential of dietary additives in improving aquafeed physical quality, offering strategies for optimizing feed formulation in catfish aquaculture.*

**Keywords**:
*Saccharomyces cerevisiae*, Sodium Bicarbonate, Floatability, Stability, Feed

## INTRODUCTION

Fish feed plays a crucial role in determining fish growth, health, and production efficiency. Therefore, understanding the relationship between ingredient composition and feed properties is crucial for optimizing fish feed formulation and promoting more sustainable aquaculture practices (Kumar *et al*., 2017). Stability and floatability are critical for ensuring nutrient availability and minimizing feed wastage (Tacon and Metian, 2015). Floatability determines whether the feed remains accessible on the water surface, especially for surface-feeding species, while water stability ensures that nutrients are not lost before consumption (Falaye *et al*., 2014). Feed stability in water is essential to prevent nutrient leaching and maintain water quality (NRC, 2011). Achieving an optimal balance between floatability and stability is a major challenge in fish feed formulation. Research has shown that the inclusion of ingredients such as cassava starch, soybean meal and fish meal can significantly affect the buoyancy and durability of feed (Ademola *et al*., 2017).

## MATERIALS AND METHOD

### Experimental Area

The research was carried out in Fisheries and Aquaculture fish farm, Faculty of Agriculture, Bayero University, Kano (latitude of 11.977616° N and longitude of 8.424571° E).

### Sources and Processing of Feed Ingredients

The feedstuffs used for the experiment were purchased from Rimi Market in Kano State. The soybean meal was toasted and milled, while the remaining feedstuffs were crushed and stored separately in a cool, dry containers. The major feed ingredients were subjected to proximate analysis to determine their

chemical content.

**Diets Formulations**

Eleven tilapia diets were formulated using Pearson's square method. The diets were formulated to contain 30% crude protein with different inclusion levels of floating catalyst yeast (Saccharomyces cerevisiae) and baking powder ($NaHCO_3$). The diets included a control diet (0% inclusion) and experimental diets with varying levels of *Saccharomyces cerevisiae* and Sodium bicarbonate respectively at 1%, 2%, 3%, 4%, and 5%.

**Feed Floatability Test**

Pellets produced for experimental diets were subjected to floatability test by dropping 10 pieces of pellets into measuring cylinder filled with 250ml of water. A digital stop watch was used to record the numbers of pellets that float on water.

**Bulk Density Test**

The bulk density was calculated using the formula as described by Adeparusi and Famurewa, 2011;

$$\text{Bulk density} = \frac{M2-M1}{V}$$

**Water Absorption Index Test (WAI)**

$$Water\ Absorption\ Index = \frac{M2 - M1}{M1}$$

**Water stability**

Water stability (%) was calculated as:

$$\textbf{\textit{Water stability}}\ (\%) = \frac{\textbf{\textit{weight of retained whole pellet}}}{\textbf{\textit{weight of the total pellet}}} \times \mathbf{100}$$

**Data Collection and Analysis**

Statistical analysis, including analysis of variance (ANOVA), was conducted to determine the significance of differences in floatability and stability between different ingredients compositions

The results were compared to identify the formulations that provide the best balance of floatability and stability for local farm made fish feed

## RESULTS AND DISCUSSION

**The floatability**

Table 1 reveals diets containing sodium bicarbonate (D7–D11) exhibited the highest floatability, reaching up to 100% at 300 seconds, whereas the control diet (D1) showed no floatation. Yeast-based diets (D2–D6) improved floatability moderately, with higher inclusion levels (D6) showing superior performance compared to lower levels. These findings align with reports that leavening agents such as sodium bicarbonate enhance pellet aeration and buoyancy by increasing porosity (Abdulrahman *et al.*, 2021). Similarly, yeast supplementation has been noted to improve pellet texture and floatability through protein–polysaccharide interactions (Olukunle and Ayeni, 2020).

**Water Absorption Index (WAI)**

From Table 2, WAI ranged from 0.55 to 2.30 g/g, with the control diet (D1) recording the highest absorption. Yeast diets maintained moderate WAI (1.16–1.99), while sodium bicarbonate diets (D7–D9) showed the lowest values (<0.80). The reduction in WAI with sodium bicarbonate is consistent with earlier findings that highly porous, floating pellets absorb less water due to their compact surface structure (Falaye *et al.*, 2022). Moderate yeast inclusion balanced absorption and floatability, reflecting

its ability to enhance hydration properties without weakening pellet integrity (Tiamiyu *et al*., 2021).
Bulk density ranged between 0.32 and 0.39 g/cm$^3$ (Table 3). The control diet and some sodium bicarbonate diets (D1, D9) had the lowest densities, corresponding with better floatability. Higher values (D5, D10, D11) indicated denser pellets that were less buoyant. This pattern supports previous observations that reduced bulk density enhances floatation capacity in aquafeeds (Okorie *et al*., 2018; Shittu *et al*., 2022).

The result of stability as shown in table 4 was found to be highest in sodium bicarbonate diets (D7–D11), ranging from 90.67% to 96.37%, compared to yeast diets (81–85%) and the control (79.17%). Improved stability with sodium bicarbonate may be linked to better pellet binding and reduced solubility (Gbadamosi *et al*., 2020). Yeast diets achieved moderate stability, which is in line with reports that microbial additives can improve pellet cohesiveness but may not match the stability-enhancing effect of binders like sodium salts (Oladele *et al*., 2021).

**Table 1:** Floatability of the On-farm Made Feed

| F | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 | D10 | D11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 300secs | 0.00 ±0.00$^{g}$ | 10.00 ±10.00$^{f}$ | 3.33 ±3.33$^{g}$ | 23.33 ±3.3$^{e}$ | 36.66 ±3.33$^{d}$ | 56.67 ±3.33$^{c}$ | 80.00 ±5.77$^{b}$ | 93.33 ±3.33$^{a}$ | 100.00 ±0.00$^{a}$ | 100.00 ±0.00$^{a}$ | 96.60 ±3.33$^{a}$ |
| 600secs | 0.00 ±0.00$^{f}$ | 3.33 ±3.33$^{f}$ | 3.33 ±3.33$^{f}$ | 13.33 ± 3.3$^{e}$ | 20.00 ±3.33$^{e}$ | 46.67 ±3.33$^{d}$ | 73.33 ±3.33$^{c}$ | 86.67 ±8.82$^{b}$ | 100.00 ±0.00$^{a}$ | 83.33 ±3.33$^{b}$ | 83.33 ±33$^{b}$ |

F- Floatability

**Table 2:** Water Absorption Index of the On-farm Made Feed

| Diet | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 | D10 | D11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WAI | 2.30± 0.05$^{a}$ | 1.67± 0.00$^{e}$ | 1.99± 0.00$^{b}$ | 1.74± 0.00$^{d}$ | 1.82± 0.00$^{c}$ | 1.16± 0.00$^{f}$ | 0.61± 0.01$^{h}$ | 0.59± 0.01$^{h}$ | 0.55± 0.00$^{h}$ | 0.74± 0.00$^{g}$ | 0.78± 0.00$^{g}$ |

WAI-Water Absorption Index

**Table 3:** Water stability of the On-farm made feed

| Diet | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 | D10 | D11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WS | 79.17 ± 0.20 $^{g}$ | 81.57 ± 0.26 $^{f}$ | 82.26 ± 0.39 $^{f}$ | 83.17 ± 0.33 $^{e}$ | 85.00 ± 0.58 $^{d}$ | 91.43 ± 0.3 5$^{c}$ | 96.37 ± 1.32 $^{a}$ | 93.53 ± 0.29 $^{b}$ | 94.20 ± 0.42 $^{b}$ | 90.67 ± 0.33 $^{c}$ | 93.40 ± 0.31 $^{b}$ |

WS- Water stability

**Table 4:** Bulk Density of the Feed

| Diet | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 | D9 | D10 | D11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BD (g/cm $^3$) | 0.32± 0.00 $^{c}$ | 0.34± 0.00 $^{b}$ | 0.34± 0.00 $^{b}$ | 0.35± 0.01 $^{b}$ | 0.39± 0.00 $^{a}$ | 0.34± 0.00 $^{b}$ | 0.35± 0. 01 $^{b}$ | 0.37± 0.01 $^{ab}$ | 0.32± 0.01 $^{c}$ | 0.38± 0.00 $^{ab}$ | 0.37± 0.00 $^{ab}$ |

BD- Bulk density

## CONCLUSION

The study shows that *Saccharomyces cerevisiae* moderately improves feed floatability but cannot sustain buoyancy beyond 600 seconds. In contrast with sodium bicarbonate, which dramatically enhances and stabilizes floatability, with some diets achieving 100% floatation. Therefore, sodium bicarbonate is more

effective as a functional additive for producing floating catfish feed.

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# EVALUATION OF PROXIMATE, PHYTOCHEMICAL AND ANTI-NUTRIENT COMPOSITION OF PEEL AND SEED OF *Carica papaya* (PAWPAW) AS CONSTITUENTS OF FISH FEED

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**ABSTRACT**
*The study investigated the proximate, phytochemicals and anti-nutritional composition of peel and seeds of Carica papaya (pawpaw). The sample, which includes the peels and seeds, was collected freshly, processed, and analyzed for their proximate, phytochemical, and anti-nutrient composition. The result showed that significant amount of mean value for moisture content in processed seed was (87.28%). The mean value for crude protein in processed seed was higher (18.76%) than that of processed peel (11.43%). The mean composition of crude fibre in processed seed was (18.75%), high than in peel, which was (10.81%). The findings revealed that the Carica papaya samples of both seed and peel were tested and was highly rich in potassium and calcium. The mean values of the sodium composition in processed seed and processed peel were 155.83mg/kg and 161.67mg/kg, while those of potassium were 733.33 mg/kg and 513.33mg/kg for both processed seed and processed peel, respectively. The result also shows that anti-nutrient elements were also present in pawpaw seed and peel. The four elements include flavonoid, alkanoid, steroid and tannins. These elements were all found in the sample in varying amounts except tannins, which are absent in the processed peel. The mean for alkanoid in the processed seed was 11.89, and significantly lower in the processed peel (8.07). The flavonoid content was 8.89 in the processed seed and 5.09 in the processed peel. The steroid was significantly higher in processed seed (13.08) but lower in the peel (0.07).*

**Keywords**: Proximate, Phytochemical, Seed, Composition and *Carica papaya*

## INTRODUCTION

Pawpaw (*carica papaya*) is a vital plant that is predominant in tropical Africa, more so Nigeria has been identified as the third largest producer in the world (FAO, 2004). The economic and nutritional potential of the plant has made it fruit and vegetable of choice (Oresegun and Alegbele, 2001). The papaya , (pawpaw) is the plant species Carica papaya, one of the 21 accepted species in the genus Carica of the family Caricaceae. Papaya is also the name of its fruit. It is grown in several tropical countries. Fish cannot synthesize Essential Amino Acids (EAAs) and often remain inadequate, but are needed for growth and tissue development, Xing (2024). Fish meal is known to contain complete EAAs profile that is needed to meet the protein requirement of most fish species (Madu *et al.*, 2003). Since fish meal and fish oil expensive as a feed ingredient, the use of non-conventional feedstuff has been reported with good growth and better cost benefit values (Sobgbesan *et al.*, 2006). The utilization of conventional feedstuff of plant origin had been limited as a result of the presence of alkanoids, glycosides, oxalic acids, phytates, protease inhibitors, haematoglutinin, saponegin, momosine, cyanoglycoside, linamarin to mention but few despite their nutrient values and low implications (Sagbean *et al.*, 2006). Furthermore, therefore need to be subjected to various processing techniques to reduce their impact.

Non-conventional feed resources (NCFRs) are feeds that are usually common in the markets and are not the traditional ingredients used for commercial fish feed production (Madu *et al.*, 2003 and Ugwumba,

2008). These feeds are credited for being noncompetitive in terms of human consumption, very cheap to purchase, by products or waste products from agriculture, farm made feeds and processing industries and are able to serve as a form of waste, management in enhancing good sanitation. Considering these aspects, the objective of the present study was is to determine the proximate, and phytochemicals composition of C*arica papaya* peels and seed.

## MATERIAL AND METHODS

### Experimental site

The Study was conducted at fish feed mill and Agro-chemical laboratory Faculty of Agriculture Usman Danfodiyo University Sokoto. Other Studies such as proximate, phytochemicals, and anti-nutritional were carried at university of Jos and National vetenary research Institute Vom, Jos, Plateau State.

### Collection and Processing of Carrica papaya (Pawpaw) Peel and Seed

C*arica papaya* were freshly collected and dried at 350$^0$C for 96 hours (4 days) and the samples were weighed 2kg and 0.2kg dried, and the seed were weighed 0.3kg which was grinded into powder form for analysis.

Papaya pomace is the by product containing peels and seeds obtained after excitation of juice from the juice from the fruits. It is a potential alternative since it has protein content (Rejuven *et al*, 2006).

### *Processing of Carica papaya* Seeds

C*arica papaya* seeds weighed 0.7kg oil dried, after dried and weighed at about 0.65kg dried *carica papaya* seed were ground into fine powder using grounding machine in the feed mill.

### Chemical Analysis of the Proximate

Chemical analysis of the proximate, phytochemicals and mineral composition of the feed stuffs was carried out in triplicates.

### Determination of Moisture Content

Two gram of *carica papaya* peels were already into powdered sample and were dried in hot and mixed the sample thoroughly.

### Determination of Ash

Char the residue from the moisture determination in the muffle furnace between 500$^0$- 600$^0$C until the ash is grey or nearly white, cool and weigh.

Two (2) gram of *carica papaya* peel, seed were obtained from the already powder material which are then ashes in e thermal furnace at 600$^0$C for 3 hours, after which the sample were cooled in the dessicators. The ash content were determined through the formula described by (Ogunwale and Udo, 1980):

$\% \text{ ash} = \frac{W2-W0}{W1-Wo}$ x 100. Where, $W_0$ = Weight of empty crucible, $W_1$ = initial weight of sample before ashing, $W_2$ = final weight of sample after ashing.

### Crude fat determination (ether-extract)

Ether-extract (oil): Fit up a soxhlet extractor with reflux condenser and a small flask which has been previously dried in the oven and weighed. 2gm of samples were transferred to a fat-free extraction thimble, and lightly with cotton wool, then place the thimble in the extractor and add `about 150cm$^3$ of petroleum ether (B.P. 60-80$^0$C) into the flask until it siphons over once. Add more ether until the barrel of the 100ml extractor is half full, replace the condenser, see that that the joints are tight and place on the water bath or electrothermal heating mantle. Adjust the source of heat so that the ether boils gently and leave it to siphon over for at least 8 hours. Finally watch until the ether is just short of siphoning over, then

detach the flask and siphon the contents of the barrel of the extractor into the ether stock bottle. Drain well remove the thimble and dry in the oven. Replace the condenser and continue distilling the ether until the flask is practically dry. Detach the flask (which now contains all the oils), clean the exterior and dry it in the oven to constant weight. Keep the extracted residue for the fibre determination.

$$\% \text{ Crude fat} = \frac{W1-W2}{2} \text{ X } 100.$$

Where, $W_1$ = weight of thimble and powdered sample, $W_2$ = weight of empty extraction Flask

**Determination of Crude Fibre**

Two (2) grams of the powdered sample of *carica papaya* peel, seed were diluted in 100ml of distilled water in five separate conical flasks, and 20ml of 10% sulphuric acid was added and then boiled gently on heater for 30mins. The sample were after that cooled and filtered. The filtrate is subjected to the same procedure using 10% sodium 20ml of concentrated methanol and passed three times in petroleum ether after, which was dried in over right at $105^0$C and gradually cooled in the desiccator, the samples were then weighed respectively, and therefore, ashed maintain $600^0$C for 9minutes and then re-weighed crude fibre content were calculated using following formula as described by (Krishna and Ranjhan 1980).

$$\% \text{ crude fibre} = \frac{W1 - W2}{2} \text{ x } 100.$$

Where $W_1$ = weight of residue before ashing, $W_2$ = weigh of residue after ashing

**Determination of Carbohydrate Content (Nitrogen free extract)**

According to (Ogunwale and Udo, 1980) the nitrogen free extraction (NFE) refer to the soluble carbohydrate content and it is not determined directly but obtained as a different between the sum of crude protein, crude fibre, and total ash and subtracted from 100. Therefore, % Carbohydrate = 100 – (% ash + % crude protein + crude fibre + crude fat).

**Determination of Alkaloids, Saponins and Tannins**

About 1.0g of each extract was stirred with 10ml of 1% aqueous hydrochloric acid on a steam bath; 1ml each of the filtrate was treated with a few drops of Mayer's reagent, dragendoriis reagent, picric acid solution.

Precipitation with either of these reagents was taken as preliminary evidence for the presence of alkaloid in the extract (Evans, 1978).

About 1g of each plant extract was shaken with 10ml water in a test tube. Frothing which persist ion warming was taken as preliminary evidence for the presence of saponin (Wall *et al.*, 1952 and 1954).

About 1g of each plant extract was stirred with 10ml of distilled water, filtered, and ferric chloride reagent added to the filtrate. A blue-black, green, or blue green precipitate was taken as evidence for the presence of tannins, Sogbesan, (2016).

**Statistical Analysis**

The data obtained were statistically analyzed using one way analyzing of variance (ANOVA) with SPSS version 10.0 statistical package and the result were reported as mean ± standard deviation of the values. LSD was applied to determine the direction of the difference between mean at 50% level of significant.

**RESULT**

**Chemical composition of *carica papaya***

The result of chemical composition of *carica papaya* presented in table (1). The data obtained from the analysis was subjected to inferential statistical tools in the form of independent sample t-test. The

findings of the research show that, the mean value for moisture content in the processed seed was significantly higher (87.28±0.37%) than the mean values (1.40±0.16%) content for moisture in the processed peel of *carica papaya*.

The mean composition for crude protein is higher (18.76±0.45%) in the processed seed at compared to (11.43±0.39%) for processed peel of *carica papaya*.
The crude protein in processed seed was also significantly higher 18.76±0.45% than (10.81±0.20%) recorded in the processed peel.

The fat content in processed seed was significantly lower (2.81±0.2%) than (10.81±0.20%) values obtained processed peel.
The Ash content in the processed seed was slightly lower at mean value of 10.41±0.10% than that of the processed in peel samples.
The result of this study shows that, NFE content in processed seed was 37.96±0.46% which is lower than that of the processed peel at 56.28±0.15% recorded in the processed peel.

**Table 1:** Proximate composition of pawpaw seed and peel

| Nutrients (%) | Processed Seed | Processed Peel |
|---|---|---|
| Moisture | 87.28±0.37 | 1.40±0.16 |
| Ash | 10.41±0.10 | 11.36±0.25 |
| Crude protein | 18.76±0.25 | 11.43±0.39 |
| CruSde fibre | 18.76±0.45 | 10.81±0.20 |
| Fat | 2.81±0.2 | 10.81±0.20 |
| NFE | 37.96±0.46 | 56.28±0.15 |

***Source:*** *Labaran N. D. (2017)*

**Anti-nutritional composition of pawpaw seed and peel**
The anti-nutritional composition for pawpaw seed and peel were analyzed in this study. Four anti nutritional elements were tested and these include Alkaloid, Flavonoid, Steroid and Taninns. The mean value for alkaloid content in processed seed was 11.90±0.28% and processed peel was 8.07±036, flavonoid was 8.81±0.25 in the processed seed and 5.09±0.11 in the processed peel while the steroid in processed seed was 1.12±0.11and 13.08±0.00 in the processed peel. The result shows that only processed seed has low percentage of tannins while the processed peel contained no tannins. Table (3)

**Table 3:** Anti-nutrients composition of pawpaw seed and peel

| Anti -nutrients (%) | Processed Seed | Processed Peel |
|---|---|---|
| **Alkanoid** | 11.90±0.28 | 8.07±036 |
| **Flavonoid** | 8.81±0.25 | 5.0± -0.11 |
| **Steroid** | 1.12±0.11 | 13.08±0.00 |
| **Tannins** | 0.07±0.01 | --- |

## DISCUSSION

**Chemical Composition of Pawpaw**
The study on proximate composition of papaya peel, and seeds reveals a significant of nutritional factors such as ash, protein, crude fibre, fat, NFE and moisture contents, Maisarah *et* al., (2014) The moisture contents recorded in the present study for the fresh *carica papaya peels was similar* to 83.74 reported by Maisarah (2014).

The findings of the research show that, the mean value for moisture content in the processed seed was 87.28±0.37% significantly higher than the mean content for moisture in the processed peel of *carica papaya* (1.40±0.16%). This implies that the moisture content in both the processed seed and processed peel was lower compared to fresh seed and peel. This significantly indicates the impact of processing pawpaw seed and peels for fish meal. The result implies that, pawpaw peel contains a high percentage of fat that makes it a very good source of fat in fish meal. The finding corresponds with Naveed *et al.* (2007) who stressed that "fat is one of the required essential nutrients in feed formulation" This finding is in line with Maisarah *et* al. (2014) who stated that "processing of pawpaw seed and peel for fish meal, reduce the moisture content and enhance storage ability of the feed".

The value for crude protein is higher (18.76±0.45%) in the processed seed at compared to (11.43±0.39%) that of processed peel of *carica papaya*. This implies that, the peel and the seed of *carica papaya* contains a significant amount of crude protein which makes it valuable to be inculcated in fish feed formulation.

The findings correspond to Naveed *et al.* (2007) who reported that "Papaya pomace is the product peels and seeds obtained after extraction of juice from the fruit. It is a potential alternative feed stuffs since it has high protein content".
The result of this study implies that, *carica papaya* seed and peels are rich in crude fibre which makes it a very good component in fish feed formulation.

The fat content in processed seed was significantly lower (2.81±0.2%) than that of processed peel (10.81±0.20%). The result implies that, pawpaw peel contains a high percentage of fat that makes it a very good source of fat in fish meal. The finding correspond with Sogbesan. (2016) who stressed that "fat is one of the required essential nutrients in feed formulation".
The Ash content in the processed seed was slightly lower (10.41±0.10%) than (11.36±0.25%) observed in the processed peel. This implies that, the Ash content in both the processed seed and processed peel was higher due to the effect of processing techniques involved compared to the fresh peel. The result of this study shows that, NFE content in processed seed was lower than that of the processed peel.

This finding was supported by Imaga and Okeniyi, (2015) who reported that, significant amount of protein content makes pawpaw leaf suitable for the supplementation of the food product with a high carbohydrate to protein ration while the presence of fibre in appreciable quality would find usefulness as an aid to the digestion process. The significant amount of ash, protein and fibre contents render this leaf a potentially viable plant that might find usefulness in fish diet.

**Anti-nutritional Composition of Pawpaw Seed and Peel**
The anti-nutritional composition for pawpaw seed and peel were analysed in this study and four elements were obtained these include: alkanoid, flavanoid, saponins and tannins. Anti-nutritional properties of *carica papaya* seeds, fruits, leaves, peels, and aerial part have been documented from various mention but a few studies reviewed. Wong Kong (2014) reported that *carica papaya* seed to be a promising source of food anti-nutrients. The seeds of papaya are rich in total alkaloid, tannins, and flavanoid in the ethyle-acetate and butanol fraction (Alkaloid 30.32, Flavanoid 59.54, tannin 25.24 mg/GAE/100g dry weight) (Olawoye, 2016).

The steroid content of pawpaw both seed and peel reported in present study was high than those reported by Wilson, (2011), the disparity in variety may be attributed to the processing techniques introduces. Similarly the steroid content of *carica papaya* seed and peel both fresh and processed reported in the present study were lower than those reported in Oyelami, (2007). The disagreement

could be due to the sources, processing and environmental factors that are likely to affect the content of steroid in the study areas.

## CONCLUSION

The findings of this study indicate that, the sample tested was highly rich in crude protein, crude fibre and other essential required in fish feed formulation. A lower percentage of moisture contain was observed after the analysis. The tested was also rich in NFE while the Ash content was very low in the tested samples.

The result also shows that, pawpaw seed contain anti-nutritional elements including alkaloid, flavonoid, steroid and tannins at varying level and percentage.

### Recommendations

The sample showed appreciable quantity of all dietary elements tested, which make them partial or complete substitute for the non-conventional feed ingredients. It is therefore recommended that, their utilization in feed formulation should be encouraged, through feeding trials still need to be conducted in order to established level of inclusion, productive and economic efficiency using pawpaw seeds. This study showed that non-conventional feed ingredients is reach source of nutrient and so may be recommended to substitute conventional feed materials for fish feed formulation.

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# FROM ETYMOLOGY TO APPLICATION: UNDERSTANDING PROBIOTICS AND THEIR ROLE IN AQUACULTURE

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**ABSTRACT**

*The rapid expansion of aquaculture to meet global protein demands has intensified disease outbreaks due to increased stocking densities and stress levels in cultured species. Traditional antimicrobial treatments have led to antimicrobial resistance (AMR), environmental contamination, and public health concerns. This review examines probiotics as sustainable alternatives to synthetic antimicrobials in aquaculture. Probiotics, derived from Latin "pro" (for) and Greek "bios" (life) meaning "for life," operate through competitive exclusion, inhibitory compound production, immune enhancement, and digestive enzyme production. Bacterial probiotics, particularly Lactobacillus, Bacillus, and Enterococcus species, demonstrate consistent benefits including improved growth performance, enhanced feed conversion efficiency and reduced disease-related mortality. Applications extend beyond growth promotion to include water quality improvement, reproductive performance enhancement, and pathogen control. Indigenous probiotics isolated from aquatic species show superior colonization efficiency compared to terrestrial-origin strains thereby necessitating need for more research on probiotics of aquatic origin for use in aquaculture. Despite challenges in survival during processing, species-specific compatibility, and regulatory frameworks, probiotics represent a scientifically validated, economically viable solution for sustainable aquaculture. The global probiotics market, valued at over $70 billion in 2025 is projected to reach $134 billion in 2033 which reflects growing industry adoption.*

**Keywords:** Aquatic probiotics, aquaculture, antimicrobial resistance, sustainable fish farming.

## INTRODUCTION

Aquaculture has emerged as the fastest-growing animal production industry globally surpassing the rate of captured fisheries producing approximately 94 million tons of farmed fish with Africa contributing 7% of this total production volume annually (FAO, 2024). This growth addresses sustained depletion of capture fisheries while meeting escalating protein demands. However, intensive aquaculture operations have elevated stress levels and disease susceptibility in cultured species, making disease outbreaks a major limiting factor in system advancement (Magnadottir, 2010).

Historically, antimicrobials have been widely employed for disease prevention and treatment. However, excessive antibiotic use has promoted emergence of virulent, resistant pathogen strains while impairing host immune systems (Undap and Tumbol, 2016). The accumulation of antibiotic residues poses human health risks, while antimicrobial resistance genes spread between aquatic bacteria and human pathogens (Rhodes *et al*., 2000). With projections that AMR could cause deaths in millions of humans, animals and plants above that caused by another other by 2050 (Ahmed, 2024), alternative therapies have become critical. Natural antimicrobials, particularly probiotics, offer promising solutions. Unlike conventional antibiotics targeting specific bacterial molecules, natural compounds often act on multiple targets, making resistance development more difficult (Fan *et al*., 2018). Probiotics have demonstrated potential

to increase aquaculture efficiency and sustainability while antagonizing fish pathogens (Bentzon-Tilia *et al*., 2016; Tesdorpf *et al*., 2022). This review aims to understand the etymology of probiotics since their discovery and explore the different types of probiotics used in aquaculture practices, addressing their critical role in managing fish diseases and contributing to the global fight against AMR.

## PROBIOTIC ETYMOLOGY AND DEFINITION

The term "probiotic" derives from Latin "pro" (for) and Greek "bios" (life), first used by Kollath (1953). The concept evolved from Dr. Elie Metchnikoff's 1905 observations of beneficial bacteria, initially termed "Probiotika." Key definitional milestones include Parker's (1974) first host-microorganism interaction definition and Fuller's (1989) refinement as "live microbial feed supplement that beneficially affects the host animal by improving its intestinal microbial balance". Havenaar and Huis (1992) described they could be administered as monoculture or mixed culture. Guarner and Schaafsma (1998) introduced “dose-dependence” of probiotics in host. Also, in 1998, Moriarty describe probiotics as microbial “water additives” that can help improve water quality.

UN-recommended selection criteria include: viability through gastrointestinal transit, colonization ability, pathogen competition for adhesion sites, inhibitory effects against pathogens, resistance to disinfectants, proper labelling with taxonomic identification, accurate dosage information, and safety data confirming no infection risks to immunocompromised animals. Therefore, contemporary definitions recognize probiotics as various bacterial and yeast strains contributing to intestinal microbial balance and host health when consumed in adequate amount (Badguzar *et al*., 2024).

## PROBIOTIC CLASSIFICATION AND MECHANISMS OF ACTION

### Classification

Probiotics used in aquaculture include bacteria, yeasts, and bacteriophages (Nakandakare *et al*., 2013).
Bacterial probiotics dominate applications, including: *Lactobacillus* species (*L. plantarum*, *L. acidophilus*, *L. casei*, *L. rhamnosus*) enhance fish health through competitive exclusion and bacteriocin production. *Lactococcus lactis* produces nisin with broad-spectrum antimicrobial activity (Balcázar *et al*., 2006). Bacillus Species are valued for spore-forming ability providing stability during feed processing. *B. subtilis* demonstrates improved growth performance and disease resistance, while *B. licheniformis* produces digestive enzymes enhancing nutrient utilization (Hong *et al*., 2005).
Other groups of probiotics such as *Saccharomyces boulardii* (a yeast) exhibits gastrointestinal resistance and acid stability, showing improved health status and survival in various fish species. Research demonstrates immunomodulatory potential with anti-inflammatory effects (Perdichizzi *et al*., 2023). Newer and emerging strains of Probiotics include microalgae such as *Chlorella* species demonstrate immune enhancement and pathogen inhibition, while *Spirulina* provides high protein content and phycocyanin production, enhancing fish coloration and immune function (Güroy *et al*., 2012).

### Mechanisms of Action

Probiotics operate through four primary mechanisms:
**Competitive Exclusion:** Probiotics adhere to intestinal mucus, blocking pathogen infection routes. Moriarty (1998) observed total exclusion of *Vibrio harveyi* populations in probiotic-treated prawn farms, with increased survival rates.

**Inhibitory Compound Production:** Probiotics produce bacteriocins, organic acids, hydrogen peroxide, and siderophores. Yang *et al*. (2010) reported two LAB strains released bacteriocin-like compounds with potent inhibitory effects against *Vibrio metschnikovi*, *V. harveyi*, and *Staphylococcus aureus*.

**Immune Response Enhancement:** Probiotics stimulate both innate and adaptive immune responses. Rengpipat *et al*. (2000) demonstrated tiger prawns were protected against disease through activation of cellular and humoral immune defenses using *Bacillus sp*. Probiotics.

**Digestive Enzyme Production:** Probiotics enhance nutrient utilization by producing proteases, amylases, and lipases. Gao *et al*. (2016) observed silver pomfret fed probiotics exhibited enhanced growth rates linked to elevated digestive enzyme activity.

## APPLICATIONS IN AQUACULTURE

The shift from terrestrial-origin to fish-derived probiotics represents a significant advancement, as native probiotics demonstrate superior colonization efficiency and host compatibility (Wanka *et al*., 2018). Indigenous probiotics address physiological differences between aquatic and terrestrial hosts, resulting in more effective interventions.

In Aquatic environment probiotics have been administered either via feed or water. Feed probiotics utilize binders like eggs and cod liver oil for beneficial microbial effects. They achieve higher feed conversion ratios by breaking down antinutritive factors in plant proteins. Survival is temperature-dependent, with higher viability at 4°C versus 20-22°C storage (Irianto and Austin, 2002b). Common formulations contain *Lactobacillus* sp., *Bacillus* sp., or *Saccharomyces cerevisiae*. *Bacillus subtilis* in rainbow trout enhanced growth and immune response with survival improvement from 40-70% (Wang *et al*., 2024). *Kocuria* SM1 reduced mortality to 16% with enhanced immune response (Sharifuzzaman and Austin, 2009). *Saccharomyces boulardii* in carp Improved health status, growth performance, and survival at 2.5% inclusion (Savin *et al*., 2019).

On the other hand, water probiotics are applied directly to culture facilities, improving fish health by eliminating pathogens and enhancing water quality. They regulate microflora, control pathogens, and minimize toxic gases including $NH_3$, $N_2O$, and methane (Verschuere *et al*., 2000). Studies show significant improvements in water quality parameters and fish performance. Mixed probiotics containing *Bacillus* sp., *S. cerevisiae*, *Nitrosomonas* sp. reduced nitrogen and phosphorus concentrations and increased shrimp yields (Wang *et al*., 2005). Many commercially available products significantly decreased pH, ammonia, and nitrite levels while improving growth performance.

### Uses of Probiotics in Aquaculture

#### Fish Meal Processing

Hendalia *et al*. (2019) proposed probiotics as alternatives for fish meal processing, eliminating traditional heating that causes nutrient loss. Lactic Acid Bacteria (LAB)-processed fish meal showed complete *Salmonella* inhibition at 1-2% inclusion levels, lacked bad odours as LAB utilized decomposition ammonia, and provided cheaper, sustainable alternatives to commercial fish meal while generating additional income for fishermen.

#### Antimicrobial Activity

Probiotics demonstrate significant antimicrobial activity against harmful bacteria. Sharifuzzaman *et al*. (2017) reported *Rhodococcus* SM2 with high bacteriocinogenic potential against *Vibrio anguillarum* and *V. ordalii* through lactic acid production. Indigenous *Leuconostoc mesenteroides* from Nile tilapia inhibited *Vibrio* sp. and *Mycobacterium* sp. (Zapata and Lara-Flores, 2013). Probiotics also possess antifungal activity against *Saprolegnia* spp.

#### Feed Additive Applications

Probiotics serve as functional feed sources reducing production costs. El-Dakar *et al*. (2007)

demonstrated 73-78% reduction in rabbit fish feed costs through probiotic-prebiotic supplementation. Probiotics increase fish appetite, improve digestion, enhance nutrient absorption by increasing fat and protein retention, and facilitate proper nutrient absorption through vitamin production and compound detoxification (Abdelhamid *et al*., 2009).

**Immune Modulation**

Probiotics represent sustainable alternatives to antimicrobial immunostimulants (Hoseinifar *et al*., 2015). They enhance immune systems by stimulating innate and cellular responses, increasing cytokine expression, and modulating immune parameters including phagocytic activity, lysozyme activity, respiratory burst, and antioxidant enzyme activities. Purwandari and Chen (2013) showed *B. subtilis* significantly increased innate cellular response and respiratory burst activity in orange-spotted grouper, with effects becoming more significant over time.

**Reproductive Performance Enhancement**

Probiotic supplementation improves reproductive parameters including gamete quality, fertilization success, and hatching rates. Ariole and Okpokwasili (2012) demonstrated improved reproductive outcomes in C*larias gariepinus* including reduced incubation time, enhanced hatching rates, and increased larval survival using indigenous bacterial consortiums. Mehdinejad *et al*. (2018) showed significant improvements in goldfish reproductive parameters including sperm quality, egg metrics, fecundity indices, and fertilization rates following probiotic supplementation.

**Water Quality Improvement**

Probiotics improve water quality by competing with pathogens before host infection. Nogami *et al*. (2001) reported *Thalassobacter utilis* effectively reduced *Vibrio* species presence. *Rhodopseudomonas palustris* significantly decreased ammonia, nitrogen compounds, and sulfide levels (Wen *et al*., 2008). Probiotics maintain beneficial bacterial loads while reducing pathogenic populations in fish ponds (Padmavathi *et al*., 2012).

**Challenges of Probiotics Use**

**Survival and Viability Challenges**

Maintaining probiotic survival throughout production, storage, and application presents primary challenges. Feed pelleting processes involving high temperatures (80-100°C) significantly reduce viability. While spore-forming *Bacillus* species show better survival, many probiotics require special protection methods (Verschuere *et al*., 2000). Storage stability in tropical climates accelerates degradation, while aquatic environment survival depends on water quality parameters affecting establishment.

**Host-Specific Compatibility**

Effectiveness depends on probiotic-host compatibility. Different fish species have distinct digestive physiologies, gut communities, and immune systems influencing probiotic effectiveness. Species specificity requires extensive research for each target species, significantly increasing development costs (Balcázar *et al*., 2006). Life stage variations further complicate applications, as larval fish have different requirements than juveniles and adults.

**Regulatory and Economic Challenges**

Lack of comprehensive regulatory frameworks creates challenges for producers and users. Safety assessment requirements include pathogenicity testing, antibiotic resistance profiling, and environmental impact evaluations. High-quality products are expensive, requiring demonstrated cost-benefit relationships. Quality control standardization remains inconsistent, while successful

implementation requires technical expertise often unavailable in many operations.

## CONCLUSION

Probiotics represent scientifically validated, environmentally sustainable alternatives to synthetic antimicrobials in aquaculture. Evidence demonstrates their effectiveness through multiple complementary mechanisms including competitive exclusion, inhibitory compound production, immune enhancement, and digestive enzyme improvement. The shift toward indigenous probiotics shows superior colonization efficiency and host compatibility compared to terrestrial-origin strains. Despite challenges in processing survival, species specificity, and regulatory frameworks, probiotics offer substantial economic benefits through improved growth performance, enhanced feed conversion efficiency, and reduced mortality.

Future success requires coordinated efforts among researchers, industry stakeholders, and regulatory agencies to address current limitations through systematic research and development. Integration with precision aquaculture technologies and advanced delivery systems holds promise for expanding application possibilities while maintaining environmental stewardship. The transition toward probiotic-based aquaculture management aligns with global trends toward reduced antimicrobial use, enhanced food safety, and sustainable production practices essential for meeting growing global aquatic protein demands.

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# EFFECT OF TWO COMBINED PROBIOTICS (Aquapro and CHC) ON THE GROWTH PERFORMANCE HAEMATOLOGICAL PARAMETERS OF *Heterobranchus longifilis* (VALENCIENNES, 1840) FINGERLINGS

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**ABSTRACT**
*This study aimed to determine the effects of combined probiotics (Aquapro and CHC) on growth performance and haematology parameters in Heterobranchus longifilis fingerlings. Four experimental diets were prepared at 0%, 0.5%, 1.0%, and 1.5%. H. longifilis fingerlings were procured from a fish hatchery and acclimatized for 14 days. The fish were randomly distributed into three experimental groups 10 fish per basin with three replicates and fed with experimental diets at 3% of their body weight twice daily. Fish fed with 1.5% combined diets showed significantly higher growth performance in terms of weight gain (342.46±4.39), specific growth rate (1.97±0.41), protein efficiency ratio (4.77±0.00) and best feed conversion ratio (1.61±0.00) compared to the fish fed with control diet (161.45±2.26%, 1.50±0.00%, 1.95±0.01 and 4.43±0.01) respectively. Haematological parameters increased with response to combined probiotic supplementation at 1.5%, and decrease in MCH and MCV. Dietary combined probiotic did not affect the survival rate of the fish. It is concluded that combined probiotics (Aquapro and CHC) supplementation up to 1.5% inclusion levels showed best results on H. longifilis fingerlings. Combined probiotic can be effectively recommended as an effective growth promoter for fish and safe to use in aquaculture.*

**Keywords:** Growth performance, Probiotics, *H. longifilis*, Haematology

## INTRODUCTION

Probiotics are beneficial microorganisms used as a supplement to enhance fish growth, optimize feed utilization, improve stress resistance and boost immune response in aquaculture ((Shehata et al., 2024). Antibiotics were used for years to prevent bacterial diseases. However, regular application caused serious health concerns such as antibiotic residue leftover in the tissues and imbalance in the gastrointestinal microbiota, as a result it is good to avoid use of antibiotics in aquaculture (Rahayu *et al.*, 2024). Catfish (*H.longifilis*) is common an important fish species with high nutritional value, this species are omnivorous fish, the tolerates poor water quality, due to these characteristics it is considered an excellent aquaculture species. Haematological serve as reliable indicators of fish health and stress in aquaculture (Chen and Luo, 2023). The purpose of this study was to determine the effect of combined probiotics (Aquapro and CHC) on growth performance, feed utilization and haematological parameters of *H. longifilis* fingerlings at different inclusion levels. This study will improve the knowledge of administering probiotics to fish diets.

## MATERIAL AND METHODS

### Experimental Design and Data Collection

The experiment was conducted in the aquarium of Biological Sciences, Bayero University Kano, Nigeria. Kano State. A total number of 280 *longifilis* fingerlings, with initial weight and length range from 5.33-5.37g were obtained from Manissad farm, Lagos State, Nigeria and were transported to the experimental site in fifty 50 litters capacity jerricans. The fish were stocked in a concrete tank with water holding capacity of 3000 liters and allowed to stay in laboratory aquarium for two (2) weeks acclimatization. During this period, the fish were fed with a (40%) CP locally pelleted feed at (3%) of their body weight

twice daily, in the morning 7.00 – 900am and evening 5.00-7.00pm. After two weeks of acclimatization (14) days, the fish were starved for one (1) day in order to empty their stomach and prepare their appetite for the experimental feed. The experiment was conducted in a completely randomized design (CRD) with three (3) replicate per treatment, a total of thirty of (30) fish was used per treatment (10 fish per tank). Fresh borehole water was used throughout the experiment, water was changed twice a week by siphoning before feeding to maintain water quality and prevent the buildup of uneaten feed and waste. The physicochemical parameters of the water were monitored daily. Four experimental diets were prepared to have varying inclusion level of probiotics combined (Aquapro and CHC) and control at 0%, 0.5%, 1.0%. and 1.5% respectively (Opiyo *et al.*, 2019). The diets were prepared using Pearson square method. Dietary ingredients in powdered form were manually combined with water, oil, and probiotics (Aquapro and CHC) was added to form a soft dough. The dough was pelletized using a hammer mill machine. The diets were kept in sealed plastic bags in a cool dry place. Fish sampling was carried out every two weeks from each tank with the help of a scope net throughout the experimental period. Growth rate was recorded using a digital weighing scale in grams. Mean body weight, standard length and total length were taken every two weeks and the ration fed were adjusted in order to correspond with the new body weight.

**Growth Parameters**

The fish weight was measured, and the number of fish in each replicate was also recorded. Growth parameters, were determined using the following formulae.

$$\text{WG\%} = \text{Final body weight} - \text{initial body weight initial body weight} \times 100$$

$$\text{Weight gain (g)} = W_2 - W_1$$

$$\text{SGR} = \frac{L_n W_2 - L_n W_1}{t} \; x \; 100$$

$$\text{FCR} = \frac{\text{Amount of feed fed (g)}}{\text{Weight gain (g)}} \; X \; 100$$

$$\text{PER} = \frac{Weight\ gain}{Protein\ fed}$$

$$\text{SR} = \frac{Number\ of\ fish\ harvested}{Number\ of\ fish\ stocked} \times 100$$

**Haematological Parameters**

Five fish were randomly selected from each basin, and their blood was collected from the caudal vein by using 3-ml syringes and stored in EDTA bottles. Haematological parameters were determined according to standard methods described by Svobodová *et al.* (1991).

**Statistical Analysis**

R statistical software version 4.2 was used to analysed the data. One-way analysis of variance (ANOVA) was used to determine the differences between set of treatments. Ducan multiple comparisons test was used to detect treatments' pairs with significance difference ($P<0.05$).

**RESULTS**

**Growth and feed utilization**

Dietary supplementation with combined (Aquapro and CHC) probiotics significantly ($P< 0.05$) enhanced the growth performance and feed utilization of *H. longifilis* fingerlings compared to the control group (Table 1). Significantly higher ($p < 0.05$) mean weight gain % was observed in fish fed with 1.5% (342.46±4.39), followed by 1.0% (338.18±0.74) and 0.5% (245.80±1.36) combined probiotics

supplemented diets, compared with the control group which recorded the least value of mean weight gain (161.45±2.26). Significantly (P< 0.05) higher SGR was observed in fish fed with 1.5% (1.97±0.41), 1.0% (1.97±0.47) and 0.5% (1.95±0.00) combined probiotics supplemented diets compared with the control group (1.50±0.00). Dietary supplementation significantly reduced (P<0.0.5) the FCR in fish fed with 0.5% 1.0% and 1.5% combined probiotic supplemented diets in comparison to the control group.

**Table 1:** Mean Growth and Feed Utilization Performance of *H. longifilis* fed Combined Experimental Diets.

| Parameters | Probiotic inclusion levels | | | |
|---|---|---|---|---|
| | Control 0.00% | $T_1$ 0.50% | $T_2$ 0.10% | $T_3$ 1.50% |
| MIW (g) | 5.35±0.11[a] | 5.37± 0.16[a] | 5.34±0.07[a] | 5.33±0.08[a] |
| MFW (g) | 166.81±2.37[b] | 251.17±2.23[a] | 344.52±0.86[a] | 348.79±4.33[a] |
| MWG (g) | 161.45±2.26[b] | 245.80±1.36[a] | 338.18±0.74[a] | 342.46±4.39[a] |
| SGR (%) | 1.50±0.00[b] | 1.95±0.00[a] | 1.97±0.47[a] | 1.97±0.41[a] |
| FCR | 1.95±0.01[b] | 1.63±0.00[a] | 1.62±0.00[a] | 1.61±0.00[a] |
| PER | 4.43±0.01[b] | 4.76± 0.00[a] | 4.72±0.01[a] | 4.77±0.00[a] |
| Condition Factor (K) | 1.12±0.28[b] | 1.18± 0.06[a] | 1.26±0.03[a] | 1.30± 0.02[a] |
| MFL (cm) | 21.53±1.20[b] | 38.73±1.50[a] | 36.12±0.53[a] | 39.85±2.17[a] |
| MTL (cm) | 26.26±2.35[b] | 41.8±0.97[a] | 45.91± 5.17[a] | 47.10±3.92[a] |
| SR (%) | 93.00[b] | 100.00[a] | 100.00[a] | 100.00[a] |

Means with similar superscripts in the same row are not significant at (P<0.05).

**KEY:** Initial weight (IWG), final weight (FWG), mean weight gain (MWG), specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), condition factor (K), mean standard length (MSL), mean total length (MTL), survival rate (SR).The haematological parameters of *H. longifilis* in response to combined probiotics in the diets are shown in Table 2: Values of RBC, WBC, PCV and HB showed a significant increase (P< 0.05) with increasing levels of combined probiotics in diets compared to the control group, and the highest values were recorded in 1.5% combined probiotics supplemented diets. Moreover, MCH showed a significant decrease (P<0.05) in response to increasing combined probiotics supplementation in diets compared to the control group. Dietary supplementation with combined probiotics did not have negative effect on the values obtained (P>0.05) for haematological parameters.

**Table 2:** Mean Haematological Parameters of *H. longifilis* Fed with Combine (Aquapro and CHC) Probiotics Supplemented Diets

| Parameters | Probiotic Inclusion levels | | | |
|---|---|---|---|---|
| | Control (0.00%) | $T_1$ (0.50%) | $T_2$ (1.00%) | $T_3$ (1.50%) |
| RBC ($10^6 mm^{-3}$) | 3.95±0.03[b] | 4.05±0.02[a] | 4.03±0.05[a] | 4.01± 0.08[a] |
| WBC ($10^6$/L) | 8.54±0.00[b] | 9.61±0.04[a] | 9.61±0.06[a] | 9.62±0.00[a] |
| PCV (%) | 33.00±1.42[b] | 35.20±3.01[a] | 35.40±2.00[a] | 35.80±1.66[a] |
| HB (g/dl) | 10.17±0.02[b] | 13.53±1.43[a] | 13.55±1.51[a] | 13.58±0.20[a] |
| MCH (pg) | 42.19±0.26[a] | 38.56±0.63[a] | 40.42±0.31[a] | 35.86±0.24[b] |
| MCHC (g/dl) | 33.40±0.32[a] | 33.30±3.64[a] | 33.24±1.22[a] | 33.20±0.10[a] |
| MCV (fl) | 115.57±4.32[a] | 106.72±0.48[b] | 106.98±4.87[b] | 106.93±6.23[b] |

Means with similar superscripts in the same row are not significantly different at $P<0.05$.
**KEY:** Red blood cell (RBC), white blood cell (WBC), packed cell volume (PCV), haemoglobin: (Hb), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), mean corpuscular volume (MCV).

## DISCUSSION

The application of antimicrobial chemotherapeutics such as antibiotics in aquaculture has been banned in some countries due to residual effects such as microbial resistance and accumulation in fish muscles (Abdel-*Latif et al*., 2023). Application of probiotics as a disease control in aquaculture improved nutrient digestibility, fish health and microbial flora within the gastrointestinal tract (GI) (Li *et al.*, 2019), which resulted in better growth performance and nutrients utilization (Sharma *et al.*, 2022). In the present study, commercial combined probiotics were used as a supplement in diet of *H. longifilis* fingerlings. The study, assessed the impacts of commercial probiotic in *H. longifilis* fingerlings diets. There was significant improvement in growth parameters and haematological parameters in all the probiotic supplemented diets ($T_1$, $T_2$, and $T_3$) compared to the control (0). The present experiment demonstrated that the highest weight gain, PER, specific growth rate and condition factor were obtained in combined probiotics supplemented diet at ($T_3$) followed by $T_2$ then $T_1$, while the least was recorded in combined group. The lowest FCR were recorded in ($T_1$, $T_2$, and $T_3$), while control group recorded the highest FCR values. The results of probiotics supplemented groups might be due to improved intestinal microbial flora of the experimental fish. Our findings were also similar with the results obtained in several studies, Tanveer *et al*. (2023) reported that dietary supplements with a probiotic mixture in the diet of *Clarias batrachus* improved digestion, nutrient absorption, and triggered growth performance by stimulating digestive enzymes of *H. longifilis*. Salam *et al*. (2021) reported similar observation on *Barbonymus gonionotus* gut isolates significantly improved the growth performance of examined *B. gonionotus* by improving haematological and intestinal histomorphological parameters.

## CONCLUSION AND RECOMMENDATION

Applications of probiotics for improving growth performance, feed utilization and nutrient digestibility in fish is increasing due to demand for environment-friendly and sustainable aquaculture. In the present study, different commercial probiotics were supplemented in the diets at different inclusion level 0%, 0.5% and 1.0%. Based on the data obtained on growth parameters, feed utilization, and haematological parameters, the experiment revealed that probiotics have significant efficiencies in improving growth performance and haematological parameters in *Heterobranchus longifilis* fingerlings. Therefore, probiotics can be suggested to be use as a supplement in the diet of *H. longifilis* fingerlings and as eco-friendly tool for healthy production and safe application in aquaculture practices.

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# PROXIMATE AND PHYTOCHEMICAL ANALYSES OF *Alstonia congensis* PLANT AND ITS POTENTIAL USE FOR FISH FEED AND DRUG

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**ABSTRACT**
*Natural plants are the main sources of biologically active compounds and have potentials for the development of novel common fish disease curative and preventive drugs. This study was conducted to determine the phytochemical contents, proximate and mineral analyses of leaf, bark and root of Alstonia congensis. Phytochemical and proximate component of A. congensis leaf, bark and root reveal the presence of alkaloids, steroids, tannins, saponin, flavonoids, cardiac glycosides, phenols, oxalate, phytate and terpenoids, while anthraquinones was absent. Saponin was not detected in the root extract. The proximate analysis reveal crude fibre content ranged from 3.50% (leaf and bark) to 4.05% (root); Ash: 9.00% (leaf) to 20.40% (bark); moisture content: 10.23% (leaf) to 10.82% (bark); crude lipid: 9.00% (root) to 35.00% (bark); carbohydrate: 26.63% (bark) to 61.17%; protein content: 3.43% (bark) to 9.66% (leaf). Mineral element analysis elucidate that the selected plant parts contained low levels of metals with iron (5.28-6.57 mg/l), zinc (5.37-8.42 mg/l), copper (1.27-9.36 mg/l) and potassium (0.36-2.35 mg/l). All the studied plant parts have potential of serving as supplementary sources of common fish disease drugs and essential nutrients to man and other livestock.*

**Keywords:** *Alstonia congensis, phytochemical, proximate, fish disease, parasites, feed and drugs*

## INTRODUCTION

The medicinal value of plants lies in some chemical substances that produce a definite physiological action on the animal body. The most important of these bioactive constituents of plants are alkaloids, flavonoids, and phenolic compounds (Hill, 1985). Phytochemicals are non-nutritive plant chemicals that have protective properties. They are nonessential nutrients, meaning that they are not requiring by animal body for sustaining life (Odebiyi *et al.*, 1979). It is well – known that plants produce these chemicals to protect themselves but recent researches demonstrate that they can also protect animals against diseases (Sofowara, 2006).

There are more than thousand known phytochemicals. Presently, many scientist and organizations are in search of traditional remedies as alternative medicine. It has been estimated that about 25% of all prescribed medicines today are substances derived from plants (Biswas *et al.*, 2002). The African continent is one of the continents endowed with the richest biodiversity in the world with many plants used as herbs, health and food for therapeutic purpose (Okwu, 2004). It is however observed that these purposes vary from one country to another.

Numerous plants and herbs are used all over Nigeria by animal scientists (Shoforowa, 2006). Plants have contributed more than 7,000 different compounds in use today as antibiotics, laxative, anticancer agents, and contraceptives, diuretics, decongestants and analgesics compounds. *Alstonia* sp. are tropical plants of family *Apocynaceae* growing in various parts of Africa and South Asia. There are more than 40 known species of genus *Alstonia*, however the most studied include *A. scholaris*, *A. Booinei A. congensis* and *A. magrophylla*. The various species of *Alstonia* are highly rich in alkaloide, steroids and triter period and

phenolic compounds (Afolabi *et al.*, 1995). *A. congensis* has been used in several cases as a medicinal plant for treatment of diseases like gill rot that affects fishes of different species (Ajero and Mbagwu, 2005; Sofowara, 2006). To complement these studies, this study is undertaken on the proximate and phytochemical composition of the parts of the plant and attempts to establish the scientific basis for their use in treating and prevention of fish disease and parasites.

## MATERIALS AND METHODS

### Collection of Plant Materials

*Alstonia congensis* plant was identified and authenticated at the Department of Forestry Herbarium, Michael Okpara University of Agriculture Umudike, Abia State. The fresh specimens of the plant were collected at the early hours of March 2014 from Emekuku areas of Owerri Imo State. The leaves were segregated from the plant while the bark was pulled from the stem. Roots were collected by digging it out from the ground. The specimens were transported to the laboratory where they were washed and air dried at room temperature for 14 days. The plant was selected based on previous reports of its traditional use for antibiotic therapy in Nigeria.

### Preparation of Crude Extract

The dried samples were powdered in an industrial grinding machine. The powder was weighed and collected into clean cellophane bags and labeled to prevent mix up. The samples were kept in a cool dry place till further use, while fresh parts were used immediately after collection from the plant.

### Extraction of Plant Materials

Fifty grams (50g) of the pounded dried plant materials (leaf, bark and root powder) were weighed and extracted with 400 ml of aqueous (distilled water) and 400 ml of ethanol using Tedong extraction method. The processes were run for 2 hours each after which the samples were evaporated to dryness using water bath. The dried extracts were weighed and kept in a well labeled sterile specimen bottles stored in a refrigerator at 4 degree Celsius until is required.

### Phytochemical Screening

The ethanol extracts of the plant were subjected to phytochemical test to determine their chemical constituents using standard method of analysis (Evans *et al.*, 2002).

### Proximate Analysis

The proximate analysis of the powdered plant samples for protein, fat, fibre, ash and dry matter was determined using the methods described in AOAC (1990) at New Concept Chemical Engineering and Environmental Services, Obinze, Imo State.

### Mineral Analysis

The mineral composition of the samples was analyzed on aliquots of dry-ash. 1g of the test portion, was weighed into glazed high-form at 500°C, and allowed to cool. The ash was wet with 10 drops of water, and 3-4 ml carefully evaporated on hot plate set to 100-120°C. The crucible was returned to the furnace for re-ashing for additional 1hr at 500°C after which the crucible was cooled and the ash dissolved in 1ml HCI (1+1), and transferred quantity (Model Accusy 211 Bulk Scientific USA), potassium by flamephometer (Model FP6410 Harris Meduca Essex, England), (AOAC, 1990) (AOAC official method 975.03 (AOAC).

## RESULTS AND DISCUSSION

Phytochemical analyses of bark, leaf and root of ethanol extracts of *Alstonia congensis* plant is illustrated in Table 1 and reveal the presence of alkaloids, steroids, tannins, saponin, flavonoids, cardiac glycosides,

phenols, Oxalate, Phytate and terpenoids while anthraquinones was absent. Saponine was not detected in the root extract. The phytochemicals present in the studied plant parts corroborates the previous studies of Tiwari and Rao (2002) and Ogbe *et al.* (2012). Research reports indicate the presence or these phytochemicals in other plants (Shoforowa, 1993, Okwu, 2004, Osuagwu and Eme, 2013). The plants and their products are as a result of the presence of these phytochemicals in them (Edeoga *et al.*, 2005). There was at least moderate concentration of alkaloids in the parts of the plant. The presence of alkaloid confirms the findings of Ajaiyeoba *et al.* (2006) that the traditional use of the plants for the treatment of common fish disease was due to the presence of alkaloids. The medicinal plants that are moderately rich in alkaloids and tannins have potential health promoting effects (Ikewuchi and Ikewuchi, 2008; Jigam *et al.*, 2010). Saponins have anti carcinogenic properties and other health benefits. Adesokan and Akanji (2010) reported this in addition to anti carcinogenic properties and significant role in anti-inflammatory activity of plants. All the plant parts contain high or moderate quantity of cardiac glycosides used for treating heart problems that may result from severe viral and bacterial attack (Fatoba *et al.*, 2003).

The results of the proximate analysis of the fresh parts as shown in Table 2, reveal that the fresh parts of *A. congensis* contain more of lipids and carbohydrates. These values indicate that fresh parts of *A. congensis* can serve as good source of energy because carbohydrate and fat are known to be the main source of energy for organisms which include human, animal, or microorganism. The protein content of *A. congensis* in this study is lower than the percentage recommended by the Food and Agriculture Organization (FAO, 2003) which is in the range of 12-15%. This suggests the need to supplement a diet base on *A. congensis* with a complementary protein source to make it more nutritious.

The ash contents indicate the degree of the inorganic matter content of the samples. The percentage ash contents are 9.2±0.24, 20.4±0.22 and 10.8±0.33, for leaf bark and root respectively; this can be attributed to the mineral composition of the plant. When ash content is abnormally high there is a very good chance the forage is contaminated with soil which is desirable. The percentage crude fiber were 3.5±0.40, 3.5±0.44, 4.0±0.40 obtained for fresh leaf, bark and root respectively. These indicate that paristalysis. The percentage of moisture contents were 10.2±0.26, 10.8±0.24, 10.6±0.25 fresh leaf, bark and root respectively which is good attribute for storage (Sadowsky *et al.*, 2008).

The mineral analysis is shown in Table 3. The result of mineral analysis of fresh *Alstonia congensis* shows low concentration of minerals such as Fe, Zn, K, and Cu compared to the dry contents of *A. congensis* and as such, lower than the percentage recommended by the Food and Agriculture Organization (FAO, 2003). This suggests the need to supplement any diet based on *A. congensis* with a complementary mineral element source to make it more nutritious. In conclusion, this study reveals it as a supplementary source of antimalarial drugs and essential nutrients to man and livestock.

**Table 1:** Phytochemical Analysis of bark, leaf and root of *Alstonia congensis* plant

| Sample | Alkanoids | Steroids | Tannin | Saponin | Flavonoid | Cardiac Glycosies | Phenol | Oxalate | Phytate | Terpenoids | Anthraquinone |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LEAF | ++ | +++ | ++ | +++ | ++ | ++ | +++ | +++ | ++ | ++ | - |
| BARK | +++ | + | +++ | +++ | ++ | +++ | ++ | ++ | ++ | + | - |
| ROOT | ++ | +++ | +++ | - | ++ | ++ | + | + | + | + | - |

**Key:** +++ = high; ++ = moderate; + = low; - = none or absent

**Table 2:** Proximate Analysis of *Alstonia congensis* plant

| Plant Sample | Crude (%) | Fibre (%) | Mois ture (%) | Lipid (%) | Carbohydrate (%) | Protein (%) |
|---|---|---|---|---|---|---|
| **Root** | 4.05≠8.00 | 10.80≠0.33 | 10.61≠0.225 | 9.00≠020 | 61.17≠0.19 | 3.69≠0.50 |
| **Leaf** | 3.50≠0.47 | 9.00≠0.24 | 10.23≠0.26 | 33.80≠0.35 | 33.84≠0.35 | 0.66≠0.34 |
| **Bark** | 3.50≠0.04 | 20.40≠0.22 | 10.82≠0.24 | 35.00≠0.33 | 26.63≠0.18 | 3.43≠0.46 |

**Table 3:** Mineral Analysis of *Alstonia congensis* plant

| Parameter | Fe, mg/1 | Zn, mg/1 | Cu, mg/1 | K, mg/1 |
|---|---|---|---|---|
| Sample | | | | |
| **Root** | 6.75≠8.05 | 8.42≠8.00 | 1.27≠4.16 | 2.35≠417 |
| **Bark** | 5.16≠8.40 | 5.37≠8.40 | 9.13≠6.20 | 0.47≠2.40 |
| **Leaf** | 5.28≠6.60 | 6.22≠8.40 | 9.36≠6.81 | 0.36≠2.80 |

*Values are means of two different determinations* ≠SEM

## CONCLUSION

There are numerous fish diseases that can affect aquatic environment, these are categorized in difference ways; parasitic, bacterial, viral, fungal and other issues. These are all subject to prevention and treatment as the case may be. Fish feed formulation could be a very source for the disease prevention while preparation of drug of organic compound would help to maintain the fish health and save some stress for the fish farmer.

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# EFFECT OF *Sesamum radiatum* LEAF DIETS AS A FEED BINDER ON THE GROWTH PERFORMANCE OF *Clarias gariepinus* FINGERLINGS

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**ABSTRACT**
*This study investigated the effect of incorporating Black Benniseed (Sesamum radiatum) Leaf Meal (BBLM) as a natural feed binder on the growth performance and water quality of African catfish (Clarias gariepinus) fingerlings. Four experimental diets containing 45% crude protein were formulated: TD1 (control, 6% wheat flour), TD2 (2% BBLM), TD3 (4% BBLM), and TD4 (6% BBLM). Fish with an initial mean weight of about 10±0.02g were stocked in triplicate tanks and reared for 140 days under uniform management conditions. Results showed that growth performance improved with increasing levels of BBLM. Fish fed TD4 recorded the highest mean final weight (1100.55 ± 0.05 g), specific growth rate (3.35 ± 0.12), and protein efficiency ratio (2.22 ± 0.08), while the lowest feed conversion ratio (1.35 ± 0.03) was also observed in this group. Water physico-chemical parameters, including temperature (27.0–27.9°C), pH (7.02–8.26), dissolved oxygen (4.33–5.10 mg/L), and ammonia (0.30–0.42 mg/L), remained within the optimal range for C. gariepinus culture. The findings indicate that inclusion of BBLM up to 6% in 45% protein diets significantly enhances growth, feed utilization, and environmental quality without adverse effects on fish health. Therefore, BBLM can be recommended as a sustainable, low-cost, and eco-friendly alternative feed binder in aquafeed formulation.*

**Keywords**: Catfish, Black Benniseed, binder.

## INTRODUCTION

Numerous natural binders have been employed to produce firm pellets with the purpose of increasing their stability in water and to reduce nutrient loss. Polysaccharides such as starch, cellulose etc are non-toxic and available in abundance and are gaining importance as promising biopolymers to be employed as binders (Volpe, *et al*., 2010). Few examples of these binders are corn starch, rice starch, yam starch, cassava starch, and so on. Binders have a significant role in aquaculture feed production, but due to high cost of conventional synthetic binders, pelleted feed production at on-farm level becomes difficult mostly for peasant and medium scale farmers. This makes farmers to resort to arbitrary inclusion of any available unconventional binding agents for feed production at any inclusion level (Orire, *et al.*, 2019).
The use of natural binding agents for enhancing on-farm floating feed may replace the expensive expanded floating feeds produced by extrusion (Singh, *et al*., 2008, Orire, *et al.*, 2019). The use of a vegetable, black benniseed **(***Sesamum radiatum***)** leaf powder as a binder in aquaculture has not much been explored, hence the study.

## MATERIALS AND METHODS

### Experimental Design and Procedures

Twelve plastic containers of 1 x 1 x 1$m^3$ diameter were used for the experiment. Thesetup was a completely randomized design and all treatments were in triplicates. Three hundred (300) fingerlings were randomly distributed into twenty (12) experimental replicated plastic containers with 25 fingerlings per container with an initial weight of 10±0.02g. They were assigned to four (4) treatments

and replicated thrice. Treatment 1 had fingerlings which were fed with diet containing 6% of wheat flour as a binder (control); fish in treatment 2 were fed with diet containing 2% of black benniseed (*Sesamum radiatum*) leaf powder as a binder; treatment 3 were fed with diets containing 4% of black benniseed leaf powder as a binder and treatment 4 were fed with diet containing 6% of black benniseed leaf powder as a binder. All the experimental fish were fed at 5% body weight. At the start of the feeding trial, the acclimated fish were deprived of feed for 24 hours and initial body weight were taken, this was to prepare them for the feeding trial.

## GROWTH PARAMETERS

At the end of 140 days feeding trial, the growth performances (WGR, SGR, FCR, survival, FER) of the catfish *Clarias gariepinus* were calculated. The WGR, SGR, Survival and FER were calculated as follows:

Weight Gain Rate (WGR) (%) $=100 \times (Wf - W0) / W0$

Specific growth rate (SGR) $= 100 \times (\ln Wf - \ln W0) / t$

Survival (%) = 100 × final shrimp number / initial shrimp number

Feed efficiency ratio (FER) $= (Wf - W0) / FI$

### Statistical Analysis

Data will be analyse using one way ANOVA and the difference among means will be tested for significance ($p = 0.05$). Means comparison was done using multiple range test (Steel and Torrie, 1960).

## RESULTS

**Table 1:** Shows the percentage composition of the feed materials that was used for African catfish, *Clarias gariepinus*, using black Benniseed (*Sesamum radiatum*) as a binder.

| INGREDIENTS | CONTROL) 6% WHEAT FLOUR. | 2% BLACK BENNISEED LEAF MEAL | 4% BLACK BENNISEED LEAF MEAL | 6% BLACK BENNISEED LEAF MEAL |
|---|---|---|---|---|
| Fish meal | 40.94 | 40.44 | 40.68 | 40.94 |
| Soya bean cake | 27.29 | 26.96 | 27.12 | 27.29 |
| Groundnut cake | 13.65 | 13.48 | 13.56 | 13.65 |
| Yellow ma ize | 4.09 | 7.42 | 5.89 | 4.09 |
| Wheat bran | 2.04 | 3.71 | 2.94 | 2.04 |
| Fish oil | 3 | 3 | 3 | 3 |
| Lysine | 0.5 | 0.5 | 0.5 | 0.5 |
| Methionine | 0.2 | 0.2 | 0.2 | 0.2 |
| Multivitamins | 0.1 | 0.1 | 0.1 | 0.1 |
| Antibiotics | 0.1 | 0.1 | 0.1 | 0.1 |
| Enzymes | 0.1 | 0.1 | 0.1 | 0.1 |
| Vitamin C (antioxidant) | 0.5 | 0.5 | 0.5 | 0.5 |
| Fish premix | 0.5 | 0.5 | 0.5 | 0.5 |
| Bone meal | 1 | 1 | 1 | 1 |
| Binder | 6 | 2 | 4 | 6 |
| | **100%** | **100%** | **100%** | **100%** |
| | Mean proximate composition of analyzed feeds | | | |
| Moisture | 10.31±0.02 | 11.00±0.11 | 10.03±0.34 | 10.08±0.14 |
| Ash | 9.11±0.06 | 8.24±0.02 | 9.06±0.17 | 8.02±0.12 |
| Crude protein | 44.56±0.19 | 44.38±0.09 | 45.01±0.00 | 45.04±0.11 |
| Crude lipid | 10.23±0.00 | 11.41±0.17 | 9.21±0.28 | 5.05±0.00 |
| Crude fibre | 4.04±0.15 | 3.89±0.00 | 3.78±0.55 | 3.53±0.31 |

**Table 2:** Growth Performance of African Catfish (*Clarias gariepinus*) fingerlings experimented on Black Benniseed (*Sesamum radiatum*) Leaf Meal as a feed Binder.

| PARAMETERS | TD1 CONTROL WHEAT FLOUR 6% | TD2 BBLM 2% | TD3 BBLM 4% | TD4 BBLM 6% |
|---|---|---|---|---|
| MIW | 10.02±0.02 [a] | 10.00±0.04 [a] | 10.08±0.06 [a] | 10.04±0.03 [a] |
| MFW | 909.40±0.12 [b] | 809.21±0.12 [c] | 950.54±0.03 [b] | 1100.55±0.05 [a] |
| MWG | 899.38±0.08 [b] | 799.21±0. 10[c] | 940.46±0.14 [b] | 1090.51±0.05 [a] |
| SGR | 3.22±0.02 [b] | 3.14±0.07 [b] | 3.24±0.11 [b] | 3.35±0.12 [a] |
| PWG (%) | 8883.2±0.10 [b] | 7892.1±0.01 [c] | 9230±0.12 [b] | 10861±0,03 [a] |
| INITIAL LENGTH (CM) | 11.08±0.02 [a] | 11.06±0.03 [a] | 11.02±0.04 [a] | 11.04±0.05 [a] |
| FINAL LENGTH (CM) | 54.11±0.00 [b] | 50.54±0.05 [c] | 55.21± 0.09[b] | 56.33±0.03 [a] |
| LENGTH INCREASE (CM) | 43.03±0.05 [b] | 39.48±0.07 [c] | 44.19±0.14 [b] | 45.29±0.08 [a] |
| FCR | 1.43±0.11 [b] | 1.53±0.02 [b] | 1.38±0.05 [a] | 1.35±0.03 [a] |
| PER | 1.55±0.14 [b] | 1.46±0.11 [b] | 1.61±0.04 [b] | 2.22±0.08 [a] |
| CONDITION FACTOR (K) | 0.57±0.10 [a] | 0.63±0.03 [a] | 0.52±0.00 [a] | 0.62±0.06 [a] |
| SURVIVAL RATE | 95±0.00 [a] | 95±0.00 [a] | 95±0.00 [a] | 100±0.00 [a] |

BBLM= Black Benniseed Leaf Meal, MIW= Mean Initial Weight, MFW=Mean Final Weight, MWG= Mean Weight Gain, SGR= Specific Growth Rates, PWG= Percentage Weight Gain, FCR= Feed Conversion Ratio, PER= Protein Efficiency Ratio, Survival Rate.
Mean ± SD with different superscript (a, b, c) are significantly different ($P \leq 0.05$).

**Table 3:** Results of water physico-chemical quality parameters during the experiment

| parameters | TD1 CONTROL WHEAT FLOUR 6% | TD2 BBLM 2% | TD3 BBLM 4% | TD4 BBLM 6% |
|---|---|---|---|---|
| Temperature ( °C) | 27.55±0.10 [ab] | 27.00±0.04 [b] | 27.55±0.06 [ab] | 27.90±0.06 [a] |
| pH | 7.80±0.12 [b] | 7.02± 0.08 [c] | 8.26±0.09 [a] | 8.22±0.00 [a] |
| DO mg/l | 4.55±0.01 [b] | 4.33±0.03 [b] | 4.90±0.52 [ab] | 5.10±0.02 [a] |
| Ammonia mg/l | 0.39±0.04 [ab] | 0.42±0.08 [a] | 0.35±0.05 [b] | 0.30±0.05 [b] |

## DISCUSSION

The results of the present study showed that the inclusion of Black Benniseed Leaf Meal (BBLM) as a feed binder significantly influenced the growth performance of *Clarias gariepinus* fingerlings. Fish fed the diet containing 6% BBLM (TD4) exhibited the highest mean final weight (1100.55 ± 0.05 g), mean weight gain (1090.51 ± 0.05 g), and specific growth rate (3.35 ± 0.12), while the control diet (TD1) recorded lower performance. The progressive increase in weight gain and growth indices with higher BBLM inclusion suggests that BBLM improved feed utilization and binding efficiency, leading to better feed intake and nutrient absorption.

These findings agree with the report of Olukunle (2011), who observed that plant-based feed binders improved feed texture and minimized nutrient leaching in fish diets. Similarly, Fagbenro and Arowosoge (1991) noted that diets with stable pellet structure enhance nutrient retention and reduce feed wastage, contributing to improved growth. The observed high growth in the 6% BBLM diet aligns with the results

of Adebayo *et al*. (2018), who reported that natural feed binders such as cassava starch and mucilage promote weight gain and feed conversion in catfish culture.

The feed conversion ratio (FCR) ranged from 1.35 ± 0.03 to 1.53 ± 0.02, with the lowest value recorded in TD4 (6% BBLM), indicating efficient feed utilization. A lower FCR reflects better conversion of feed to body mass. The improved FCR values obtained in this study are comparable to those reported by Gabriel *et al*. (2007), who established that African catfish show optimal growth performance when feed binders improve pellet water stability and digestibility. The protein efficiency ratio (PER) increased from 1.46 ± 0.11 in TD2 to 2.22 ± 0.08 in TD4, implying that protein was efficiently converted into fish biomass as BBLM inclusion increased. This observation corroborates the report of Akinwole and Faturoti (2007), who emphasized that efficient nutrient utilization is closely linked to feed physical quality and protein digestibility.

The condition factor (K) values (0.52–0.63) obtained in this study indicate that the fish were in good physiological condition across all treatments. This is consistent with the findings of Bagenal and Tesch (1978), who noted that a condition factor around 1.0 indicates optimal well-being, while slightly lower values may occur under intensive culture conditions. The 100% survival rate in TD4 further demonstrates that BBLM inclusion supports good feed stability and environmental compatibility.

**Water Quality Parameters**

The water physico-chemical parameters remained within the acceptable range for Clarias gariepinus throughout the experimental period, indicating that BBLM inclusion had no detrimental effects on the aquatic environment.

Temperature values (27.00–27.90 °C) showed slight but significant variations ($p < 0.05$), with the highest temperature recorded in TD4. This range is suitable for catfish growth, as optimal metabolic and feeding activity typically occur between 26–30 °C (Boyd, 1990; Akinwole & Faturoti, 2007). pH values ranged from 7.02 to 8.26, indicating slightly alkaline conditions conducive to catfish health and enzymatic activity. These results are consistent with Gabriel *et al*. (2007), who reported that African catfish thrive best in water with pH 6.5–9.0.

The dissolved oxygen (DO) concentration ranged between 4.33 and 5.10 mg/L, significantly higher in TD4 (6% BBLM) than in the control ($p < 0.05$). According to Akinwole and Faturoti (2007), DO levels above 4 mg/L are essential for optimal feed utilization and growth in catfish. The slightly higher DO in the 6% BBLM group could be linked to lower feed wastage and reduced organic load in the tanks, which promote oxygen stability.

Ammonia concentrations (0.30–0.42 mg/L) were not significantly different among treatments ($p > 0.05$) and remained below the toxic threshold (< 1 mg/L), as reported by Boyd (1990). The lower ammonia values in TD3 and TD4 suggest improved feed digestibility and reduced metabolic waste accumulation, possibly due to the enhanced binding capacity of BBLM, which minimizes feed disintegration in water.

In conclusion, the combined analysis of growth and water quality results shows that the inclusion of BBLM up to 6% in diets containing 45% crude protein improved growth performance, feed utilization, and water quality without any adverse effects on fish health. The improved water quality parameters further supported the higher survival and growth rates observed, confirming a strong relationship between feed quality, fish metabolism, and aquatic environment stability.

Thus, Black Benniseed Leaf Meal can serve as a cost-effective, eco-friendly, and nutritionally beneficial

binder in aquafeed formulations for C*larias gariepinus*, promoting sustainable aquaculture production.

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# PHYTOCHEMICAL AND PROXIMATE VALUES OF GUAVA AND PAWPAW LEAF MEALS AND CONCENTRATES

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**ABSTRACT**
*Fresh Pawpaw and Guava leaves were collected from Modibbo Adama University Farm and staff quarters then brought to the Dry Laboratory of the Department of Fisheries for further analyses. The leaves were divided into two equal halves. One part was used for extraction of the leaf concentrate while the other for the preparation of leaf meal. The results of the analysis showed that all the phytochemicals were significantly different ($p \leq 0.05$) among the samples analysed. The crude protein of the pawpaw leaf meal and concentrate are not significantly different ($p \geq 0.05$) while those of the guava leaf meal and concentrates were significantly different ($p \leq 0.05$).*

**Keywords:**
Phytochemicals, Proximate, Guava, Pawpaw, Leaf meal, Concentrate

## INTRODUCTION

Special feeds are administered to fish in fish farms in combination with other substances for particular purpose such as boosting of the growth of fish, improving the coloration, controlling disease outbreak or infections, increasing of the profit margin, to mention a few (Manam, 2023). One of the current innovations in managing fish is to boost or stimulate their immune system for better performances. Immunostimulants, as dietary supplements, can improve the immune system of animals which provide resistance to pathogens during periods of high stress, such as grading, reproduction, transfer of fish from one pond to another, and application of vaccines (Seerengaraj *et al.*,2024). Phytogenic or phytobiotic compounds are plant derivatives added in the feed to improve the growth and health performance of the fishes. These plant products have different properties like antioxidant, antimicrobial, anticarcinogenic, analgesic, insecticidal, antiparasitic, anticoccidial, growth promoter's appetite enhancement, stimulant of secretion of bile and digestive enzyme activity etc as documented by Asimi and Sahu (2013).

These phytobiotic components are heterogeneous feed additives originating from different part of the plants, viz., leaves, roots, tubers, fruits and spices. These components are used in different forms (oil, powder or extract (Alemayehu *et al.*, 2018). Various phytogenic compounds used in aquaculture include: Allicin which is present in Garlic (*Allium sativum*) and helps to controls & increases immunostimulation against bacterial diseases in cultured fishes (Nya *et al.*, 2010) and also improved haematological indices and developed resistance against *Aeromonas hydrophila* infection in catfish fingerlings (Thanikachalam and Rathinam, 2010); Rosmarinic acid found in Rosemary (*Rosmarinus officinalis*) along with Carnosic, Carnosol, Essential Oils to mention a few and helps to reduces mortality against *Streptococcus inae* in Nile Tilapia (Ziberg *et al.*, 2010); Glucosinonates found in *Moringa oleifera* and reduces *Aeromonas hydrophila* infection and transportation –induced stress in Nile tilapia (Gbadamosi *et al.*, 2016) ; Guajaverin a phyogenic compound found in Guava along with Quercetin, Avicularin, Tannins and Essentials oils which controls *A. hydrophila* infection in Tilapia (Pachanawan *et al.* ,2008) and *Astragalus radix* root extract which increased the leucocytic phagocytosis and Lysozyme activity in Nile tilapia (Yin *etal*,2006). The research is aimed at providing the active chemical composition both in phytochemical and nutrient for guava and pawpaw leaf meal and substrate for the purpose of using them as additives in the diet of fish.

## MATERIALS AND METHODS

### Experimental location

Adamawa state is located within the climate of Northern Guinea Savannah Zone and lies between latitude 8° and 11° N and Longitude 11.5° and 13°E and climate is tropical with two distinct seasons which are Dry and wet seasons. The research was carried out in the Dry and Analytical Laboratory of Department of Fisheries, Moddibo Adama University, Yola Adamawa State ( Adebayode and Liman, 1999)

### Experimental Set-Up

This an analytical experiment which involves collection, processing and laboratory analysis of sample. Guava and Pawpaw leaves were used for this experiment

### Collection and Processing of Leaf Meals and Concentrates

Fresh Pawpaw and Guava leaves were collected from Modibbo Adama University Farm and staff quarters then brought to the Dry Laboratory of the Department of Fisheries for further analysis. The leaves were divided into two equal halves. One part was used for extraction of the leaf concentrate while the other for the preparation of leaf meal.

### Preparation of Guava and Pawpaw Leaf Meal and Concentrate

### Guava and Pawpaw Leaf concentrates

One kilogram leaves of each of the samples was washed to remove dirt, blended with distilled water and then the leaf juice was separated from the residue using sieve. The separated juice of the leaves was heated to 80-90°C for about 20minutes, and centrifuged at 15000 rpm for 10min to coagulate the concentrate and then the water was decanted. The coagulum was filter with cloth filter, and the leaf concentrate obtained was air dried for period of 72hrs, completely air-dried and then packaged in polythene bags prior to feed formulation (Yahaya *et al*., 2024).

### Guava and Pawpaw Leaf Meal

One kilogram leaves of each of the samples was washed to remove dirt and first oven dried at 80 °C for 30 minutes to remove moisture, then air-dried in the laboratory until when dried and was milled into powdered form, and then packaged in a polythene bags prior to feed formulation (Sogbesan, 2014)

### Phytochemical Screening and Proximate analysis Guava and Pawpaw leaf meal and concentrate

The qualitative and quantitative phytochemical analysis were carried out using standard methods described by Association of Official Analytical Chemists (AOAC, 2000). The phytochemicals screened for the presence of biologically active compounds including Tannins, Saponins, Flavonoids, Glycosides, Oxalates, Phytate, Essential oil, Phenols, Steroids, Alkaloids Terpenoids and vitamin C.

### Statistical analysis

Data for each parameter measured was expressed as arithmetic mean ± standard deviation (SD). One-way ANOVA was used to analyse the data and comparison of the mean values was done by using Least Significant Difference (LSD) at 5% level of significance differences. The software programme SPSS (Version 14.0) (SPSS) for Windows was used.

## RESULTS AND DISCUSSION

Table 1 presented the qualitative analysis of the phytochemicals in the guava and pawpaw leaf meal and concentrates while Table 2 showed the mean results of all the quantitative phytochemicals present in the guava and pawpaw leaf meal and concentrates with the statistical analysis. All the phytochemicals were

significantly different ($p \leq 0.05$) among the samples analysed. Table 3 showed the proximate compositions of the leaf's meal and concentrates.

**Table 1:** Qualitative Screening of Guava and Pawpaw Leaves and Concentrates

| Phytochemicals | Guava Leaf Meal | Guava Leaf Extract Concentrates | Pawpaw Leaf Meal | Pawpaw Leaf Extract Concentrates |
|---|---|---|---|---|
| **Tannins** | + | +++ | ++ | + |
| **Saponnins** | ++ | ++ | + | + |
| **Flavonoid** | ++ | + | + | + |
| **Steroids** | +++ | ++ | + | + |
| **Glycosides** | + | ++ | + | + |
| **Oxalates** | + | + | ++ | ++ |
| **Alkaloids** | ++ | + | ++ | ++ |
| **Phytates** | + | ++ | + | + |
| **Essential oils** | + | + | ++ | +++ |
| **Phenols** | + | ++ | + | + |
| **Terpenoids** | + | + | ++ | + |
| **Vitamin C** | ++ | ++ | + | + |

**Keys: + Moderately Present; ++ High; +++ Very High; - Not Present/detected**

The results of the phytochemicals and proximate from this experiment showed the qualitative profile, quantitative values, and the proximate composition details. This pattern agrees with the report of Eyo (2001) and Sogbesan and Bashir (2018) that detailed phytochemicals and proximate can represent the chemical compositions of a plant or phytoadditives and this also corroborate with NRC (2003).The qualitative screening of the *Psidium guajava* and C*arica papaya* phytochemicals in the leaves and thier concentrates showed the presence of tannins, saponins, flavonoids, steroids, Glycosides, oxalates, alkaloids, phytates, essential oils, phenols, terpenoids agreed with the results of Kumar *et al*. (2021).

**Table 2:** Quantitative Screening of Guava and Pawpaw Leaves and their Concentrates (g/100g of sample)

| **Phytochemicals** | **Guava Leaf Meal** | **Guava Leaf Concentrate** | **Pawpaw Leaf Meal** | **Pawpaw Leaf Concentrate** |
|---|---|---|---|---|
| Tannins | $1.1 \pm 0.1^{c}$ | $3.6 \pm 0.3^{a}$ | $2.7 \pm 0.2^{b}$ | $1.0 \pm 0.3^{c}$ |
| Saponins | $2.4 \pm 0.3^{a}$ | $2.7 \pm 0.2^{a}$ | $0.3 \pm 0.1^{b}$ | $0.9 \pm 0.1^{b}$ |
| Flavonoids | $2.8 \pm 0.2^{a}$ | $0.6 \pm 0.1^{b}$ | $0.9 \pm 0.1^{b}$ | $1.1 \pm 0.2^{b}$ |
| Steroids | $5.8 \pm 0.3^{a}$ | $2.0 \pm 0.2^{b}$ | $0.7 \pm 0.1^{c}$ | $1.3 \pm 0.1^{bc}$ |
| Glycosides | $0.2 \pm 0.1^{b}$ | $1.6 \pm 0.2^{a}$ | $0.4 \pm 0.1^{b}$ | $0.8 \pm 0.2^{b}$ |
| Oxalates | $0.8 \pm 0.1^{b}$ | $1.2 \pm 0.1^{b}$ | $3.6 \pm 0.3^{a}$ | $3.0 \pm 0.2^{a}$ |
| Alkaloids | $2.8 \pm 0.3^{a}$ | $1.3 \pm 0.2^{b}$ | $2.9 \pm 0.2^{a}$ | $2.9 \pm 0.3^{a}$ |
| Phytates | $1.0 \pm 0.1^{c}$ | $2.6 \pm 0.2^{a}$ | $1.7 \pm 0.1^{b}$ | $1.1 \pm 0.1^{c}$ |
| Essential oils | $0.6 \pm 0.1^{b}$ | $0.8 \pm 0.1^{b}$ | $2.7 \pm 0.3^{a}$ | $2.7 \pm 0.2^{a}$ |
| Phenols | $0.9 \pm 0.1^{b}$ | $2.7 \pm 0.3^{a}$ | $0.7 \pm 0.1^{b}$ | $0.9 \pm 0.1^{b}$ |
| Terpenoids | $0.8 \pm 0.1^{b}$ | $0.6 \pm 0.1^{b}$ | $1.7 \pm 0.2^{a}$ | $0.6 \pm 0.1^{b}$ |
| Vitamin C | $2.28 \pm 0.2^{a}$ | $2.18 \pm 0.1^{a}$ | $1.1 \pm 0.1^{b}$ | $1.1 \pm 0.1^{b}$ |

**Means on the same row with different superscripts are significantly different ($p \leq 0.05$)**

**Table 3.** Proximate Compositions (%) of the Guava and Pawpaw leaf meal and concentrates

| Ingredients | Proximate compositions (%) | | | | | |
|---|---|---|---|---|---|---|
| | Crude Protein | Crude Lipid | Crude Fibre | Ash | Nitrogen Free Extract | Dry Matter |
| Guava Leaf Meal | 12.69±1.1 [b] | 8.00±1.0 [b] | 37.50±1.2 [a] | 1.50±0.1 [b] | 37.31±3.4 [a] | 97.00±1.3 [a] |
| Guava Leaf Concentrate | 15.70±1.4 [ab] | 8.00±1.3 [b] | 32.70±0.9 [ab] | 6.00±0.1 [a] | 32.05±2.6 [a] | 94.50±1.8 [a] |
| Pawpaw leaf Meal | 17.01±1.2 [a] | 19.00±1.2 [a] | 35.50± 2.1 [a] | 5.00±0.2 [a] | 17.49±2.5 [b] | 94.00±1.5 [a] |
| Pawpaw Leaf Concentrate | 18.06±1.1 [a] | 12.00±1.1 [ab] | 29.00±1.2 [b] | 1.80±0.1 [b] | 35.14±2.9 [a] | 96.00±1.6 [a] |

Means on the same column with different superscripts are significantly different ($p \leq 0.05$)

These researchers also reported that Guava leaves also contains many secondary metabolites, such as flavonoids, triterpenoids, sesquiterpenes, glycosides, alkaloids, saponins, and other phenolic compounds. These compounds play a key role as immune stimulators and modulators of chronic diseases including diabetes, cancer, and gastrointestinal, neurodegenerative, and cardiovascular diseases. Guava leaves essential oils also has antioxidant, antimicrobial, and antiproliferative activity.The results from this study on pawpaw leaves and the concentrates for phytochemicals and proximates were not far from the reports of other scientist. Pawpaw leaves contained alkaloids, saponins, glycosides, phenolic compounds, and flavonoids have anti-inflammatory and anticancerous as documented by Indran *et al*. (2011). In their report, Halim *et al.* (2011) study showed that vitamins, minerals, and amino acids of papaya leaves are quite helpful to improve the total haemoglobin, proteins, and immunity.

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# FISHERIES POSTHARVEST TECHNOLOGY, VALUE ADDITION AND PRODUCT DEVELOPMENT – FPVP

# PROXIMATE AND ESSENTIAL AMINO ACID COMPOSITIONS OF *Clarias gariepinus* SMOKED WITH DIFFERENT FIRE WOOD

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**ABSTRACT**
*This study was carried out in two phases; the first was a pilot survey using structured questionnaire to identify the types of firewood used by fish processors at Hadejia, Jigawa State, Geriyo Adamawa State and Laranto Plateau State. While the second phase was a laboratory work to determine the proximate and essential amino acid composition of the sampled fish species. Smoked and fresh Clarias gariepinus samples were collected from the study areas. Three types of wood reported through the questionnaire as commonly used by fish processors were also used to smoke the fresh Clarias gariepinus purchased. AOAC (2020) method was used in the determination of proximate composition while amino acid analysis was performed on reverse phase-high pressure liquid chromatography (HPLC) (Buck scientific BLC 10/11 Las Vegas USA) equipped with UV 338nm detector. The questionnaire results showed that majority of the respondents (64.58%) in Hadejia used firewood from Neem tree, in Geriyo majority (63.26%) used firewood from Chew tree and in Laranto majority (58.00%) of the respondents used firewood from Tallow tree for smoking their fish. The results obtained showed significance difference between moisture content in fresh and smoked fish samples. The highest increase in crude protein was observed in Clarias gariepinus sampled from Geriyo 65.63% while the lowest was observed in Clarias gariepinus smoked with Chew tree firewood 63.1%. There is also significant different($p<0.05$) between crude lipid composition in fresh and smoked Clarias gariepinus samples. The results of essential amino acids analysis showed that all the fish samples have essential amino acids. Leucine, Phenylalamine, Valine and Arginin are the most concentrated essential amino acids in the samples while Threonine and Methionine are the least detected.*

**Keywords:** Proximate, Amino acids, *Clarias gariepinus*, smoked, Different wood

## INTRODUCTION

Fish is an important dietary component of people all around the world and represents a relatively cheap and accessible source of high-quality protein for poorer households (Adeyeye, 2016).In West Africa, fish has been reported to provide 40%–70% of the protein intake of the population (Ikutegbe&Sikoki, 2014), and it is a critical source of dietary protein that is not readily available in the carbohydrate-based staple foods of the population. In Nigeria, fish has an edge over meat because it is cheaper and relatively more abundant (Eyo, 2001). Research over the past few decades has shown that the nutrients and minerals in fish, and particularly the omega-3 fatty acids found in pelagic fish, are heart-friendly and can improve brain development and reproduction. This has highlighted the role of fish in the functionality of the human body (Aremu, *et al.*, 2013). Fish are consumed in several forms – fresh, dried, fermented, smoked or brined depending on consumer preference in many parts of the world, but smoked fish is the most common one in Nigeria and in many parts of Africa, especially due to its taste (Adeyeye, 2016). Mafimisebi (2012), reported that the majority of the Nigerian people had a preference for fresh fish; however, limitations such as the low keeping quality of the fish after harvesting and the tendency of fish to spoil quickly make this very difficult. Smoking of fish has been found to enhance keeping quality, which extends the shelf-life of smoked fish (Adeyeye, 2016).

Fish smoking have been found to affect food composition as well as losses in nutrients in processed fish. The nature of fish as well as the effect of the processing methods on the fish to be processed should be taken into consideration in the cause of food processing. The objectives of this study are to determine the proximate and essentials amino acid compositions of C*larias gariepinus* smoked with different woods.

## MATERIALS AND METHODS

This research was conducted in two phases, the first phase is a pilot survey to ascertain the types firewood used by fish processors in Hadejia, Jigawa State, Geriyo Adamawa State and Laranto in Plateau State using structured questionnaire and the second phase was Laboratory work to determine proximate and essential amino acid composition of the sampled fish species (C*larias gariepinus*).

### *Collection of Fish Samples and Wood for Fish Smoking*

Smoked C*larias gariepinus*, was purchased from fish processors (smokers) at Hadejia, Geriyo and Laranto fish markets in Jigawa, Adamawa and Plateau State, respectively. The wood type used at the three locations were collected and brought to the Department of Forestry and wildlife, Modibbo Adama University, Yola for proper identification. The wood types were purchased and used for smoking fresh samples of the fish species at Binyaminu Usman Polytechnic, Hadejia. Fresh samples of C*larias gariepinus* were purchased at the landing site of Hadejia River and transported in fish box to Hadejia where smoking of the fish was done.

### Proximate analysis

The moisture, ash, crude fat, crude protein, crude fibre and carbohydrate were determined in accordance with AOAC (2000) methods. All proximate analyses of the fish sample was carried out in triplicate and all chemicals used were of Analytical grade.

### Determination of amino acids.

The sample (30mg) was hydrolyzed with 6N HCI at 110°C for 24h. Amino acid analysis was performed on reverse phase-high pressure liquid chromatography (HPLC) (Buck scientific BLC 10/11 Las Vegas USA) equipped with UV 338nm detector. A C18, 2.5 x 200mm, 5um column and a mobile phase of 1:2:2 (100mM sodium phosphate, pH 7.2: Acetonitrile: methanol) was used at a flow rate of 0.45 mL/minute and an operating temperature of 40°C. Mixed standards were analyzed in a similar manner for identification. All chemicals and standards were of analytical grade from Sigma-Aldrich, St. Louis, MO. Peak identification was conducted by comparing the retention times of authentic standards and those obtained from the samples, these data were integrated using peak Simple chromatography data system processor; (Buck SCi. chromatopac data processor).

### Data Analysis

The data collected were subjected to graphical representation (Barchart) and One-way analysis of variance (ANOVA). The Least Significance Difference (LSD) was used to test for the difference between the treatments' values with significance difference at $p \leq 0.05$. Microsoft Excel Data Analysis and VPAST were used for analyses the data.

## RESULTS AND DISCUSSION

The proximate composition of Fresh and smoked C*larias gariepinus* samples is presented in Table 1

**Table 1.** Proximate compositions (Mean±SD) of Fresh and Smoked *Clarias gariepinus*

| | | Smoked | | | | | |
|---|---|---|---|---|---|---|---|
| **Composition (%)** | **Fresh** | **Hadejia** | **Geriyo** | **Laranto** | **Tallow** | **Neem** | **Chew** |
| Moisture | 56.10±9.8 $^{a}$ | 10.05±1.1 $^{b}$ | 10.55±0.9 $^{b}$ | 10.10±0.7 $^{b}$ | 10.50±1.2 $^{b}$ | 10.70±0.4 $^{b}$ | 10.25±0.8 $^{b}$ |
| Ash | 5.80±0.50 $^{c}$ | 9.60 ±0.3 $^{b}$ | 10.50±0.4 $^{b}$ | 11.98±0.8 $^{a}$ | 10.54±0.5 $^{a}$ | 10.17±0.9 $^{ab}$ | 9.61±0.8 $^{b}$ |
| Crude lipid | 10.40±0.9 $^{d}$ | 15.05±0.9 $^{a}$ | 13.17±0.8 $^{bc}$ | 13.94±1.0 $^{b}$ | 13.41±0.9 $^{b}$ | 14.35±1.1 $^{ab}$ | 11.70±1.2 $^{c}$ |
| Crude Protein | 28.50±2.50 $^{d}$ | 65.25±3.8 $^{a}$ | 65.63±4.3 $^{a}$ | 63.75±5.6 $^{a}$ | 64.88±6.3 $^{a}$ | 64.63±5.2 $^{a}$ | 63.10±4.9 $^{a}$ |
| Nitrogen free extract | 0.20±0.01 $^{c}$ | 0.5±0.01 $^{b}$ | 0.9±0.01 $^{a}$ | 0.23±0.01 $^{c}$ | 0.67±0.03 $^{b}$ | 0.15±0.04 $^{c}$ | 0.35±0.06 $^{c}$ |

Means on the same row with different superscripts are significantly different ($p<0.05$)
The results showed significantly ($p<0.05$) high moisture content in fresh C*larias gariepinus* compared to smoked samples. This is due to loses in water content during smoking. This observation is in agreement with the findings of Ande *et al.*, (2013). The moisture loss is necessary in increasing shelflife of the fish during storage. The result also showed that there is significant different between moisture content in fresh and smoked fish samples.

The ash content showed high percentage in smoked fish samples compared to unsmoked fish samples. The increase in ash content of smoked fish sample is due to loss in moisture (Salan *et al*., 2006).
Both fish samples (smoked and fresh C*larias gariepinus* fish) show good percentage of ash content. The range (5.80 – 11.98%) for the ash content gave an indication that the fish samples may be good sources of minerals such as calcium, potassium, zinc, iron and magnesium (Andrew, 2001).

The high lipid content of the samples is an indication that there was so much fat reserve in the muscle of the fish. However, the smoked fish samples were higher ($p<0.05$) than the fresh.
Onyia *et al*., (2007) also reported that the lipid level in the fish could have been due to the impact of the feed. The result of the lipid content of catfish obtained from this study was slightly lower than the report of Usman (2017) who recorded a range of 14.47 – 15.53% for smoked C*larias gariepinus* in Lapai, Niger State, Nigeria.

Fish protein is of high quality and contains sufficient amounts of all the essential amino acids required by the body for growth, maintenance of lean muscle tissue and active metabolism (Akinwumi, 2014). In this study, there is significant increase in the crude protein level in smoked catfish, when compared with the fresh fish. Fapohunda and Ogunkoya (2006) reported that smoked drying methods increased the protein, ash and fat contents of C*larias gariepinus* and this tallied with observation in this study.

**Essential Amino acids concentrations of Fresh and smoked C*larias gariepinus***
The amino acid composition of fresh and smoked C*larias gariepinus* samples is presented in Figure 1. It was observed that among the essential amino acids, leucine, Phenylalanine, valine and arginine were the most abundant in all the smoked fish samples. Arginine is essential for children's growth and was present in reasonable levels in all the fish samples. Phenylalanine is also high in large quantity is a precursor of some hormones and the pigment melanin in hair, eyes and tanned skin (Aremu *et al.*, 2013). Valine which is also concentrated in large quantity is one of the branched chain amino acids that enhanced energy, increase endurance and aid in muscle tissue recovery and repair. Leucine allows muscle mass to be maintained during the period of weight loss, as long as sufficient protein is consumed. Leucine also serves an important role in maintaining serum glucose levels during fasting states. All these amino acids are important in the proper metabolism of protein in animals.

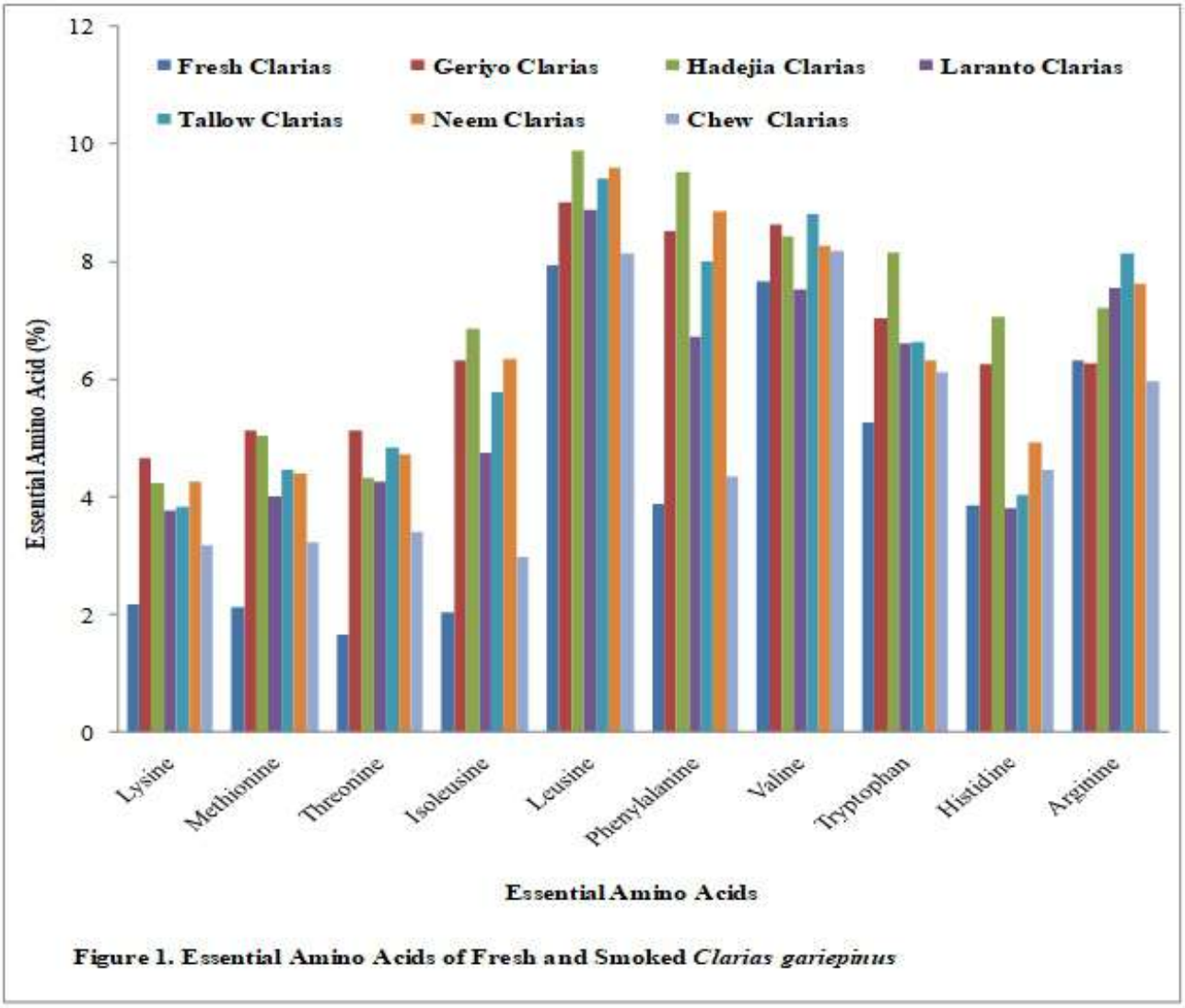



**Figure 1. Essential Amino Acids of Fresh and Smoked *Clarias gariepinus***

This study showed that smoking methods have no adverse effect on the amino acid compositions of all selected fish samples. This agreed with the findings of Adeyeye *et al.*, (2017). The results indicated that these processing methods had no adverse effect on the amino acid composition compared with that of fresh fish. Similarly, locational differences did not influence the Proximate and amino acid compositions of the fish samples.

## CONCLUSION

This study has established that smoked *Clarias gariepinus* has higher nutrients (Crude protein, crude lipid and ash) concentration than the fresh unsmoked ones. This study also revealed that smoking of fish helps to reduce the moisture content thereby increasing the shelf life as well as the nutritional values. It was also established that smoking has no adverse effect on the quality and quantity of essential amino acids. It is therefore recommended that C. gariepinus should be smoked/processed in order to enhance nutrients content and increase the shelf life during storage.

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# EFFECT OF GARLIC FORTIFICATION ON NUTRITIONAL STABILITY AND LIPID OXIDATION INDICES OF HOT SMOKED *Chrysichthys nigrodigitatus*

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**ABSTRACT**
*In response to the growing demand for naturally preserved, nutritionally enhanced fish products with extended shelf life, this study examines the effect of garlic fortification on the nutrient-energy profile and lipid oxidation indices of Chrysichthys nigrodigitatus subjected to hot smoking. Proximate composition revealed that moisture content was highest in fresh samples (77.03 ± 0.37%) and significantly decreased in hot smoked (9.65 ± 0.22%) and garlic-fortified smoked fish (9.27 ± 0.15%). Crude protein increased markedly, with garlic-fortified samples showing the highest value (53.61 ± 0.60%). Crude fat and ash contents also rose after smoking, though garlic fortification slightly reduced fat content. Carbohydrate levels remained low and statistically unchanged across treatments. Energy content increased from 372 kJ/100 g in fresh samples to over 1200 kJ/100 g in smoked fish, with garlic fortification slightly enhancing protein energy contribution (PEP > 58%) and useful protein energy utilization (UEDP%). Lipid oxidation indices showed that garlic-fortified smoked fish retained a higher iodine value (6.57%) than non-fortified smoked fish (1.60%). Peroxide and thiobarbituric acid values were also lower in garlic-treated samples. Free fatty acid levels were statistically similar across treatments. These findings suggest that garlic fortification improves the nutritional stability and lipid quality of smoked C. nigrodigitatus, enhancing its functional and shelf-stable attributes.*

**Keywords:**
Nutrient-energy profile, marine fish, lipid oxidation, lipid quality, Nigeria

## INTRODUCTION

Fish remains a vital component of the human diet, offering high-quality protein, essential fatty acids, vitamins, and minerals (Balami *et al*., 2019). Its nutritional richness contributes significantly to food security, especially in developing countries where fish serves as a major source of animal protein. However, the high moisture and polyunsaturated fatty acid (PUFA) content of fresh fish make it highly perishable, leading to rapid spoilage through microbial proliferation and lipid degradation (Abraha *et al*., 2018; Moruf *et al*., 2021a). To mitigate post-harvest losses and preserve nutritional integrity, effective preservation techniques are essential. Smoking is a traditional and widely accepted preservation method that enhances flavor, improves texture, reduces microbial load, and extends the shelf life of fish products (Adeyeye and Oyewole, 2016). Despite these advantages, hot smoking exposes lipids to high temperatures, which can accelerate lipid oxidation, resulting in the deterioration of sensory quality and nutrient loss, particularly in PUFA-rich species (Puke and Galoburda, 2020).

*Chrysichthys nigrodigitatus*, commonly known as the Bagrid catfish, is a commercially important freshwater species in West Africa due to its taste, size, and availability. It is often processed by traditional hot smoking methods to enhance shellife and market value. However, the oxidative stability of its lipid-rich flesh remains a major concern during and after processing, as lipid peroxidation leads to rancidity, off-flavors, and diminished nutritional quality (Ogunbambo, 2020). Currently, synthetic antioxidants such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) are commonly used to control lipid oxidation in smoked fish. However, growing health and safety concerns over these additives, coupled with their limited consumer acceptance, have created the need to explore natural alternatives

like garlic for enhancing nutritional stability and oxidative protection in C. *nigrodigitatus*.

In recent years, there has been a growing shift toward using natural antioxidants for food preservation to prevent lipid oxidation and improve the overall quality of processed fish. Garlic (*Allium sativum*) has attracted significant interest because it contains sulfur-based compounds such as allicin, diallyl disulfide, and ajoene, that possess strong antioxidant, antimicrobial, and lipid-stabilizing effects (Ozma *et al*., 2023). Several studies have reported that garlic supplementation in meat and fish products can retard lipid oxidation, maintain unsaturated fatty acids, and preserve sensory attributes (El-Saber *et al*., 2020; Ozma *et al*., 2023). Its application in hot smoked fish processing could offer dual benefits—nutritional enhancement and oxidative protection. This study, therefore, examined the effect of garlic fortification on the nutritional stability and lipid oxidation indices of hot smoked C. *nigrodigitatus*, with the aim of providing an evidence-based strategy to improve the quality and shelf-life of smoked freshwater fish products.

## MATERIALS AND METHODS

### Sample Collection and Preparation

Fresh specimens of C.*nigrodigitatus* (average weight: 350 ± 25 g) were sourced from a reputable fish landing site in Lagos, Nigeria. The fish were immediately transported on ice to the laboratory, where they were washed, degutted, and divided into three groups: (i) fresh (un-smoked) (ii) a control group, which was hot smoked without garlic treatment, and (iii) treated group, which was hot smoked after marination in a 10% garlic paste solution for 30 min.

### Smoking Procedure and Storage Conditions

Both smoked groups were previously subjected to hot smoking using a traditional drum kiln. The smoking was carried out at 70–90 °C for 6 hours using hardwood as fuel, until the internal temperature of the fish reached 65 °C. Smoked fish samples were cooled to ambient temperature (27 ± 2 °C). All samples were stored at ambient conditions (27 ± 2 °C; relative humidity: 60–70%) for a period of 14 days.

### Laboratory Analysis

The proximate composition, iodine value, peroxide value, thiobarbituric acid (TBA) value, and free fatty acid (FFA) content were determined using standard AOAC (2019) methods. The energy value of fish samples was calculated using the Atwater general factor system-Protein: 4 kcal/g, Fat: 9 kcal/g and Carbohydrate: 4 kcal/g. Lipid extracts were analyzed spectrophotometrically to assess oxidative and hydrolytic rancidity.

### Statistical Analysis

Data were analyzed using SPSS version 25.0 to perform two-way ANOVA among means, which were separated using Tukey's HSD test at a significance level of $p < 0.05$.

## RESULTS AND DISCUSION

### Nutrient-Energy Composition

The proximate composition of C. *nigrodigitatus* showed significant variations across treatments. Moisture content was highest in fresh samples (77.03±0.37%) and significantly reduced in both hot smoked (9.65±0.22%) and garlic-fortified hot smoked samples (9.27±0.15%), consistent with the moisture-reducing effect of smoking reported by Adepoju et al. (2018), who observed similar reductions in milkfish. Crude protein increased markedly in smoked samples, with garlic-fortified fish showing the highest value (53.61±0.6%), likely due to concentration effects from dehydration and the possible proteolytic activity of garlic, aligning with the findings of Barros *et al.* (2023) on fortified smoked fish. Crude fat content was significantly higher in smoked samples compared to fresh, although slightly

reduced in garlic-fortified fish (5.85±0.05%) relative to the non-fortified (6.43±0.55%), suggesting garlic's potential antioxidative effect on lipid preservation, as supported by Khan *et al*. (2020). Ash content followed a similar trend, increasing after smoking, which is attributed to mineral concentration from moisture loss, aligning with reports by Msuku and Kaputе (2018). Carbohydrate values remained low and statistically similar, indicating minimal influence from smoking or garlic treatment. These results collectively affirm that hot smoking and garlic fortification enhance nutrient density by reducing moisture and concentrating essential nutrients.

**Table 1:** Proximate composition of Fresh and Garlic-Fortified Hot Smoked C*hrysichthys nigrodigitatus*

| Parameters (%) | Fresh | Non-Fortified Hot Smoked | Garlic -Fortified Hot Smoked |
|---|---|---|---|
| Moisture | 77.03±0.37 [a] | 9.65±0.22 [b] | 9.27±0.15 [b] |
| Crude Protein | 17.53±0.51 [a] | 51.34±1.38 [b] | 53.61±0.6 [b] |
| Crude Fat | 1.31±1.05 [a] | 6.43±0.55 [b] | 5.85±0.05 [b] |
| Ash | 2.64±0.01 [a] | 27.41±0.00 [b] | 26.67±0.02 [b] |
| Carbohydrates | 1.49±0.56 [a] | 5.17±0.61 [a] | 4.60±0.26 [a] |

**Keys**: Mean ± Standard Error; Values with different superscripts across row are significantly different at ($P < 0.05$)

The compositional energy values presented in Table 2 indicate a significant increase in total energy content from fresh (372 kJ/100 g) to hot smoked (1199–1206 kJ/100 g) C. *nigrodigitatus*, with garlic-fortified samples exhibiting slightly higher values. This increase is attributed to moisture loss during smoking, which concentrates macronutrients, especially protein and fat (Salami *et al*., 2024). The proportion of energy derived from protein (PEP) rose markedly from 19.6% in fresh samples to over 58% in fortified smoked fish, aligning with findings by Moruf *et al.* (2021b), who reported protein-dominated energy profiles in grilled crab. Fat-derived energy (PEF) also increased from 3.2% to around 15%, consistent with the lipid concentration effect during smoking (Han *et al*., 2023). Garlic fortification had minimal effect on total energy but slightly enhanced protein energy utilization (UEDP%), suggesting a potential protective effect of garlic on protein stability during heat processing, as similarly observed by Hussein *et al*. (2023) in garlic-treated Nile tilapia. Overall, smoking and garlic fortification enhanced the calorific and nutritional density of the fish, improving its value as a protein-rich food.

**Table 2:** Compositional energy values of Fresh and Garlic-Fortified Hot Smoked C*hrysichthys nigrodigitatus*

| Parameter | Unit | Fresh | Non-Fortified Hot Smoked | Garlic-Fortified Hot Smoked |
|---|---|---|---|---|
| Total energy | kJ $100g^{-1}$ | 372 | 1199 | 1206 |
| | kcal $100g^{-1}$ | 88 | 284 | 285 |
| PEF | % (kJ $100g^{-1}$) | 3.2 (48) | 15.9 (238) | 14.2 (216) |
| | % (kcal 100g-$^{-1}$) | 3.3 (12) | 16.3 (58) | 14.5 (53) |
| PEC | % (kJ $100g^{-1}$) | 1.7 (25) | 5.9(8.8) | 5.1 (78) |
| | % (kcal $100g^{-1}$) | 1.6 (1.7) | 5.8 (21) | 5.1 (18) |
| PEP | % (kJ $100g^{-1}$) | 19.6 (298) | 58.3 (873) | 59.8 (911) |
| | % (kcal $100g^{-1}$) | 19.4 (19.6) | 57.8 (205 | 59.2 (214) |
| UEDP% | kJ | 11.7 | 35 | 35.9 |
| | kcal | 11.6 | 34.7 | 35.5 |

**Keys**: Proportion of total energy due to fat (PEF), Proportion of total energy due to carbohydrate (PEC), Proportion of total energy due to protein (PEP), utilization of energy value due to protein (UEDP%).

**Lipid Oxidation**

The results in Table 3 show that garlic fortification significantly influenced the lipid oxidation profile of C. *nigrodigitatus* during hot smoking. While the non-fortified hot smoked samples exhibited the lowest iodine value (1.60%), indicating higher degradation of unsaturated fatty acids, the garlic-fortified samples retained a value (6.57%) closer to that of fresh fish (7.07%), suggesting better preservation of lipid unsaturation. Similar trends were observed for peroxide and TBA values, where garlic-treated samples had notably lower levels (3.38 meq/kg and 6.04 mg/100g, respectively) compared to non-fortified smoked fish (5.30 meq/kg and 8.08 mg/100g), reflecting reduced primary and secondary lipid oxidation. This aligns with the findings of Khan *et al*. (2020), who reported that natural antioxidants, including garlic, slow down lipid peroxidation in smoked fish products. However, FFA values were not significantly different among the treatments ($p > 0.05$), which agrees with the observation of Nadeem *et al.* (2017) that FFA content is less sensitive to antioxidant treatments in short-term storage. Overall, garlic fortification demonstrated a protective effect against oxidative rancidity, enhancing the lipid stability of smoked fish.

**Table 3:** Lipid Oxidation Indices of Fresh and Garlic-Fortified Hot Smoked C*hrysichthys nigrodigitatus*

| Parameters (%) | Fresh | Non-Fortified Hot Smoked | Garlic -Fortified Hot Smoked |
|---|---|---|---|
| Iodine Value | 7.07 ±0.07 [a] | 1.60 ±0.14 [b] | 6.57 ±0.03 [a] |
| Peroxide Value (MEq/kg) | 0.67 ±0.05 [a] | 5.30 ±0.06 [b] | 3.38 ±0.01 [b] |
| Thiobarbituric Acid Value (mg/100g) | 1.38 ±0.04 [a] | 8.08 ±0.08 [b] | 6.04 ±0.31 [b] |
| Free Fatty Acid (MgKOH/g) | 1.11 ±0.02 [a] | 1.87 ±0.03 [a] | 2.17 ±0.05 [a] |

**Keys**: Mean ± Standard Error; Values with different superscripts across row are significantly different at ($P < 0.05$)

## CONCLUSION

The results confirm that hot smoking significantly enhances the nutrient density and energy content of C*hrysichthys nigrodigitatus*, primarily through moisture reduction and nutrient concentration. Garlic fortification further improved protein content and preserved lipid integrity, indicating its potential functional role in smoked fish processing. The garlic-fortified samples exhibited the most favorable nutrient-energy profile, with elevated protein contribution to energy and reduced lipid degradation. These findings support the inclusion of garlic as a natural additive for improving the nutritional quality and oxidative stability of smoked fish products.

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# COMPARATIVE EXTRACTION OF FISH OIL FROM *Brycinus nurse AND Hydrocinus forskahlii* WITH VALUE ADDED SPICE PRODUCTION FROM THE RESIDUAL CARCASS

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**ABSTRACT**

*This study sought to compare extraction of fish oil from Brycinus nurse and Hydrocynus forskahlii with value-added spice production from their residual carcass. The aim of the study was to: assess the quality and nutrient composition, compare the oil yields from both fish species, and evaluate the quantity and quality of fish oil produced from Brycinus nurse and Hydrocynus forskahlii. The fish samples were boiled for about two hours at temperatures between 90-degrees Celsius to -98o until oil separation was observed. The chaff was ground into powder with use of a 3G blender and mixed with some grounded spices (ginger, garlic, black pepper, nutmeg, coriander, cinnamon, fennel seed, and table salt) for the preparation of fish spices. The findings revealed that H. forskahlii takes more time to produce oil than B. nurse. However, results revealed that, quantity of oil produced from B. nurse had higher oil, measuring 420ml compared to H. forskahlii which had only 60ml of the oil extracted. The quality of fish oil by characterization of acid value, saponification, and relative density of the two species were found to be within the recommended value of less than 165 -195 mgKOH/g oil. These elements help in improving the fish oil quality in terms of taste, colour, odour, and its shelf life. This study demonstrates the efficiency of the boiling method in oil extraction and underscores the importance of bio-utilization of fish chaff for food product development and waste reduction in small-scale fish oil processing.*

**Keywords:** Fish oil, Fish oil extraction, *Brycinus nurse*, *Hydrocynus forskahlii*, Fish spices

## INTRODUCTION

Fish oils are valued for their n-3 PUFAs like EPA and DHA, crucial for human health (Dave *et al.*, 2024; Njinkoue *et al.*, 2017). These fatty acids support cardio-metabolic functions, reduce cardiovascular and coronary heart diseases, and lower mortality from ischemic heart disease and dyslipidemia (Christmann *et al.*, 2021; Lee *et al.*, 2009). They also prevent cognitive decline in the elderly, mitigate oxidative stress and inflammation, and positively impact Renal, brain and retinal development (Allen and Roswitha, 2020; Bali´ c *et al.*, 2020; Colson *et al.*, 2019; Gonçalves *et al.*, 2018; Lokuruka, 2024; Meital *et al.*, 2019; Nchoutpouen *et al.*, 2020; Njinkoue *et al.*, 2017; Welty, 2023). Additionally, n-3 PUFAs stimulate endothelial function, increase insulin sensitivity, and improve cholesterol, triglycerides, blood pressure, and blood glucose levels (Boukhari *et al.*, 2013; Dos Santos and Fleming, 2020; Lakshimi and Kavitha, 2023; Makni *et al.*, 2010). Besides fatty acids, fish oils contain beneficial compounds such as phenolics, phytosterols, pigments, vitamins, and minerals (Awuchi *et al.*, 2022). Phenolics enhance cardiometabolic health, while sterols lower LDL cholesterol. Phytosterols and carotenoids are precursors to vitamins D2 and A, respectively. Vitamin A aids growth and hormone regulation, and vitamin D lowers diabetes and cardiovascular disease risks. Carotenoids and vitamin E act as antioxidants, and essential minerals are vital for various bodily functions (Awuchi *et al.*, 2022; Dongho *et al.*, 2023). Considering all these benefits of fish oils, it is crucial to promote daily consumption (Dongho *et al.*, 2023).

*Hydrocynus forskahlii* also known as the elongated tigerfish, is species of predatory characin from the

family Alestidae which is found in northern and western Africa. *Hydrocynus forskahlii* is found in central Africa in Lake Albert, Lake Turkana and Lake Gandjule and in the Congo River, Omo River and Nile. In West Africa, it occurs in the Chad Basin, Niger River, Benue River west to the Senegal River and River Gambia. It is also present in the coastal river basin and in the Cross River basin, Wouri River and Sanaga River (Sarah *et al.*, 2011). In some basins it is sympatric with *Hydrocynus brevis*. *H. forskahlii* is pelagic potamodromous species of open water, it prefers the well oxygenated surface waters (Christopher and Keneth, 2016). *Brycinus nurse* is found in most freshwaters of Nigeria; including Lake Chad, Tiga Dam in Kano State, River Benue and Niger as well as Gubi Dam. *Brycinus nurse* spawns during the peak of the floods with the specific months varying with the locality, July and October in Chad (Blache, 1964), July and September in Ivory Coast, (Paugy, 1980), June and July in River Asa and Galma, Nigeria (Omotosho, 1990).

## MATERIALS AND METHOD

The study was carried out in department of Fisheries, Federal College of Freshwater Fisheries Technology Baga, along Ngala Road, Gamboru, Borno state, Nigeria. Four (4) kilograms of *Hydrocynus forskahlii* and *Brycinus nurse each* were obtained from Alau Dam and River Yobe in Gashua Yobe state for this experiment using Gura Mali (Malian Trap). The fresh fish were kept at room temperature for subsequent experiment. Prior to the cooking of fresh fish for oil extraction, the fish were removed from the refrigerator and poured into plastic robber where clean water from tap were used to wash and remove all debris, sand, and blood on the fish. The head was cut, degutted, descale, the fin where removed, wash thoroughly with water to remove slime and blood and the fish where then transfer to pot for proper cooking. The prepared fish was weight and transferred into the cooking pot filled with about 1/3 clean tap water. The local methods of oil extraction were adopted in this study. fire was generated with fuel wood. The two species of fish were cooked between 90°C and 100°C. The *Hydrocynus forskahlii* was cooked for 2hours, 3minutes while *Brycynus nurse* was cooked for 2hours 15minutes. After boiling the fish tissues for several hours, oil start forming at upper water part of the water. The process continued until when the fish carcass stops producing oil. The oil is then separated from the water using cooking spoon, the oil is collected at the upper part leaving the water and the supernatant. The oil is then transferred into 1litre plastic bottle to allow to settle over-night. This was to provide enough room for oil to settle in the bottle, while only pure, clear oil were obtained. The oil was taking to NAFDAC for characterization based on determination of saponification value, acid value, and relative density. fish samples are also analyzed for dry matter, crude protein, crude fibre, ether extract or fat, ash, carbohydrate and nitrogen free extract (NFE) according to AOAC method, (1990) 15$^{th}$ edition. Finally, remaining chaff (supernatant) was collected and sun dried on a drying tray for three (3) days The chaff was grounded into powder with the use of a 3G blender, and mixed with some grounded spices like ginger, garlic, black pepper, nutmeg, coriander, senamon, fennel seed, and salt for the preparation of fish 'spices. The 'spices' was then packed into the container.

## RESULTS

The result showed that sample start to produce oil at 46 min at temperature between 90°C - 98°C. At 53 minutes' oil point increases. The oil points continued to increase gradually up to about 103 minutes. Finally, at 113 minutes the oil formation completed.

### Quantity of oil Extracted

The quantity of oil produced from two different species is presented in Table 1 and figure 14. The result of the study showed that species of *Brycinus nurse* had 420 ml of oil. While *Hydrocynus forskali* had only 60ml of fish oil, this shows that *Brycinus nurse* contained more oil than *Hydrocynus forskahlii* in the present study.

**Table 1:** Quantity of oil produced by two species

| Species | Weight of fish (g) | Mean Quant ity of oil produced (ml) mean oil yield | |
|---|---|---|---|
| *Hydrocynus Forskali* | 4000 | 60.00 ml | 1.50% |
| *Brycinus nurse* | 4000 | 420.00ml | 10.50% |

**Quality determination of fish oil from two species**.

The quality of fish oil from both species is presented in table in 2 below. Result shows that, sample A, has a saponification mean value of 178.95, while sample B has a mean value of 183.53.

The acid value for sample A is 2.07 while for sample B is 3.18. Oleic acid in sample A has a mean value of 0.1129 and 0.1691 in sample B. Palmetic acid has a mean value of 0.0100 in sample A and 0.150 in sample B, and Lauric acid in sample A has a mean value of 0.0081 and 0.1201 in *sample B*. All the acid values are within the standard value of less than 165 -195 mgKOH/g oil

**Table 2**: Characterization quality of fish oil

| **PROPPERTIES** | **SAMPLE A (Mean Value)** | **SAMPLE B (Mean Value)** |
|---|---|---|
| Saponification value (mgKOH/g oil) | 180.05±0.36 | 183.53±0.40 |
| Acid value (mgKOH/g oil) | 2.07± 0.06 | 3.18±0.07 |
| Oleic acid (g) | 0.1129±0.0002 | 0.1691±0.0004 |
| Palmitic acid (g) | 0.0100±0.00015 | 0.1500±0.00031 |
| Lauric acid (g) | 0.0081±0.00015 | 0.1201±0.00035 |
| Relative density | 0.9131±0.0001 | 0.9141±0.0001 |
| Vitamin A | + | + |

**Keys: Sample A***: B nurse*. ***Sample B:*** *H forskahlii*

**Proximate composition of *Bracynus nurse* and *Hydrocynus forskahlii***

The proximate composition of *Bracynus nurse* and *Hydrocynus forskahlii*, in which the highest crude protein was recorded in *Hydrocynus forskahlii* with a mean value of $25.05\pm0.30^{a}$ whereas the least was obtained in *Bracynus nurse* with a mean value of $23.06\pm0.30^{b}$. The highest moisture contents were recorded in *Hydrocynus forskahlii* with the mean value of $71.600.67^{a}$ and the least was obtained in *Bracynus nurse* with the mean value of $69.65\pm0.67^{a}$. The result of fat does not show significant different in both species. The carbohydrates the highest value was obtained in *Hydrocynus forskahlii* with value $1.72\pm0.28^{a}$ and the lowest was obtained in *Bracynus nurse* with value $1.39\pm0.28^{a}$. In the ash content the highest value was obtained in *Hydrocynus forskahlii* with the mean value of $1.35\pm0.05^{a}$ and the least in *Bracynus nurse* with mean value of $1.10\pm0.05^{b}$respectively.

**Table 3:** Proximate composition of *Bracynus nurse and Hydrocynus forskahlii*

| Tre atment | *Bracynus nurse* | *Hydrocynus forskahlii* |
|---|---|---|
| Moisture content | 69.65±0.67 $^{a}$ | 71.600.67 $^{a}$ |
| Ash content | 1.10±0.05 $^{b}$ | 1.35±0.05 $^{a}$ |
| Crude protein | 23.06±0.30 $^{b}$ | 25.05±0.30 $^{a}$ |
| Fat | 2.65±0.70 $^{a}$ | 2.65±0.70 $^{a}$ |
| Carbohydrate | 1.39±0.28 $^{a}$ | 1.72±0.28 $^{a}$ |

## DISCUSSION

The present finding indicates that fish oil can be produced using local method of oil extraction. The findings revealed that *Hydrocynus forskali* takes more time to produce oil than *Brycinus nurse*. This might be attributed to big size of *Hydrocynus forskali* than *Brycinus nurse*. The greater amount of oil produced by *Brycinus nurse* may be attributed the natural characteristic of the species.

The proximate composition of *Brycinus nurse* and *Hydrocynus forskahlii*, in which the highest crude protein was recorded in *Hydrocynus forskahlii* with a mean value of $25.05 \pm 0.30^{a}$ whereas the least was obtained in *Bracynus nurse* with a mean value of $23.06 \pm 0.30^{b}$. The highest moisture contents were recorded in *Hydrocynus forskahlii* with the mean value of $71.600.67^{a}$ and the least was obtained in *Bracynus nurse* with the mean value of $69.65 \pm 0.67^{a}$. The result of fat does not show significant different in both species. The carbohydrates with highest value were obtained in *Hydrocynus forskahlii* with value $1.72 \pm 0.28^{a}$ and the lowest was obtained in *Bracynus nurse* with value $1.39 \pm 0.28^{a}$. In the ash content the highest value was obtained in *Hydrocynus forskahlii* with the mean value of $1.35 \pm 0.05^{a}$ and the least in *Bracynus nurse* with mean value of $1.10 \pm 0.05^{b}$respectively.

The characterization/quality table shows that, sample A, has a saponification mean value of 178.95, while sample B has a mean value of 183.53. The acid value for sample A is 2.07 while for sample B is 3.18. Oleic acid in sample A has a mean value of 0.1129 and 0.1691 in *sample B*. Palmetic acid has a mean value of 0.0100 in sample A and 0.150 in *sample B*, and Lauric acid in sample A has a mean value of 0.0081 and 0.1201 in *sample B*. All the acid values are within the standard value of less than 165 -195 mgKOH/g oil. These findings correlate with finding of D. Ngo Hagbe *et al.,* (2025), on his comparative study of oil extraction methods, where he obtained slight variation in the recommended acid value with 3.51± in viscera of *H. niloticus* compared to its carcass with 3.06 mgKOH/g. however, in the current study, acid value in sample B *(H. forskahlii*), is found to meet the recommended acid value of ≤ 3.00mgKOH/G.In a similar research, Domiszewski *et al.,* (2011) evaluated the acid value of catfish fillet and observe that the raw catfish fillet had an acid value of 6.45±0.06mg/KOH lipid. The acid value quantifies the amount of acid present. It is the mass of potassium hydroxide in mg that is required to neutralize 1g of chemical - substance (Wrolstad *et al.,* 2005). The result shows a positive sign for vitamin in both *sample A* and *B*. This indicate availability of vitamins in the samples**,** this finding is within the range of standard value of fish oil (165 -195 mgKOH/g oil) as reported by Bello *et al,* (2016).

## CONCLUSION

This study demonstrated successful oil extraction using unconventional method, from Brycinus nurse and Hydrocinus forskahlii, with *B. forskahlii* yielded more oil than *H. forskahlii*. The use of fish carcass for spice production highlights an effective method of value addition and waste reduction. The quality of fish oil by characterization of acid value, saponification value, and relative density of the two species were found to be within the standard value of less than 165 -195 mgKOH/g oil. And these elements help in improving the fish oil quality in terms of taste, color, odor, and shelf life. This approach can support sustainable fisheries and offer a potential for small scale fish processing industries.

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# ASSESSMENT OF SENSORY EVALUATION AND PROXIMATE QUALITY OF SMOKED BONYTONGUE FISH (*Heterotis niloticus* CUVIER, 1829) TREATED WITH DIFFERENT SEASONINGS FROM MAIDUGURI, BORNO STATE NIGERIA

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**ABSTRACT**

*This study investigated the effects of different seasonings salt (5%), garlic (3%), and ginger (3%) on the sensory and proximate quality of smoked Heterotis niloticus (bonytongue fish) in Northeastern Nigeria. The results showed that garlic- and ginger-treated fish had significantly higher sensory scores than salt-treated and control samples, especially in taste, aroma, appearance, texture, and overall acceptability. Garlic-treated fish had the highest overall acceptability (7.60 ± 0.49), followed by ginger (7.50 ± 0.50), while the control scored the lowest (5.00 ± 0.45). In terms of proximate composition, garlic- and ginger-treated samples had the lowest moisture (28.90% and 28.60%) and lipid content (15.70% and 15.50%), suggesting improved shelf life. Salt-treated samples showed the highest protein content (48.30%), while all treatments had similar ash and crude fiber content. The use of natural seasonings like garlic and ginger in fish smoking not only enhances taste and aroma but also reduces moisture and fat content, improving both quality and shelf stability. It is therefore recommended that fish processors adopt these natural additives in traditional smoking processes. Training programs should be introduced to encourage their use among small- and medium-scale processors, while policy support should promote the use of indigenous spices to reduce reliance on chemical preservatives and improve public health and food security.*

**Keywords**: *Heterotis niloticus*, smoked fish, sensory quality, proximate composition and natural seasonings

## INTRODUCTION

Fish is an essential source of high-quality protein and micronutrients crucial for human health (FAO, 2020). It is widely consumed in Nigeria due to its affordability, availability, and high nutritional value (Eyo, 2001). Fish contributes significantly to food security, providing a substantial proportion of animal protein in the diet of many Nigerians (Olaoye and Ojebiyi, 2018). Among various fish species, *Heterotis niloticus* (bonytongue fish) is a freshwater species valued for its taste, market demand, and adaptability to aquaculture systems (Oladejo and Akinbile, 2021).

The preservation of fish is crucial in ensuring food safety, reducing post-harvest losses, and extending shelf life. Smoking is one of the oldest and most commonly used methods of fish preservation (Adeyemi *et al*., 2017). It enhances flavor, reduces moisture content, and inhibits microbial growth, thus improving the shelf stability of fish products (Adebayo-Tayo *et al*., 2011). Traditional fish smoking methods have been widely practiced across Nigeria, with salt being the most common seasoning used in the process (Rahman *et al*., 2020).

However, in recent years, research has explored alternative seasonings such as garlic and ginger due to their potential antimicrobial, antioxidant, and preservative properties (Kumar *et al*., 2018). Garlic (Allium sativum) and ginger (Zingiber officinale) contain bioactive compounds that have been reported

to inhibit bacterial growth, enhance taste, and improve the shelf life of food products (Abdullahi *et al*., 2019). Incorporating these natural seasonings in fish smoking may offer an innovative approach to improving both the sensory and proximate quality of fish.

The demand for high-quality, well-preserved fish products has grown as consumers become more health-conscious (FAO, 2020). Studies suggest that different seasonings can influence the taste, texture, and chemical composition of smoked fish (Oladejo and Akinbile, 2021). However, limited research has been conducted on how alternative seasonings like garlic and ginger affect the sensory and proximate composition of*H. niloticus*. Understanding these effects is essential for improving fish processing techniques and increasing consumer acceptability.

In Northeastern Nigeria, smoked fish is a common dietary component, but there is a lack of consistency in processing techniques, leading to variations in quality (Adeyemi *et al*., 2017). Investigating the effects of different seasoning treatments on H. *niloticus* will provide valuable insights into optimizing fish smoking methods. This study aims to assess the sensory evaluation and proximate quality of smoked *H. niloticus* treated with salt, garlic, and ginger.
However, little research has examined the effects of garlic and ginger on the sensory and proximate quality of *H. niloticus*. This study aims to fill this gap by evaluating the impact of these natural seasonings on taste, texture, aroma, color, and nutritional composition of smoked bonytongue fish from Northeastern Nigeria.

## MATERIALS AND METHODS

### Study Area

The research was conducted at the fish processing unit of the Federal College of Freshwater Fisheries Technology, Baga (Latitudes $11^{0}$51'43" N and Longitudes $13^{0}$13'36" E), between June and July 2025.

### Experimental Design and Treatments

This study employed a completely randomized design (CRD) to assess the effects of different seasoning treatments on the sensory and proximate quality of smoked *Heterotis niloticus*. The experimental treatments include:

1. Control (No seasoning, smoked only)
2. Salt-treated (Salt at 5% w/w of fish weight)
3. Garlic-treated (Garlic at 3% w/w of fish weight)
4. Ginger-treated (Ginger at 3% w/w of fish weight) Onah *et al*., 2022: Adaka *et al*., 2024

Each treatment replicated three times, and fish samples were randomly assigned to these groups to minimize bias.

### Sample Collection and Preparation

Live adult *Heterotis niloticus* specimens of about 300g to 450g were purchased from Gamboru fish market and transported in ice-packed containers to the laboratory to maintain freshness. The fish was gutted, cleaned, and divided into four experimental groups. The fish samples were marinated with the designated seasoning, allowed to sit for 3 hours for proper absorption, and then smoked using a traditional smoking kiln at 60-80°C for 8 hours (Eyo, 2020; Rahman *et al*., 2021).

### Sensory Evaluation

Sensory evaluation was conducted using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) and assessed appearance (color, surface texture), Aroma (smokiness, seasoning impact), Taste (flavor intensity, seasoning balance), Texture (firmness, juiciness, chewiness) and Overall

acceptability. A panel of 10 trained sensory evaluators (Lecturers and technologists) assessed the smoked fish samples. Each panelist received coded fish samples under controlled conditions (white light, room temperature, no distractions).

**Proximate Analysis**
The proximate composition of smoked *Heterotis niloticus* was analyzed following AOAC (2019) standard procedures to determined Moisture content, Crude protein, Crude lipid, Ash content and Crude fiber. Each analysis was conducted in triplicate for accuracy.

**Statistical Analysis**
The data obtained were analyzed using SPSS (Statistical Package for the Social Sciences) version 25. Descriptive Statistics such as Mean and standard deviation used for sensory and proximate data. One-Way ANOVA was used to determine significant differences between treatments. Post-hoc Tukey's Test was applied were ANOVA shows significant differences to identify which treatments differ. The Results was considered significant at $p < 0.05$.

## RESULTS

**Sensory Evaluation of Smoked *Heterotis niloticus***
The sensory scores of smoked *Heterotis niloticus* treated with different seasonings are presented in Table 1. Significant differences ($p < 0.05$) were observed across treatments in all evaluated attributes.

**Table 1:** Sensory Attributes of Smoked *Heterotis niloticus* Treated with Different Seasonings (Mean ± SD)

| Treatment | Appearance | Aroma | Taste | Texture | Overall Acceptability |
|---|---|---|---|---|---|
| Control | 5.10 ± 0.32 $^{c}$ | 4.80 ± 0.42 $^{c}$ | 4.60 ± 0.70 $^{c}$ | 5.00 ± 0.47 $^{bc}$ | 5.00 ± 0.45 $^{c}$ |
| Salt (5%) | 6.30 ± 0.48 $^{b}$ | 6.10 ± 0.60 $^{b}$ | 6.20 ± 0.63 $^{b}$ | 6.10 ± 0.40 $^{ab}$ | 6.20 ± 0.55 $^{b}$ |
| Garlic (3%) | 7.40 ± 0.51 $^{a}$ | 7.60 ± 0.52 $^{a}$ | 7.50 ± 0.60 $^{a}$ | 6.90 ± 0.38 $^{a}$ | 7.60 ± 0.49 $^{a}$ |
| Ginger (3%) | 7.10 ± 0.57 $^{a}$ | 7.40 ± 0.43 $^{a}$ | 7.30 ± 0.41 $^{a}$ | 6.80 ± 0.44 $^{a}$ | 7.50 ± 0.50 $^{a}$ |

Values with different superscript letters within a column differ significantly ($p < 0.05$)

**Proximate Composition of Smoked *Heterotis niloticus***
The proximate composition of the differently treated fish samples is shown in Table 2. Significant differences ($p < 0.05$) were observed in moisture, protein, and lipid content.

**Table 2:** Proximate Composition (%) of Smoked *Heterotis niloticus* (Mean ± SD)

| Treatment | Moisture Content | Crude Protein | Crude Lipid | Ash Content | Crude Fiber |
|---|---|---|---|---|---|
| Control | 32.80 ± 0.58 $^{a}$ | 44.90 ± 0.55 $^{c}$ | 18.20 ± 0.46 $^{a}$ | 3.20 ± 0.18 $^{a}$ | 1.10 ± 0.14 $^{a}$ |
| Salt (5%) | 30.40 ± 0.40 $^{b}$ | 48.30 ± 0.48 $^{a}$ | 17.00 ± 0.32 $^{b}$ | 3.30 ± 0.14 $^{a}$ | 1.00 ± 0.11 $^{a}$ |
| Garlic (3%) | 28.90 ± 0.49 $^{c}$ | 46.50 ± 0.62 $^{b}$ | 15.70 ± 0.33 $^{c}$ | 3.10 ± 0.12 $^{a}$ | 1.00 ± 0.13 $^{a}$ |
| Ginger (3%) | 28.60 ± 0.43 $^{c}$ | 46.20 ± 0.50 $^{b}$ | 15.50 ± 0.28 $^{c}$ | 3.20 ± 0.15 $^{a}$ | 1.00 ± 0.10 $^{a}$ |

Values with different superscript letters within a column differ significantly ($p < 0.05$).

## DISCUSSION

The results reveal that garlic- and ginger-treated samples had significantly higher scores in all sensory attributes compared to the control and salt-treated samples. Garlic-treated fish had the highest overall acceptability (7.60 ± 0.49), closely followed by ginger-treated fish (7.50 ± 0.50). This can be attributed to the presence of flavor-enhancing compounds such as allicin in garlic and gingerol in ginger, which enhance taste and aroma (Kumar *et al.*, 2018; Abdullahi *et al.*, 2019). These findings support those of Oladejo and Akinbile (2021), who noted improved sensory profiles in fish treated with natural spices.
Control samples scored the lowest across all parameters, indicating the limitations of smoking without any seasoning. Salt-treated samples performed moderately well, reflecting salt's basic flavor-enhancing role, although lacking the complexity of garlic and ginger flavors.

Moisture content was significantly lower in ginger- (28.60 ± 0.43%) and garlic-treated fish (28.90 ± 0.49%) than in control (32.80 ± 0.58%), supporting the findings of Akinwumi *et al*. (2014), who reported that natural spices reduce water activity and improve shelf life in smoked fish. This reduction may be due to the antimicrobial and hygroscopic nature of ginger and garlic, which limits microbial growth and moisture retention. Ahmed *et al*. (2020) similarly observed that ginger-treated fish retained less moisture due to enhanced dehydration during smoking. However, Eyo (2001) documented higher moisture levels (>35%) in traditionally smoked fish, showing a contrast with this study, likely due to differences in seasoning and smoking duration.

Protein content was highest in salt-treated samples (48.30 ± 0.48%), consistent with the report of Tobor (1990), which highlighted salt's role in protein retention during smoking. Garlic- and ginger-treated fish also retained high protein levels (46.50 ± 0.62% and 46.20 ± 0.50%, respectively), supporting Oladejo and Akinbile (2021), who found comparable protein retention across salt and spice treatments in *Heterotis niloticus*. In contrast, Olusegun and Adepoju (2015) observed lower protein content in ginger-treated fish, suggesting that spice concentration and exposure time may influence nutrient retention.
Lipid content was significantly reduced in garlic- (15.70 ± 0.33%) and ginger-treated fish (15.50 ± 0.28%) compared to control (18.20 ± 0.46%), likely due to oxidative effects of these spices as antioxidants. This aligns with Kumar *et al*. (2018) and Rahman *et al*. (2020), who found that garlic and ginger minimize lipid oxidation in meat and fish products. However, contrary findings were presented by Gokoglu and Yerlikaya (2015), who reported no significant change in fat content with spice application, indicating that the effect might depend on smoking intensity and fish species.

Ash and fiber contents remained relatively unchanged across treatments (3.10–3.30% ash; 1.00–1.10% fiber), which corresponds with the findings of Akande and Tobor (1992) and Adebayo-Tayo *et al*. (2011), who also reported minimal variation in ash and fiber in smoked freshwater fish regardless of treatment type.

## CONCLUSION

This study established that the use of natural seasonings such as garlic and ginger significantly improved both the sensory and nutritional quality of smoked *Heterotis niloticus*. Garlic-treated samples were most preferred in terms of aroma, taste, and overall acceptability. Proximate analysis showed that garlic and ginger treatments reduced moisture and lipid content, thereby potentially extending shelf life and enhancing food safety. Salt-treated fish retained the highest protein levels but scored lower in sensory evaluations than garlic and ginger treatments.

## RECOMMENDATION

Based on the results of this study, it is recommended that fish processors adopt natural seasonings such as garlic and ginger during the smoking of *Heterotis niloticus* to enhance the sensory appeal (taste, aroma,

texture, and color) and improve proximate quality by reducing moisture and lipid content while retaining protein. These treatments not only improve consumer acceptability but also contribute to longer shelf life and safer fish products. Therefore, training programs should be organized for small- and medium-scale fish processors across Northeastern Nigeria to encourage the adoption of spice-enhanced smoking methods. Policymakers and extension agents should also promote the use of indigenous natural preservatives to reduce dependency on chemical additives, enhance value addition in fish processing, and support nutrition-sensitive agriculture for improved public health and food security.

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# REVOLUTIONIZING POST-HARVEST FISHERIES: A REVIEW OF DIGITAL TRACEABILITY AND SMART COLD CHAIN SYSTEMS APPLICABILITY IN NIGERIA

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**ABSTRACT**
*Post-harvest losses in Nigeria's fisheries sector pose major threats to food security, economic returns and export competitiveness. This paper explores the potential of digital traceability and smart cold chain systems in transforming post-harvest fisheries in Nigeria. It reviews the current post-harvest landscape, assesses the inefficiencies and economic losses incurred and examines how digital technologies, already successfully deployed in other countries can be adapted to the Nigerian fishery sector. The synergistic application of digital traceability and Smart Cold Chain System (SCCS) technology could significantly reduce spoilage, ensure compliance with international standards and strengthen food value chains. Barriers to the adoption of this technology such as infrastructure gaps, digital illiteracy and cost, are also discussed with recommendations for policy, cooperative engagement and public-private partnerships. The study concludes that integrating these innovations is critical for Nigeria to build a resilient and sustainable fisheries economy.*

**Keywords:** Fish postharvest, digital traceability, smart cold chain, food security, value chain

## INTRODUCTION

Approximately one-third of the world's fish catch is or wasted annually (FAO, 2020) translating to over 1.3 billion tons of food waste (WWF, 2021). This waste contributes about 8% of greenhouse gas emissions from the global food sector (WWF, 2021). In Nigeria, similar challenges persist with studies showing post-harvest losses ranging from 20-40% annually especially among artisanal fishers (Ajala & Emokara, 2020). These losses are a major driver of the country's resilience on fish imports which cost approximately $625 million annually (Ogundari & Ojo, 2019). The application of digital traceability and Smart Cold Chain Systems (SCCS) has been proven to address these issues. Digital tracing via Radio Frequency Identification (RFID) and Internet of Things (IoT) improves supply chain visibility and helps reduce spoilage, theft and food safety risks (Future of Fish, 2019). Smart cold storage maintains optimal temperatures (0-4°C), preserving quality and reducing post-harvest loss, while also contributing to lower emissions due to reduced waste (FAO, 2020; WWF,2021).

### What is Digital Traceability?

Digital traceability in fisheries is a process of tracking fish from the point of origin or harvest to sale using technology. This involves the use of digital tools such as Quick Response (QR) codes, block-chain, Radio Frequency Identification (RFID) tags and mobile apps to create a transparent and accountable supply chain, ensuring that useful information about the fish history such as its origin, handling and processing is readily available. This allows fish handlers, processors, sellers and buyers have adequate knowledge of the fish, identify potential areas of hazard and promptly avoid fish spoilage and loss (Mohamed *et. al.*, 2023). Digital traceability is typically conducted by tagging fish at harvest with barcodes or RFID chips. Data on temperature, handling, and storage conditions are logged and transmitted in real time to cloud platforms accessible to stakeholders (FAO, 2021).

**What is SCCS in fisheries?**

A smart cold chain system uses technology to monitor and manage the temperature and conditions of fish throughout the supply chain, from harvest to consumer, thus maintaining quality, safety and minimizing waste. It integrates Internet of Things (IoT) sensors and GPS tracking to monitor and regulate the temperature and condition of fish in transit or storage (Chen *et. al.*, 2021). Smart cold chains take basic cold chain systems to the next level by incorporating GPS for location tracking, IoT for temperature and humidity monitoring and AI for predictive maintenance, therefore ensuring minimal fish spoilage and energy optimization (Rahman *et. al.*, 2020). Nigeria currently operates a number of cold chain systems across its states with considerable contributions to reducing postharvest loss in fisheries. However, integrating digital traceability and smart cold chain systems will not only greatly minimize fish post-harvest loss; it will also ensure transparency and accountability of fish handlers in providing consumers with high quality, nutritious fish.

**International case studies of Digital Traceability and Smart Cold Chain Systems**

In Ghana, a piloted blockchain technology to trace the tilapia value chain from pond to consumer approach was embraced which improved transparency, increased trust among buyers and helped fishers secure better prices (Anova Food LLC & USAID Oceans, 2020). Also, a Kenya's "Keep It Cool" (KIC) project introduced solar-powered cold boxes and a digital sales platform, enabling Lake Victoria fishers to double their weekly off-take and connect with urban markets. This significantly boosted incomes while reducing spoilage (Keep It Cool, 2021), Indonesia has also implemented blockchain tagging and e-logbooks in the tuna industry. The pilot improved compliance with export standards and reduced documentation fraud (Anova Food LLC & USAID Oceans, 2020).

India has invested in cold chain infrastructure through the PMMSY program, supporting the installation of cold rooms and ice plants in fisheries hubs like Manipur to reduce post-harvest losses (FAO,2021).Thailand integrated blockchain, AI and IoT into its seafood sector to automate tracking and quality control which improve both regulatory compliance and economic returns (Future of Fish, 2019). Palau and other Pacific nations are also piloting electronic vessel monitoring and camera systems to ensure legal, sustainable catch. This enables export market access even from remote fisheries (FAO, 2020).

**Importance of Digital Traceability**

Digital traceability offers several advantages for Nigeria's post-harvest fisheries system such as:

1. Increases transparency in the supply chain, allowing fish handlers and consumers make informed choices concerning the fish process history.
2. Improved food safety by assisting Nigeria's food control agencies and government to adequately track companies or fish processors violating food safety laws. Suspected fish products can be easily recalled in times of food borne disease out breaks when digital traceability technology is adequately enforced and used by all fish processors in the country. There will be less room for guesswork and health security for all consumers.
3. Reduces Illegal, Unreported, and Unregulated (IUU) fishing therefore protecting endangered fish species and preventing wastage arising from discarding by-catch or unwanted aquatic species.
4. It allows for better management of inventory, logistics, and overall supply chain efficiency. This is most effective for fish farmers and fish processors or mongers. It ensures the farmers record water, weather and feed conditions and effect on the growth outcome of fish in aquaculture systems. It also gives fish breeders record of best stock hence reducing trial and error in aquaculture and ensuring maximum harvest yield. Fish processors using digital traceability can effectively harness suppliers' records on the state of fish before processing and most effective processing and preservation methods to employ in producing high quality products, reducing waste and maximizing economic gain.

5. It also helps businesses comply with traceability regulations ultimately making government tracking and enforcing regulations easier and effective to ensure the forward growth and development of the country's economy (Bai, *et. al.,* 2023).

**Implementation strategies and frameworks for Nigeria's fishery sector**

Implantation of digital traceability and Smart Cold Chain systems into Nigeria's fisheries can follow three main models:

1. National (Government-led): Nigeria can adopt a national traceability and SCCS policy under its existing fisheries reform strategy, modelled after the African Union's continental framework (AU-IBAR, 2018). Harmonizing with the EU's General Food Law (European Commission, 2019) and FAO's catch documentation guidelines (FAO, 2021) would position Nigerian fish products for export readiness.
2. Pilot-scale (NGO/Donor supported): Regional pilots can demonstrate viability. For example, a donor-funded pilot could equip a fishing community with barcoding tools, cold storage and training. This approach allows adaptation to local contexts and scalable expansion.
3. Private-sector Driven: Private investment in traceability apps, solar cold rooms and IoT tracking devices supported by government incentives or concessional financing can accelerate adoption. This mirrors successful models like Kenya's KIC and Indonesia's private-exporter blockchain projects (Keep It Cool, 2021; Anova Food LLC & USAID Oceans, 2020).

**Environmental and climate impacts**

Current post-harvest practices generate substantial environmental costs. Globally, food wastes accounts for about8% of total GHGs emissions of which fisheries is a significant contributor (WWF, 2021). In Nigeria, repeated fishing to compensate for spoiled catch also intensifies pressure on aquatic ecosystems. SCCS helps reduce spoilage, thereby cutting GHG emissions, conserving fuel and reducing the over extraction of fish stocks. Solar-powered cooling systems can replace diesel-powered generators, promoting renewable energy use. Integrating digital monitoring discourages overfishing and supports ecosystem conservation, aligning with SDG 12 (Responsible Consumption), SDG 13 (Climate Action) and SDG 14 (Life Below Water)(FAO, 2020).

**Gender and social dimensions**

Women are central to Nigeria's fisheries value chain, particularly in processing, marketing and retail. Studies show women constitute the majority of post-harvest handlers in artisanal systems (World Fish, 2021). However, they often lack access to finance, training and digital tools. Without inclusive planning, digital transformation may widen this gap. For example, requiring smartphone literacy or ownership of barcoding systems can inadvertently marginalize women. Conversely, involving women's cooperatives in managing cold storage, providing gender-sensitive training and designing mobile apps with voice/audio functions can ensure equitable access (Rao & Rota, 2022). SCCS projects should conduct gender impact assessments and build social safeguards to ensure technologies empower, rather than exclude female stakeholders.

**Economic analysis and Return of Investment (ROI)**

Though implementing traceability and SCCS requires capital (hardware, training, software), the economic return is often significant. According to Future of Fish (2019), many seafood companies report ROI within 2-5 years after adopting electronic traceability.

- Artisanal Fisheries: Solar cold rooms and traceability systems can double sales volumes as seen in Kenya while reducing loss (Keep It Cool, 2021). Even renting cooling equipment at $4-$9/week led to rapid income growth for women fish traders.

- Industrial Fisheries: Investments in traceable systems and industrial cold storage unlocks premium export markets. The African Union recommends through credit and equipment subsidies (AU-IBAR, 2018).
- National Impact: Reducing Nigeria's fish post-harvest loss by even 10% could reclaim over $60 million annually, savings that far exceed infrastructure costs (Ogundari & Ojo, 2019).

## CONCLUSION

Nigeria's fisheries sector stands at crossroads. Without post-harvest modernization, high losses will continue to undercut its economic and food security contributions. The integration of digital traceability and SCCS offers a scalable, sustainable path forward. Policymakers, cooperatives and private sectors must collaborate to create the infrastructure, finance models and capacity-building efforts needed for widespread adoption. Adopting digital traceability and SCCS aligns with Nigeria's food security goals and the African Continental Free Trade Agreement (AfCETA). It will boost compliance with WTO fish export regulations and increase competitiveness.

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# EFFECTS OF GINGER (*Zingiber officinale*) AND BITTER KOLA (*Garcinia kola*) ON THE MICROBIAL LOADS OF SMOKED CATFISH (*Clarias gariepinus*)

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**ABSTRACT**

*The study determined the organoleptic characteristics and microbial load of smoked fish spiced with ginger (Zingiber officinale) and bitter kola (Garcinia kola) on African Catfish (Clarias gariepinus). Freshly harvested fish of 500g was obtained from Lafia Modern Market, the fish was transported to the experimental unit, cut into 50 chunks, gutted, washed and divided into 5 chunks per replicate. Ginger and bitter kola were grounded into fine powder and diluted into 5g and 10g/litre of water each Five treatments was used for the experiment, 5g, 10g of bitter kola, 5g, 10g of ginger and the control without spice respectively. Then 30 panellists were used to evaluate the samples for sensory evaluation based on 5 Likert scale. The results of the study indicated 5 species of microbes which includes: E. coli, Salmonella spp, Pseudomonas spp, staphylococcus spp, and yeast were isolated from the fish samples. Fish smoked with 10g of bitter kola recorded the lowest value of microbes (1.07) while fish smoked without spices recorded the highest value of microbes (5.29). Pseudomonas spp and yeast were not recorded in fish smoked with 5g and 10g bitter kola. In general acceptability of sensory evaluation, all fish samples are good but fish smoked with 10g of bitter kola was rated as the best. Therefore, 5g and 10g of bitter kola should further be utilized in other species of fishes.*

**Keywords:** Bitter kola, Ginger and *Clarias gariepinus*.

## INTRODUCTION

Production of catfish species (*Clarias gariepinus*), is crucial for meeting the growing global demand for protein-rich food. However, the sector faces significant challenges due to pathogenic microbial contamination, which threaten the economic sustainability of fish processing operations (El-Hack *et al.*, 2019). Ginger (*Zingiber officinale*) and bitter kola (*Garcinia kola*) have attracted attention for their potential antimicrobial properties. Both plants are renowned for their roles in traditional medicine and contain various bioactive compounds that exhibit antimicrobial activity. Wide gap exists between the total fish produced in Nigeria and that available to consumers principally due to enormous post-harvest losses as a result of inappropriate fish processing. The issue has stimulated the need for the research to provide information on the processing method which will reduce the rate of fish spoilage by reducing the microbial content in the processed fish, increase its shelf life and add value to the processed product. Furthermore, the study will also help to supply information which will be of immense benefit to the fish farmers, fish consumer, increase quality fish protein supply and GDP of the country at large.

## MATERIALS AND METHODS

### Research Area

The experiment was carried out in the processing unit of Department of Aquaculture and Fisheries Management Experimental Fish Farm, Faculty of Agriculture Shabu-Lafia Campus, Nasarawa State University, Keffi. Ten (10) kg of freshly harvested catfish (*Clarias gariepinus*), was obtained from Lafia Modern Market, Nasarawa State. Ginger and bitter kola were also obtained from Lafia Modern Market, 200g each of *Zingiber officinal*) rhizomes and *Garcinia kola* was washed with clean water, sun dried, and

cleaned of its dirt by hand picking. The rhizomes size was reduced with mortar and pestle first, then sun dried and grounded into fine powder using mortar and pestle then sieved using sieving material (household sieved 0.2mm) and kept. The bitter kola, was cut into pieces with knife and sun dried for 10 days, grounded into fine powder then sieved using sieving material (house hold) sieved 0.2mm and kept.

**Experimental Setup**

The experiment consists of four treatments and a control which were replicated twice. 5g, 10g of ginger, 5g, 10g of bitter kola and control. The fish was cut into 50 Chunks and thoroughly washed free of blood. The spices were diluted with one liter of water, and ten chunks of fish each was distributed into each treatment, immense for thirty minutes, before loading into the preheated smoking kiln. Smoking was done gradually using red hot charcoal, for 48 hours, the smoked fish was allowed to cool and then packaged in carton. Labeled in the order in which they were treated. B1, B 2, G1, G2 and C.

**Sensory (Organoleptic) Test**

Samples from the smoked fish products were subjected to sensory evaluation to obtain data. A 30-members taste panel which consist of staff and students of the University were constituted. The samples were blind coded to reduce bias. Organoleptic parameters assessed, include: appearance, flavor, taste, texture and acceptability in accordance with Poste *et al.* (1991). Five (5) point hedonic scale ranging from of 5-Excellent, 4-Very Good, 3-Good, 2-Poor 1-Very poor was adopted for each quality parameter. Pens, tissue paper and water was provided to the judges.

**Statistical Analysis**

Data obtained were subjected to descriptive statistics (mean, median, mode, frequency and percentage) and one way analysis of variance (ANOVA) using SPSS statistical tool, version 20.0.

**RESULTS**

**Table 1:** Sensory evaluation of fish smoked with different concentration of bitter kola and ginger

| | Excellent | | Very Good | | Good | | Poor | | Very poor | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Freq | % | Freq | % | Freq | % | Freq | % | Freq | % |
| Control | | | | | | | | | | |
| Appearance | 12 | 40.00 | 10 | 33.33 | 8 | 26.67 | 0 | 0 | 0 | 0 |
| Flavor | 10 | 33.33 | 5 | 16.67 | 10 | 33.33 | 0 | 0 | 0 | 0 |
| Taste | 15 | 50.00 | 10 | 33.33 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| Texture | 10 | 33.33 | 10 | 33.33 | 10 | 33.33 | 0 | 0 | 0 | 0 |
| Acceptability | 20 | 66.67 | 5 | 16.67 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| Bitter Kola 5g | | | | | | | | | | |
| Appearance | 15 | 50.00 | 10 | 33.33 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| Flavor | 10 | 33.33 | 5 | 16.67 | 10 | 33.33 | 0 | 0 | 0 | 0 |
| Taste | 15 | 50.00 | 10 | 33.33 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| Texture | 10 | 33.33 | 10 | 33.33 | 10 | 33.33 | 0 | 0 | 0 | 0 |
| Acceptability | 20 | 66.67 | 5 | 16.67 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| Bitter Kola 10g | | | | | | | | | | |
| Appearance | 13 | 43.33 | 10 | 33.33 | 7 | 23.33 | 0 | 0 | 0 | 0 |
| Flavor | 20 | 66.67 | 5 | 16.67 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| Taste | 20 | 66.67 | 5 | 16.67 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| Texture | 15 | 50.00 | 10 | 33.33 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| Acceptability | 25 | 83.33 | 5 | 16.67 | 0 | 0.00 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Ginger 5g** | | | | | | | | | | |
| Appearance | 13 | 43.33 | 12 | 40 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| Flavor | 15 | 50.00 | 10 | 33.33 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| Taste | 14 | 46.67 | 14 | 46.67 | 2 | 6.67 | 0 | 0 | 0 | 0 |
| Texture | 12 | 40.00 | 8 | 26.67 | 10 | 33.33 | 0 | 0 | 0 | 0 |
| Acceptability | 18 | 60.00 | 7 | 0 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| **Ginger 10g** | | | | | | | | | | |
| Appearance | 12 | 40.00 | 10 | 33.33 | 8 | 26.67 | 0 | 0 | 0 | 0 |
| Flavor | 20 | 66.67 | 5 | 16.67 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| Taste | 20 | 66.67 | 5 | 16.67 | 5 | 16.67 | 0 | 0 | 0 | 0 |
| Texture | 11 | 36.67 | 10 | 33.33 | 10 | 33.33 | 0 | 0 | 0 | 0 |
| Acceptability | 20 | 66.67 | 5 | 16.67 | 5 | 16.67 | 0 | 0 | 0 | 0 |



## DISCUSSION

### Sensory evaluation of fish smoked with different concentration of bitter kola and ginger

The study rated fish sample with 5g bitter kola as highest in appearance (50%) than those smoked with ginger and control. In both flavour and taste, 10g bitter kola and 10g ginger spiced fish ranked best (66.66%). The panellists commented that the taste for bitter kola was mild in the smoked fish and was not noticed until after some minutes of eating the sample. Majority of the panellists attributed the fish smoked with bitter kola as the best in general acceptability which could be due to the medicinal value possess in bitter kola. The presence of sharp, bitter flavor and slight sweetness could be a great reason why the panellists rated the fish with 10g of bitter kola as the best. The use of bitter kola in fish smoking has proven to be a good potential for organoleptic assessment and its acceptance in this study has credited the plants for further research.

### Microbial count of *Clarias gariepinus* smoked with bitter kola and ginger

The total count of bacteria was observed highest in fish samples smoked without spice (control). Fish samples smoked with bitter kola had the better results compared to those smoked with ginger. The lowest value for total bacteria count was seen in samples smoked with 10g of bitter Kola. This study shows that bitter Kola is effective against microbes and can inhibit microbial growth in smoked fish. According to Kim *et al.* (2009), the rate of microbial spoilage depends upon the number of microorganisms present on the fish and the temperature at which the fish is kept. The fish used in the study was properly cared for with high level of hygiene during the smoking process. Yeast was not detected completely from the preservatives used in the study and it shows that both bitter kola and ginger are effective against fungal growth. It was also observed that *Pseudomonas spp*s common bacteria found in human skin, and hands was not detected in bitter kola smoked fish, this indicate that bitter kola can inhibits *Pseudomonas spps* in smoked fish. The presence of *Pseudomonas spps* in fish may make its consumption hazardous to health as some of microorganisms have been reported by other authors has been hazardous for human consumption. *E. coli* was seen as the lowest microbes found in fish samples smoked with bitter Kola and ginger. According to Aberoumand (2010), *Escherichia coli* are a classic example of enteric bacteria causing gastroenteritis. *E. coli* including other coliforms and bacteria such as *Staphylococcus spps*. and sometimes enteroccoci are commonly used as indices of hazardous conditions during processing of fish. *E. coli* and *Staphylococcus aureus* were reported as the predominant microorganisms present in smoked fish in Asaba area of Delta state, Nigeria (Okonta and Ekelemu, 2005).

**Table 2:** Mean value of Microbial count CFU/g of *Clarias gariepinus* smoked with natural spices (Bitter Kola and Ginger)

| Microbial population | Bitter Kola | | Ginger | | Control |
|---|---|---|---|---|---|
| | 5g | 10g | 5g | 10g | |
| Total Count ($10^3$) | 2.18 [c] | 1.07 [e] | 3.74 [b] | 1.96 [d] | 5.29[a] |
| *E.coli*($10^3$) | 1.65 [c] | 0.89 [d] | 2.23[ab] | 2.06 [b] | 2.78 [a] |
| *Salmonella spp*($10^3$) | 0.34 [d] | 0.26 [d] | 2.87 [b] | 2.19 [c] | 5.43 [a] |
| *Pseudomonas spp*($10^3$) | ND | ND | 2.05 [b] | 1.58 [c] | 3.15 [a] |
| *Staphylococcus spp*($10^3$) | 2.65 [c] | 1.03[e] | 3.42 [b] | 2.16 [d] | 4.67 [a] |
| Yeast ($10^3$) | ND | ND | ND | ND | 1.47 [a] |

Means with the same superscripts are not significantly different (P>0.05) from each other
ND = Not detected, E. coli = *Escherichia coli*

## CONCLUSION

The results of the study indicated five species of microbes found on the fish samples among which four are bacteria (*E. coli*, *Salmonella spp*, *Pseudomonas spp*, and *Staphylococcus spp*) while one is fungal (yeast). Yeast was not detected in samples smoked with bitter kola and ginger and also *Pseudomonas spp* was not detected in fish smoked with bitter kola. Fish smoked with 10g of bitter kola was found with the lowest count of microbes than other treatments. The highest microbial count was found in the control. The study showed that bitter kola was more effective against microbes than ginger. The sensory evaluation of 10g of bitter kola smoked fish was the best in general acceptability.

## RECOMMENDATIONS

The result in the study suggest the used of bitter kola in smoking of African catfish (*Clarias gariepinus)* at 10g/litre of water. Therefore, 5g and 10g of bitter kola should further be carried out on other species of fish to reaffirm the result of this study.

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# NUTRITIONAL PROFILE OF SMOKED AFRICAN CATFISH (*Clarias gariepinus*) USING MASQUERADE TREE (*Polyalthia longifolia*) LEAF INFUSION

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**ABSTRACT**
*The study examines the effects of a plant-based extract Polyalthia longifolia commonly called Masquerade Tree on the biochemical content of the African catfish Clarias gariepinus. A total of 6Kg Clarias gariepinus were purchased, gutted and then divided into 4 groups (A to D) with each group was assigned to a specific leaf infusion concentration corresponding to sample A (20%), B (40%), C (60%) and D (0%). Traditional smoking was achieved by using Purple Orchid (Piliostigma reticulatum) as the wood source. Results from proximate and mineral content analysis reveals that the different concentration of leaf extract used were significantly different (P<0.05). Moisture and Ash content was lowest in sample c (60%) with a low of 4.921% and 8.288%. Mico elements like Copper and Zinc was significantly high in all samples and sodium were within the threshold for international standards (2350 mg/Day). Findings from the study demonstrated that sample C with 60% infusion concentration, contains the least amount of moisture after smoking and can be encouraged among local fish processors.*

**Keywords**: Biochemical, Infusion, Masquerade Tree, Smoking

## INTRODUCTION

Fish is a very important source of animal protein in the diets of man. In Nigeria, fish is mainly eaten in smoked and forms as a much-cherished delicacy that cuts across socio-economic, age, religions and educational barriers (Asiedu et al., 2018). Smoked or dried fish is a traditional part of the diet of a large section of the world's population. Preservative methods that include the use of smoking and the treatment with plant derived (organic) additives is inevitable so as to preserve the physical and chemical (nutritional) qualities, enhance the economic value and prolong the shelf-life of smoked catfish as a veritable protein source.

*Polyalthia longifolia* family Annonaceae is known locally in Nigeria as the Masquerade Tree. It is mainly used for landscaping purposes because of the exquisite beauty of its leave arrangement and the unique height of the plant itself. Its common names include Green Champa, Nigerian Mast Tree, False Ashoka and Nigerian Fir Tree (Dave et al., 2020). There have been many works on this tree and major uses recorded about *Polyalthia longifolia* has been of medicinal nature and a typical example is of the bark extract which is used in some part of the West Coast of Africa in particular Cote d'ivoire to treat haemorrhoids; decoctions of leaves as febrile and posses antimicrobial properties (Saleem et al., 2005; Ravikumar et al., 2011). In Nigeria the leaves are used traditionally to treat various skin infections, hypertension and diabetes (Tanna et al., 2009). The antimicrobial activity of *Polyalthia longifolia* Nair and Chanda (2007), Tripta et al. (2019); clerodane diterpenoids, alkaloids, trepenoids, flavonoids, phenolic compounds from *Polyalthia longifolia* seeds had been reported (Preethi *et al*., 2025).

Fish is very important to humans due to its very high-quality protein as well as the essential amino acids required by the body for growth and maintenance of muscle tissue. In Nigeria, catfish farming contributes significantly to rural livelihoods and national protein supply (Olaoye et al., 2022). *Clarias gariepinus* an important culturable makes its preservation paramount and it is in pursuance of such a

possibility that this study was conducted with the specific aim of discovering the nutritional implication of *Polyalthia longifolia* leaf infusion on the quality of smoked catfish (*Clarias gariepinus)*.

## MATERIALS AND METHOD

The study was conducted at the Fish Market, Department of Fisheries and Aquaculture, Federal University Dutsin-Ma, Katsina state. Dutsin-Ma LGA lies on longitude 12°27'18"N and latitude 7°29'29"E.

A total of 6kg of live *Clarias gariepinus* was purchased from Sauki Fish Farms in Katsina state. The fish were put on ice and transported to Federal University Dutsin-Ma Fish Market. The masquerade tree leaves were obtained from the ICT Complex Federal University Dutsin-Ma. 20g of fresh masquerade leaves (rinsed in distilled water) was infused in 250ml water for at least 15 minutes, allowed to cool, then filtered. This was made into the required quantity of 2 litres. The infusion was stored in plastic bottles for future use.

The fish were washed, gutted and coiled in preparation for smoking. Fish was divided into 4 groups (1-4) and different concentration of masquerade leave infusion of 0 (control), 20g, 40g and 60g as treatments A to D, respectively was administered. The coiled fish were soaked in the extract for at least 30 minutes according to Latifa et al. (2014) methods as slightly modified, aired for 1 hour before smoking. Purple orchid (*Piliostigma reticulatum*) 'Geza' wood due to its low Polycyclic Aromatic Hydrocarbon (PAHs) deposits (Dasuki et al., 2022) was used for the smoking process in a modified Kainji smoking kiln.
Randomly picked fish samples were milled for each group to the determine its proximate (Moisture, Ash, Lipids, Protein, Carbohydrate and Crude fibre) composition using AOAC 1990 methods while, mineral content (Calcium, Zinc, Coper, potassium, Manganese and Sodium) composition using AOAC 2000 methods.

Data obtained from the proximate analysis were analysed using one-way Analysis of Variance (ANOVA) and the differences among the means were separated using the Tukey HSD test at $P<0.05$. While data from mineral content were determined using means and standard deviation.

## RESULTS AND DISCUSSION

The proximate composition of smoked *Clarias gariepinus* treated with masquerade leaf infusion is presented in Table 1. Results revealed that the moisture content, ash content, fat content, protein content, and nitrogen free extract was significantly different ($P<0.05$). The fish sample treated with 60% leaf extract produced the lowest (4.921%) moisture content which is crucial for storage (shelf life). This result agrees with findings by Adeyemi et al. (2021) that lower moisture content elongates shelf life by reducing microbial activities.

**Table 1:** Proximate Composition of Smoked African Catfish (*Clarias Gariepinus*) Treated with Masquerade Leaf Extract

| Parameter | 20% leaf infusion (sample A) | 40% leaf infusion (Sample B) | 60% leaf infusion (Sample C) | 0% control (sample D) |
|---|---|---|---|---|
| Moisture | 6.334±0.065 [b] | 6.762±0.019 [a] | 4.921±0.006 [d] | 6.038±0.053 [c] |
| Ash content | 13.236±0 .026[a] | 12.319±0.06 [b] | 8.288±0.003 [d] | 9.686±0.028 [c] |
| Fat | 2.600±0.026 [d] | 6.879±0.047 [c] | 11.450±0.091 [b] | 14.422±0.047 [a] |
| Protein | 57.422±0.774 [c] | 49.766±0.774 [d] | 65.078±0.774 [a] | 65.625±0.000 [a] |
| Nitrogen free extract | 20.410±0.839 [b] | 24.275±0.803 [a] | 10.264±0.861 [c] | 4.23±0.129 [d] |

Sample C (60% infusion) was higher for protein content (65.078%) although the control (0%) was significantly higher (65.625%), an indication that higher dosage may enhance protein retention while a lower dose reduces protein retention as evident from this finding which corroborates with Nwosu and Okoye (2022) findings on enhanced nutritional qualities of fish preserved with plant extracts. 60% leaf extract inclusion had the lowest ash content (8.288%) which was lower than the control (9.686) and may be due to leaching as opined by Chukwuma et al. (2020).

The ash content reflects mineral matter and results are presented in Table 2. Analysis reveals that Ca content of all samples in this study was not significantly ($P < 0.05$) different. Samples C (60%) inclusion was lowest (685.5mg/100g) for Ca content. The results obtained in this work are in disagreement with the report of Tenyang et al. (2020) who noted an increase in Ca content in smoked *C. gariepinus*; similarly, it is lower than (976mg/100g) reported by Tenyang et al. (2022) for smoked *Polypterus bichir bichir*and slightly higher than 712.7 reported by Dasuki et al. (2025).

**Table 2:** Mineral composition of smoked C*larias gariepinus* (mg/100g)

| Parameter | 20% leaf infusion (sample A) | 40% leaf infusion (Sample B ) | 60% leaf infusion (Sample C) | 0% control (sample D) |
|---|---|---|---|---|
| Calcium | 725.80±0.375 | 726.30±0.443 | 685.50±0.137 | 698.90±0.499 |
| Copper | 3.32±0.002 | 1.31±0.007 | 2.88±0.003 | 2.13±0.003 |
| Potassium | 8715.00±5.880 | 9181.00±4.380 | 8841.00±4.260 | 4424.00±1.910 |
| Manganese | 6.63±0.0 08 | 8.54±0.003 | 4.31±0.003 | 8.24±0.008 |
| Sodium | 2221.00±0.290 | 2096.00±1.300 | 2107.00±1.010 | 1233.00±0.240 |
| Zinc | 24.54±0.002 | 23.68±0.003 | 22.21±0.001 | 22.80±0.006 |

Values represented as means ± standard deviation

Microelements such as copper (Cu) and zinc (Zn) were significantly different. The results 3.32 and 24.54 mg/100g were higher than 2.13 and 22.8 mg/100g reported by Dasuki et al. (2025) for onion tunic and may be attributed to size and age of fish and lower than 78.6 – 125.9mg/100g for common carp, rainbow trout and Northern pike in studies conducted by Cieślik et al. (2017). Potassium content (8841 - 9181 mg/100g) was higher in samples A, B and C when compared to the control (4424 mg/100g) which is significantly higher than 4300.8 mg/100g recorded by Cieślik et al. (2017). Sodium (Na) a macro-element was within a tolerable threshold (1233 - 2221 mg/100g) of 2350 mg $day^{-1}$.

The nutritional composition of fish is enhanced by the application of the plant-based preservative. It has been proven to be safe for consumption. Treatment of smoked C*larias gariepinus* treated with *Polyalthia longifolia* leaf infusion resulted in bioaccumulation of nutrients and mineral elements in the tissue and may be related to the feed and rearing environment.

## CONCLUSION

This study shows the potentiality of Masquerade tree (*Polyalthia longifolia*) leaf infusion as an additive in food fish preservation and is hereby recommended to Fisher folks in the business of fish processing and preservation. Further research is encouraged to check its keeping quality and other methods of its preparation.

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# EFFECTS OF COFFEE SENNA (*Senna occidentalis*) SEEDS IN THE CONTROL OF *Necrobia rufipes* IN SMOKED DRIED *Clarias gariepinus* (BURCHELL, 1822)

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**ABSTRACT**
*This study examined the proximate composition of fresh and smoked Clarias gariepinus before and after treated with Coffee Senna (Senna occidentalis seed) powder, determine the mortality cause by Coffee Senna seed powder, then assess the mortality caused by Coffee Senna on Necrobia rufipes and the organoleptic of the smoked dried Clarias gariepinus treated with Coffee Senna powder. The experiment was completely randomized into four treatments. Each treatment consists a total of 5 smoked fish with average weight of 200g on each treatment and the Senna occidentalis seed powder was applied in all treatment at different concentration of 5g (T2), 10g (T3), 15g (T4) and 0g (T1) as the control and stored for six (6) weeks. The result revealed, the mean proximate composition of smoked dried Clarias gariepinus with different quantity of concentration, where the Crude protein content is higher in treatment 2 ($34.79\pm0.67^{c}$) Crude fibre which is higher in treatment 4 ($32.50\pm0.58^{e}$), Ash content which is higher in treatment 4 ($2.00\pm0.66^{a}$), the Fat was recorded high in treatment 4 ($9.00\pm0.47^{ab}$), Moisture content were recorded, the highest was in treatment 1 ($4.84\pm0.57^{a}$), The dry matter highest value was obtained in treatment 2 ($98.79\pm0.56^{a}$), highest carbohydrates (energy) was recorded in treatment T3 ($41.21\pm0.37^{a}$) respectively. The results showed that all the Coffee Senna powder quantity ranges tested (5g-15g) repelled Necrobia rufipes though at different degrees 15g has shown high degree of repelling Necrobia rufipes with high rate of mortality. Organoleptic of the treated clarias gariepinus showed that it was acceptable. These results are important because the repellency effect of Coffee Senna seed powder on Necrobia rufipes. The proximate composition shows highest in crude protein, dry matter, crude fibre and ash content. It is recommended that Coffee Senna seed can be used as a repellent toward Necrobia rufipes at 15g concentration for better result. Further studies should be conducted on the effect of Coffee Senna (Senna Occidentalist) Seeds in the Control of Necrobia rufipes Infestation in Smoked Dried Clarias gariepinus*

**Keywords:** *Necrobia rufipes*, Coffee Senna, *Clarias gariepinus*, Smoked Dried

## INTRODUCTION

Fish and fish products play a great role in the nutritional value because they are rich source of nutrients and provide a good balance of protein, vitamins and minerals, and a relatively low caloric content. Fish also had higher levels of essential amino acids, with oleic, linoleic, palmitic, and stearic acids dominating the fatty acid. The oleic acid accounted for more than a third of the lipid content in fish (Abdel-Mobdy *et al.*, 2021). Fish is a highly consumed animal source food in Nigeria, it accounts for 10% of the total food budget and 35% of the budget allocated to animal source foods of the average Nigerian, rising to 45%. Also, fish is the cheapest animal protein consumed, with a price significantly lower than that of poultry and eggs as well as other meats, and less than half that of dairy products. This status underlines the importance of fish in Nigeria for food and nutrition security.

Stored smoked-dried fish products are susceptible to insect pest infestation by several stored product

insect pests among them are red-legged beetles (*Necrobia rufipes*) and hide beetle (*Dermestes maculatus*). Insect infestation is one of the main problems faced by fishmongers as it leads to qualitative and quantitative loss of fish during processing, transportation, marketing and storage which affect the economic value of smoked-dried fish products due to damage by the feeding of the larvae is a serious problem during storage of dried fish products for off-season consumption and export purpose. Their presence on other high value commodities such as smoked-dried fish or processed meat, etc. can lead to serious losses.

The red-legged ham beetle (*Necrobia rufipes*) is commonly known as the copra beetle in tropical countries and red-legged ham beetle in the United States. It is a cosmopolitan pest, generally found in stored commodities such as copra (dried coconut), cheese, dried fish, ham, and other products rich in protein content which causing considerable damage to stored commodities, in recent years has caused increasing damage to pet food products, with growing concerns from producers (Ayeloja *et al.*, 2020).

The use of chemical insecticides in control insect pest infestation of stored smoked-fish it causes toxicity to non-target animals and humans disrupt its continuous use (Koomson *et al.*, 2022). In Nigeria some part of various plant species has been tested against *Necrobia rufipes* infestation on smoked fish which showed that the varying concentrations of the plant materials possessed both ovicidal and larvicidal effects on *Necrobia rufipes*. They also reduced emergence of adults and increased adult mortality. Some of these plant materials also have higher and moderate repellency potentials. It showed the effectiveness of the plant materials to the insect probably due to the presence of active compounds which might impair respiration of the insect pest by blocking the spiracles thereby leading to suffocation and eventually death of the insects. This clearly revealed the potentials of plant materials as protectants against *Necrobia rufipes* and could serve as an alternative to conventional insecticides for the protection of dried fish against the *Necrobia rufipes* beetles (Shuaibu and Yahaya, 2018).

This research is focusing on the use of organic insecticides that is readily available in the immediate environment and also less hazardous to human health. The natural plant products with bioactivity toward insects include several classes of molecules such as terpenes, flavonoids, alkaloids, polyphenols, cyanogenic glucosides, quinones, amides, aldehydes, thiophenes, saccharides and polyketides. These compounds' extracts from the leaf, stem bark, flower, seed and root of many plants to suppress oviposition, prevent adult emergence and also have important ecological activities in nature, such as repellent, fungicide and insecticide (Augusto *et al.*, 2021).

Coffee senna (*Senna occidentalis*) seed contains numerous chemical constituents concentrated in different parts of the plant. Proximate analysis of seeds yielded high dry matter (92.50%), crude protein (29.54%) and crude fibre (10.18%), but with low ether extract, nitrogen free extract, ash, and calorific values. Vitamin analysis showed the seeds to be rich in vitamin B3 (1.85mg/100g), but low in vitamins B2, B1, C, and A. Mineral analysis showed (per 100g) calcium 960mg, potassium 1,200mg, phosphorus 810mg, sodium 600mg, magnesium 640mg, iron 234.60mg, zinc 53.12mg, and copper 10.48mg. Amino acid profile (per 100g protein) showed a high concentration of leucine 7.60g, histidine 2.11g, proline 2.33g, and glycine 4.11g (Manikandaselvi *et al.*, 2016). seeds also contain campesterol; 8 carbomethoxy-1, 7-dihydroxy-3-methylxanthone (cassiollin/pinselin), helminthosporin, islandicin, xanthorin and Nmethylmorpholine (Manikandaselvi *et al.*, 2016).

## MATERIALS AND METHODS

### Study Area

The study was conducted at Fish processing and Post-harvest unit Department of Fisheries, University of Maiduguri, Borno state, Nigeria. It lies between 10° 43° N and 10° 14° N, longitude 10° 15° E and 13° 17° E, occupies a total landmass of 50,778q km (Ministry of land and survey Maiduguri, 2008). The climate of the study area is characterized by wet and dry season, with mean annual temperature range of 25°C. The hottest month are March and April with maximum temperature of 35° - 45°C, while the coldest

months are December and January (Nigeria Metrological Agency, 2008). The vegetation is tropical Sahel savannah consisting of mainly grasses with few drought resistances trees (BSBLS, 2002).

**Collection and Preparation of Plant Products**

The coffee Senna (*Senna occidentalis*) seed was obtained from Ngajiram area, Nganzai Local Government, Maiduguri, Borno State. The seeds were ground into a powder using mortar and pestle. The powder seed was weighed at concentration in grams of 5g, 10g, 15g and 0g was kept in a clean plastic container and placed in a cool dry place until required.

**Fish Preparation for Smoking**

A total of 20 pieces fresh C*larias gariepinus*, with total weight of (4kg) were obtained from the Gomboru Market of Maiduguri Metropolis, and firewood were obtained from Bama Road of Maiduguri Metropolis, Borno State. The fresh fish were transported in flask with ice to retain freshness to the Fish Processing and Postharvest Unit, of the Department of Fisheries, University of Maiduguri. The fish were degutted and then appropriately wash in clean water, especially around the gill region of the fish, then was allowed to drip for 20 minutes. The average length of the fish was measure along with their average weight (fresh weight). The fish samples were smoke using an oil drum smoking kiln. The smoking kiln was prepared and firewood were loaded to heat chamber, ignited and preheated for some minutes. The fish samples waere weighed and place on smoking tray of improved drum smoking kiln. The smoking was take two to three days at an interval of four hours per day. During the smoking process, the temperature of the fire wood was monitored and controlled to prevent the burning of the fish. After smoking, the fish were carefully packed from the smoking kiln then allowed to cool in carton before subjected to further research.

**Collection and Insect Culture (*Necrobia rufipes*)**

The *Necrobia rufipes* was obtained from the infested smoked dried fish at Baga Road fish market Maiduguri, Borno State, Nigeria. The insect obtained were selected based on their physical characteristics; Adult insect length 4.5 mm. 1 litre capacity transparent bucket was use for keeping the insects and the bucket was covered to prevent the insect from escaping. The cover of the bucket was perforated in order to have good ventilation. The insects were transported to the Department of fisheries, University of Maiduguri, and kept in fish processing laboratory until needed for the experiment. Rearing the redlegged ham beetle, *Necrobia rufipes*, involves creating a controlled environment with suitable temperature range between 25-30°C to support optimal development. Provide a diet of dried meat or protein sources for the larvae, or provide a substrate of decaying animal matter, such as carrion or dried animal products. Monitor their life stages, maintain proper ventilation and cleanliness to create a healthy rearing environment. Seven (7) adult of *Necrobia rufipes* was selected and place into a cylindrical bottle, and the bottle were covered with perforated lid cover to allow air into the bottle for continue production of newly emerged larvae and adult.

**Experimental Design**

The different concentration of coffee senna (*Senna occidentalis*) seed powder of 5g for $T_2$, 10g for $T_3$, and 15g for $T_4$ while 0g for $T_1$ serves as control respectively. Each treatment was in triplicate. The seed powders were directly mixed thoroughly with smoked-dried fish (C*larias gariepinus*) for each replicated in separate transparent container. Seven (7) each of newly emerged and larvae of *Necrobia rufipes* were introduce into each container with smoked-dried fish containing powder of coffee senna (*Senna occidentalis*) seed and covered with muslin cloth in other to allow aeration and prevent insect escape and entry of other insects and each treatment replicated thrice. The mortality of the red-legged beetle (*Necrobia rufipes*) in each treatment was being observe daily.

**Data Analysis**
The data obtain from the experiment was subjected to the one-way analysis of variance (ANOVA) and the differences in mean was separated using LSD at (P> 0.05) level of significant different.

## RESULTS

**Table 1:** Proximate Composition of Smoked dried C*larias gariepinus*

| | Treatment concentration (%) | | | |
|---|---|---|---|---|
| **Nutrients ( %)** | **0g** | **5g** | **10g** | **15g** |
| Crude Protein | 39.17±0.47 [b] | 34.79±0.67 [c] | 33.13±0.67 [a] | 32.34±0.67 [d] |
| Crude Fibre | 20.00 ±0.52[b] | 29.50 ±0.54[b] | 19.50 ±0.38[a] | 32.50 ±0.58[c] |
| Ash | 1.50± 0.66[b] | 2.00±0.66 [b] | 1.50±0.66 [c] | 2.00±0.66 [a] |
| Fat | 4.50±0.47 [b] | 7.50±0.47 [a] | 4.50±0.47 [ab] | 9.00±0.47 [ab] |
| Moisture | 4.8 4±0.57 [a] | 1.21±0.67 [b] | 4.66±0.57 [a] | 4.74±0.57 [a] |
| Dry Matter | 95.16 ±0.35[a] | 98.79 ±0.56[a] | 95.34 ±0.56[a] | 95.26 ±0.56[a] |
| Energy (k/cal) | 34.49 ±0.34[a] | 32.50 ±0.34[a] | 41.21 ±0.37[a] | 28.42 ±0.31[a b] |

Means value with the same letter in a row are not significantly different (P<0.05)

**Table 2:** Effect of Coffee senna (*Senna occidentalis*) seed powder on mortality of *Necrobia rufipes on Clarias gariepinus*

| Coffee Senna (Quantity) | Insect mortality |
|---|---|
| (0g) Control | 2.00±0.40 [a] |
| 5g | 4.00±0.40 [b] |
| (10g) | 5.00±0.40 [c] |
| (15g) | 7.00±0.40 [c] |

Means value with the same letter in a row are not significantly different (P<0.05)

The number of insect observed in 6 weeks on smoked dried C*larias gariepinus* with different quantity of Coffee Senna seed powder showed in table 4.3 that the highest number of insect mortality was recorded in (15g) which means that only all the *Necrobia spp*, that were introduced on fish treated with 15g of Coffee Senna powder are all dead while lowest number of insect mortality was found in 0g (control) with significant different (p<0.05).

**Table 3:** Mortality of *Necrobia rufipes* at one week to 6 week

| Conc. (g) | 1week | 2 week | 3 week | 4week | 5week | 6week | |
|---|---|---|---|---|---|---|---|
| (0g) Corel | 0.0 ±0.00 [b] | 0.44 ±0.34 [a] | 0.34 ±0.3 [d] | 0.34 ±0.34 [a] | 0.54 ±0.0 [b] | 0.31 ±0.34 [a] |
| (5g) | 1.0 ±0.0 [ab] | 1.0 ±0.34 [a] | 2.0 ±0.6 [b] | 1.34 ±0.34 [a] | 1.0 ±0.6 [ab] | 0.7 ±0.34 [a] |
| (10g) | 1.7 ±1.21 [ab] | 1.34 ±0.7 [a] | 1.7 ±0.34 [c] | 1.34 ±0.7 [a] | 1.4 ±0.34 [a] | 0.9 ±0.34 [a] |
| (15g) | 3.84 ±0.34 [a] | 1.1 ±0.34 [a] | 2.7 ±0.6 [a] | 1.7 ±0.34 [a] | 1.2 ±0.34 [ab] | 0.8 ±0.34 [a] |

Mean values with the same superscript in a column are not significantly difference (P<0.05)

## DISCUSSION

Result shown that all the coffee senna seed powder concentrations ranges (5g-15g%) repelled flies though at different degrees as shown by percentage repellence. Anecdotal observations and reports by traditional fish processors and published literature (Davies *et al.*, 2009) had also indicated that applying repellents agents on fish while processing or drying can help repel house flies (*Musca domestica*). Results showed that the seven introduced adults of *Necrobia spp* in 0g (control) fish tissues in the containers, and

all were actively infesting the fish tissues with only two mortalities as is usually expected. However, there was only 3 live adults for Necrobia spp and the rest were dead for 5g coffee senna concentration. These results show that the Necrobia spp beetles were more susceptible to coffee senna powder. These results confirm those of Osuji (2018) who also reported that larval development in both beetles was prolonged in fish and larval mortality. According to Smith *et al.* (1995), insect activity increases moisture content through condensation of moisture resulting from respiration and this enhance the fungi growth on fish thus leading to more fish degradation and post-harvest losses which make it more important to control insect's infestation of fish. These results clearly show that use of coffee senna powder on C*larias ariepinus* can lead to tremendous reduction in post-harvest losses in smoke dried C*larias gariepinus* from *Necrobia* spp infestation.

## CONCLUSIONS

Therefore, this study concludes that Coffee senna seed powder is significant in controlling insect infestation. Fish that coffee senna powder was not use on (control) was heavily infested with the beetles as compared to fish was treated with coffee senna powder. Larval development of the *Necrobia rufipes* is severely retarded. Post-harvest losses can highly be reduced by coffee senna seed powder on C*larias gariepinus* at 15g concentration thereby enhancing and improved food security. The proximate composition shows highest in crude protein, dry matter, crude fibre and ash content, while organoleptic quality shows that the majority of panelists were neither like nor dislike of smoked-dried fish applied high concentration of *Senna occidentalis* seed powder due to the appearance of fish was affected by the plant seed powder.

## RECOMMENDATION

It is recommended that coffee senna powder can be used as a repellent toward *Necrobia rufipes* at 15g concentration for better result and less weight loss. Further studies should be conducted on the effect of Coffee Senna (*Senna Occidentalis*) Seeds in the Control of *Necrobia rufipes* Infestation in Smoked Dried C*larias gariepinus*.

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# EFFECTS OF CLOVE (*Syzygium aromaticum*) ON SENSORY EVALUATION AND MICROBIAL ACTIVITIES OF SMOKED *Oreochromis niloticus*

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**ABSTRACT**
*This study was conducted to assess the effects of clove (Syzygium aromaticum) on the sensory evaluation and microbial activities of smoked Oreochromis niloticus. The study was conducted for three months. Fish samples were treated with 0g/l, 5g/l and 10g/l of clove powder representing T1, T2 and T3 respectively. Data were analyzed and presented in percentages, mean and charts. Results showed 5g/l of clove powder was rated highest in appearance (4.60), texture (4.23), taste (4.53) and flavor (4.33) which are significantly different (P<0.05) from values obtained in 0g/l and 10g/l respectively. Ten bacteria organism (Salmonella spp, Enterococcus spp, Staphylococcus spp, E. coli, Shigella spp, Pennicillium spp, Bacillus spp, Klebsiella spp, Proteus spp, and Micrococcus) were identified from the study. Staphylococcus spp (17.50%) was having the highest percentage of occurrence while Enterococcus spp (2.50%), Klebsiella spp (2.50%), and Proteus spp(2.50%) were the least. Four fungi organisms (Yeast, Aspergillus spp, Rhizopus spp and Mucor) were identified and Aspergillus spp (20%) had the highest occurrence. Bacteria (62.50%) was the most occurred microbes compared to fungi (37.50 respectively. The control (0g/l) was recorded with the highest number of microorganisms which were 3.80 x10E$^3$, 5.08 x10E$^3$, and 8.98 x10E$^6$ compared to fish treated 5g/l of clove powder. This recommends 5g/l of clove as an alternative to synthetic preservatives to smoked Oreochromis niloticus.*

**Keywords**:
Microorganisms, antioxidant, *Oreochromis niloticus*, Clove

## INTRODUCTION

The preservation of fish products presents a significant challenge in the food industry due to their high perishability attributed to microbial spoilage, lipid oxidation, and enzymatic degradation (Ozogul *et al.*, 2018). Consequently, there is a growing demand for natural alternatives capable of effectively inhibiting microbial growth and delaying oxidative processes without introducing harmful residues (Morsy *et al.*, 2020). Clove, a staple in African traditional medicine and cuisine, has garnered scientific interest owing to its rich phytochemical composition, which includes sesquiterpenes, flavonoids, alkaloids, and phenolic compounds (Oboh *et al.*, 2020). These bioactive constituents exhibit potent antimicrobial properties against a broad spectrum of pathogenic microorganisms, including bacteria, fungi, and some parasites. Additionally, bitter leaf extracts possess remarkable antioxidant activity, scavenging free radicals and inhibiting lipid oxidation, thereby preserving the sensory attributes and nutritional value of food products (Erukainure *et al.*, 2020). The application of clove in fish preservation represents a novel approach with the potential to address the challenges associated with conventional methods while meeting consumer demands for natural and safe food additives. However, the efficacy of clove in extending the shelf life of Nile tilapia remains relatively unexplored. The preservation of fish products poses a significant challenge due to their high perishability, which is primarily attributed to microbial spoilage, lipid oxidation, and enzymatic degradation. Conventional preservation methods offer limited extension of shelf life and may compromise the sensory attributes and nutritional quality of the product. As consumer preferences shift towards natural and safer alternatives to synthetic additives, there arises a need to explore novel

approaches for enhancing the shelf life of fish products. However, the potential benefits, and efficacy of cloves in preserving fish, particularly O*reochromis niloticus* remains relatively unexplored. The findings of this study hold the potential to not only enhance the shelf life and safety of smoked O*reochromis niloticus* but also contribute to the development of sustainable and eco-friendly strategies for food preservation in alignment with consumer preferences for fish products.

## MATERIALS AND METHODS

### Study Area

The study was carried out in the Department of Fisheries Technology, College of Agriculture Science and Technology Lafia, Nasarawa State Nigeria.

### Collection of Plant Materials

The cloves were purchased from Shabu Market in Lafia, Nasarawa State. The cloves were purchased dried and was allowed to shed-dried then milled into powder and stored for use.

### Preparation of Fish Sample

Twelve kilogram (12kg) of fish (O*reochromis niloticus*) were purchased from Doma Market, Nasarawa State. The fish were transported in Jerrican to the fish process Unit, Department of Fisheries Technology. The fish used for the experiment were descaled, degutted and rinsed thoroughly in clean water before immersing in the stock solution for 15 mins.

### Experimental Design and Smoking Processing

The fish were weighed after the removal of scales, spines, and visceral organs and then distributed into three (3) treatments as T1 (control), T2 (5g) and T3(10g) of cloves respectively. Four (4) of the fish was allotted into each treatment respectively. The fish were left in the stock solution for 15 minutes to allow the content of clove dissolve into the fish tissues. Then, the fish were removed, left to drain before placing them on the racks in the modified smoking kiln and was allowed to heat until it was dried using charcoal as source of heat.

### Bacteriological Test

The bacteriological test was carried out in duplicate using standard plate count. 1g of the fish products for each of the three samples were diluted into (nine) 9mls of distilled water in sterilized universal tube (A.O.A.C., 2000).

### Statistical Analysis

The data obtained from the parameters evaluated were subjected descriptive statistics. Results are presented in charts, percentages and tables.

## RESULTS

### Sensory attributes of Smoked O*reochromis niloticus* treated with Clove

The result of the sensory evaluation of smoked O*reochromis niloticus* treated with clove is presented in figure 1 below. The panellist's evaluation showed significant variation in all the sensory parameters. There was an expression of likeness attributed to fish smoked using 5g/l of clove powder in appearance (4.60), texture (4.23), taste (4.53) and flavor (4.33) respectively. This result recorded in fish treated with 5g/l of clove is significantly different ($P<0.05$) from values obtained in 0g/l and 10g/l of clove respectively.

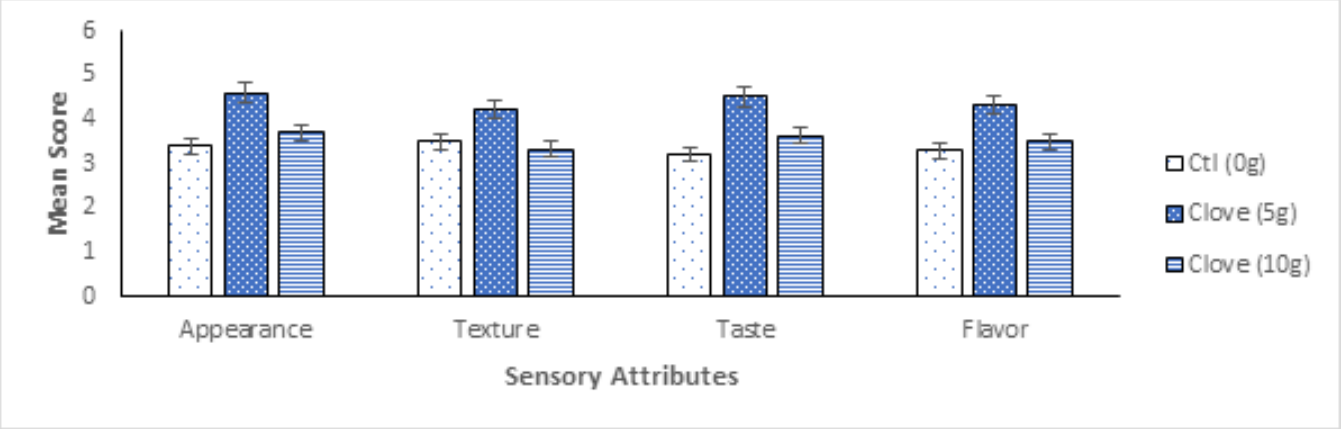



**Figure 1:** Sensory Evaluation of smoked *Oreochromis niloticus* treated Clove

**Microbial Organism identified from smoked Oreochromis niloticus at varying clove concentration**
The result in Table 1 showed the microbial organism identified from the fish smoked in the study. Ten bacteria organism (*Salmonella spp*, *Enterococcus spp*, *Staphylococcus spp*, *E. coli*, *Shigella spp*, *Pennicillium spp*, *Bacillus spp*, *Klebsiella spp*, *Proteus spp*, and *Micrococcus*) were identified from the study. *Staphylococcus spp* (17.50%) was having the highest percentage of occurrence while *Enterococcus spp* (2.50%), *Klebsiella spp* (2.50%), and *Proteus spp*(2.50%) were the least as shown in Figure 1 below. Four fungus (*Yeast*, *Aspergillus spp*, *Rhizopus spp* and *Mucor*) were identified from the study with *Aspergillus spp* (20%) having the highest fungi occurrence. Bacteria (62.50%) was the most occurred microbes while fungi (37.50%) was the lowest as shown in Figure 2 below.

**Table 1:** Microbial Organism found from Smoked Fish

| Organism Isolates | Frequency Occurrence | Percentage (%) |
|---|---|---|
| **Bacterial** | | |
| *Pennicillium spp* | 2 | 5.00 |
| *Enterococcus spp* | 1 | 2.50 |
| *Staphylococcus spp* | 7 | 17.50 |
| *E.coli* | 3 | 7.50 |
| *Shigella spp* | 2 | 5.00 |
| *Salmonella spp* | 3 | 7.50 |
| *Pennicillium spp* | 2 | 5.00 |
| *Bacillus spp* | 3 | 7.50 |
| *Klebsiella spp* | 1 | 2.50 |
| *Proteus spp* | 1 | 2.50 |
| *Salmonella spp* | 2 | 5.00 |
| Sub total | 33 | 62.50 |
| **Fungus** | | |
| *Yeast* | 2 | 5.00 |
| *Aspergillus spp* | 8 | 20.00 |
| *Rhizopus spp* | 2 | 5.00 |
| *Mucor* | 3 | 7.50 |
| Sub total | 7 | 37.50 |
| Sum total | 40 | 100 |

**Microbial Counts Recorded**

The result in Figure 2 showed microbial count of microorganism analyzed in the study. There were significant differences ($P<0.05$) in the number of total heterotrophic fungal count, total coliform count and total heterotrophic bacterial counts among the concentration of clove used in the study. The control (0g/l) was recorded with the highest number of microorganisms which were 3.80 x10E$^3$, 5.08 x10E$^3$, and 8.98 x10E$^6$ followed by 10g/l concentration and then the lowest microbial load was recorded in fish smoked using 5g/l of clove powder.

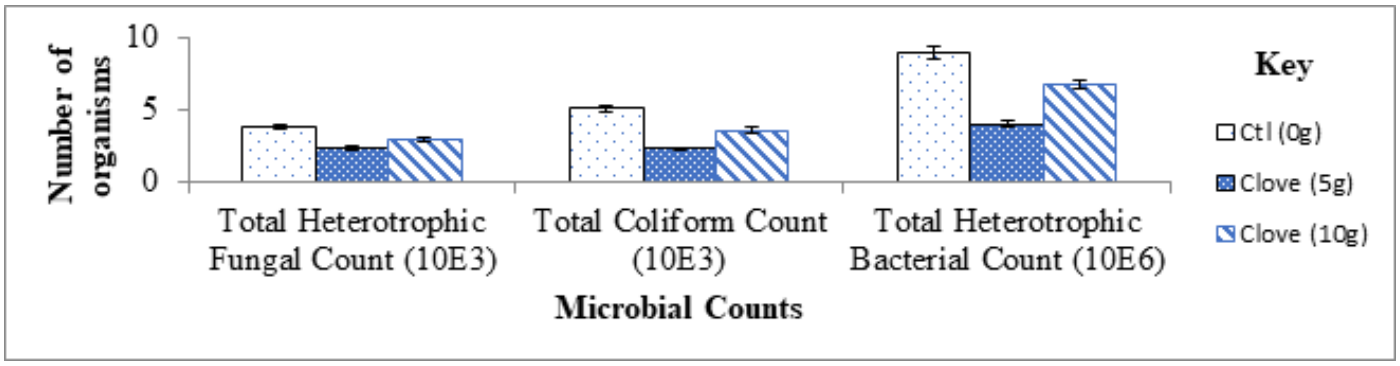



**Figure 2:** Microbial Counts from Fish (*Clarias gariepinus*) Samples

## DISCUSSION

**Sensory Evaluation of *Oreochromis niloticus* smoked using different concentration of Clove powder**

Sensory evaluation is a crucial part in food development because it determines how consumers will react towards a product (Chinma *et al.*, 2016). It is generally assumed that consumers' primary consideration when selecting and consuming the food commodity is the product's palatability and quality, with nutritional attributes taking a secondary role (Silva *et al.*, 2017). The result of the study showed that fish smoked with 5g/l of clove was rated as the highest preferred product in appearance, taste, texture and flavor. The study also showed that clove have the tendency to improve sensory attributes improve in their properties. The final record of the sensory attributes showed that, fish products had higher mean values than their initial mean values. This indicates that there were no deficiencies in the sensory attributes of the experimental samples. Even though the fish smoked in firewood showed a significant variation ($P<0.05$) in appearance, taste, texture and flavor, other heat sources also showed that smoked fish products also maintain good quality. Adeyemi *et al.* (2021) reported a similar result as observed in the current study in sensory evaluation of Nile tilapia smoked with different materials.

**Bacteria Isolated from Smoked *Oreochromis niloticus* treated with clove powder**

Fourteen microbial organisms were isolated from the fish product in the study. Ten of the organisms are bacteria isolate and four are fungus isolate. The highest occurrence and percentage were shown in *Staphylococcus spp.* High bacterial contamination recorded in the study could be due to delay smoking after dressing the fish and nature of smoking kiln. This conformed with the report of Abolagba and Uwagbai (2011) who stated that bacterial growth and invasion take place after death when the defense system of the fish breaks down and the bacteria multiply and invade the flesh. Bacterial spoilage is characterized by softening of the muscle tissue and the production of slime and offensive odors (Geoff *et al.*, 1991). This also confirm the assertion of Olayemi *et al.* (2012) who stated that lack of proper smoking and proper hygienic handling of smoked fish products would result in a very high microbial load. The total mean bacteria count in the fish smoked with natural preservation was the highest and this observation could be due to the present of microbial carriage in the fish during caught and possibly the natural environment of the fish could have accumulated unbearable number of microbial loads. Fish smoked with 10g/l of clove had the least number of bacterial and this could be due to the effectiveness of the clove plants especially the phytochemicals present. The least value of Total Heterotrophic Bacterial

Count was lower than the value of 2.0 x $10^3$ recorded by Olayemi *et al.* (2012) colony forming unit per gramme of the fish sample, though the value falls within the maximum recommended value of bacteria count for good quality fish products which is 5 x $10^5$ colony forming unit per gramme according to (ICMSF, 1986) and the Microbiological Guideline for Ready to –eat – Food which is < 10 6 (Microbiological Guideline for Ready to –eat – Food, 2007). It is certain that clove is effective in controlling microbial activities of organism in food products.

**Fungal Isolated from Smoked O*reochromis niloticus* treated with clove powder**

The fungi found in the fish samples were *Yeast*, *Aspergillus spp*, *Rhizopus spp* and *Mucor*. The most frequently occurred fungi was *Aspergillus spp*. All the fungi identified in the study are mycortoxin producing fungi. These fungus produces toxin such as aflatoxins, ochratoxins and sterigmato-cystine and are responsible of causing vomiting, abdominal pain, pulmonary oedema, convulsions, coma, and death with cerebral oedema and fatty involvement of the liver, kidney, and heart (Bolton, 2019). Aflatoxin contaminates not just smoked fish but also plants such as cereal grains and legumes such as peanuts, corn, and rice. Aflatoxin in food affects its nutritional quality (Hashem, 2011). This conforms to the findings of Oladele *et al.* (2019) who stated that aflatoxins in food materials affects the nutritional quality as well as its safety.

## CONCLUSION

The panellist's evaluation of the smoked O*reochromis nilotticus* showed that samples smoked using 5g/l of clove had the highest rating in appearance, texture, taste and flavour compared to fish smoked without clove and also 10g/l of clove concentration. The study prove clove to possess the ability of enhancing palatability of smoked fish product. Fourteen microbial organisms including ten (10) bacterial and four (4) fungal were isolated from the smoked O*reochromis niloticus* in the study. Fish smoked without cloves was recorded with the highest Total Heterotrophic Fungal Count (3.80x10E$^3$), Total Heterotrophic Fungal Count (5.08x10E$^3$) and Total Heterotrophic Bacterial Count (8.98x10E$^6$) respectively. Fish subjected to processed methods like smoking without antioxidating plants like cloves are venerable to microbial attack. Cloves concentration at 5g/l of water was effective against microorganisms due to the reduction in the number of Total Heterotrophic Fungal Count (2.31x10E$^3$), Total Heterotrophic Fungal Count (2.27x10E$^3$) and Total Heterotrophic Bacterial Count (3.98x10E$^6$) respectively.

## RECOMMENDATION

Clove should be used Microbial analysis should be carried out to ascertain the best storage condition and material for the smoked fish.

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# ANTIMICROBIAL EFFECTS OF ALOE VERA (*Aloe barbadensis miller*) EXTRACT ON SMOKED-DRIED AFRICAN CATFISH *Clarias gariepinus* (BURCHELL, 1822)

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**ABSTRACT**
*This study evaluated the antimicrobial effects of Aloe vera extract on smoked-dried African catfish (Clarias gariepinus) stored at ambient temperature (32 ± 2 °C) for 21 days. Twenty-four fish (mean weight 30.98 ± 1.32 g) were soaked in different extract concentrations (0.0, 0.5, 1.0, and 1.5%) for 30 minutes before smoking at 45–85 °C for 12 hours. Proximate composition, microbial load, weight loss, and sensory attributes were determined. Results revealed that fish treated with 1.0% extract retained the lowest moisture (6.10%), highest lipid (17.60%), and least microbial load (1 × $10^3$ CFU/g). Weight loss was lowest in 1.0% (64%) compared to the control (78%). Sensory evaluation showed improved appearance and acceptability in 0.5% treated samples. The study demonstrates that Aloe vera, particularly at 1.0%, is an effective natural preservative for smoked-dried Clarias gariepinus, enhancing economic benefit and shelf life, nutritional quality, and consumer acceptability.*

**Keywords**: Aloe vera, *Clarias gariepinus*, antimicrobial effect, proximate composition, preservation

## INTRODUCTION

Fish provides high-quality protein, essential fatty acids, and micronutrients, but its high moisture content makes it highly perishable. In tropical regions, up to 40% of harvested fish is lost due to microbial spoilage and poor preservation (Abdullahi *et al.*, 2024). Smoking is a widely used traditional method to extend shelf life; however, smoked fish remains vulnerable to bacterial contamination during storage. Chemical preservatives are commonly applied but raise health and consumer safety concerns (Adeyeye *et al.*, 2021).

Aloe vera is a medicinal plant rich in bioactive compounds such as anthraquinones, flavonoids, and saponins, which possess antimicrobial and antioxidant properties (Akinyele and Odiyi, 2019). Its application in aquaculture as a natural preservative offers a sustainable alternative to synthetic chemicals. This study investigated the antimicrobial effects of Aloe vera extract on smoked-dried *Clarias gariepinus*, focusing on proximate composition, microbial stability, and sensory quality.

## MATERIALS AND METHODS

The study was conducted at the Fish Processing Unit, University of Maiduguri. Fresh *Clarias gariepinus* (300–500 g) were purchased, gutted, and washed. Aloe vera leaves were collected, macerated, and aqueous extracts prepared at 0.5, 1.0, and 1.5% concentrations. Fish samples were soaked in the extract solutions for 30 minutes, smoke-dried in a kiln for 12 hours (45–85 °C), and stored at ambient temperature for 21 days.

Proximate composition (moisture, protein, ether extract, ash, nitrogen-free extract) was determined following AOAC (2019). Microbial load was assessed via total bacterial count (CFU/g). Sensory attributes (appearance, texture, flavour, colour, taste, overall acceptability) were evaluated by a 10-member panel using a 7-point hedonic scale. Data were analysed using one-way ANOVA at $P<0.05$.

## RESULTS

The 1.0% Aloe vera treatment had the lowest moisture (6.10%), highest ether extract (17.60%), and highest ash (1.00%), while the control recorded the highest protein (56.64%). Significant differences (P

≤ 0.05) were observed across all proximate parameters among treatments.

**Table 1:** Proximate composition (%) of smoked-dried C*larias gariepinus* treated with different concentrations of Aloe vera (*Aloe barbadensisr*) extract (g/100g)

| | Aloe vera extract (%) concentration | | | |
|---|---|---|---|---|
| **Parameters** | **AVE 0.0** | **AVE 0.5** | **AVE 1.0** | **AVE1.5** |
| Moisture | 7.50±0.50 [a] | 6.30±0.40 [b] | 6.10±0.20 [b] | 6.50±0.10 [b] |
| Crude protein | 56.64±0.12 [a] | 54.69±0.01 [c] | 56.04±0.13 [b] | 54.60±0.20 [c] |
| Ether extract | 14.50±0.30 [d] | 15.50±0.10 [c] | 17.60±0.20 [a] | 16.60±0.30 [b] |
| Ash | 0.57±0.12 [ab] | 0.53±0.25 [b] | 1.00±0.20 [a] | 0.50±0.20 [b] |
| Nitrogen free extract | 20.79±0.16 [b] | 22.98±0.16 [d] | 19.26±0.10 [a] | 21.80±0.20 [c] |

Key: AVE= Aleo vera extract

The control fish lost the highest weight (78%), followed by 0.5% (75%) and 1.5% (72%), while the 1.0% Aloe vera treatment retained the most weight with the lowest loss (64%) during 12 hours of smoking.

**Table 2:** Difference in weight lost after twelve hours of smoking C*larias gariepinus* with a solution of Aleo vera extract

| Aleo vera extract Concentration level (%) | Initial weight (g) | Final weight (g) | Weight loss (g) | Percentage weight loss |
|---|---|---|---|---|
| 0.0 | 500 | 109 | 390 | 78% |
| 0.5 | 500 | 122 | 378 | 75% |
| 1.0 | 500 | 177 | 323 | 64% |
| 1.5 | 500 | 139 | 361 | 72% |

Microbial population in fish treated with different concentrations of Aloe vera extract. The control (0.0%) had the highest microbial load of 14 x 103 while 1.0% showed the least with 1 x 103. Both 0,5% and 1.5% had similar microbial count of 2 x 103 by Day 21.

**Table 3:** Changes in microbial loads (CFU/g) of smoked-dried C*larias gariepinus* treated with different concentrations of Aloe vera extract during storage at room temperature for 21 Days

| **Parameters** | **Day 1** | **Day 7** | **Day 14** | **Day 21** |
|---|---|---|---|---|
| 0.0 | 11x $10^3$ | 4 x $10^3$ | 12 x $10^3$ | 14 x $10^3$ |
| 0.5 | 9 x $10^3$ | 7 x $10^3$ | 6 x $10^3$ | 2 x $10^3$ |
| 1.0 | 7 x $10^3$ | 6 x $10^3$ | 2 x $10^3$ | 1 x $10^3$ |
| 1.5 | 10 x $10^3$ | 9 x $10^3$ | 2 x $10^3$ | 2 x $10^3$ |

The sensory scores differed significantly (P ≤ 0.05) across treatments. The 0.5% Aloe vera extract gave the best appearance, color, and overall acceptability, while 1.5% scored highest for flavor and the control maintained the best texture. In between treatments, some attributes (e.g., appearance, flavor, general acceptance) showed clear differences, while others (e.g., texture for control, 0.5%, and 1.0%) did not differ significantly. Overall, 0.5% was most preferred.

**Table 4:** Sensory evaluation of smoked C*larias gariepinus* treated with different concentration of *Aleo vera bardnesis* extract.

| Parameters | 0.0 | 0.5 | 1.0 | 1.5 |
|---|---|---|---|---|
| Appearance | 6.50±17 [b] | 7.00±0.06 [a] | 7.00±0.12 [a] | 7.00±0.17 [a] |
| Texture | 7.00±0.12 [a] | 7.00±0.12 [a] | 7.00±0.12 [a] | 6.00±0.17 [b] |
| Flavor | 6.00±0.12 [c] | 7.00±0.06 [b] | 7.00±0.12 [b] | 7.00±0.17 [a] |
| Color | 6.40±0.17 [b] | 7.00±0.06 [a] | 6.57±0.12 [b] | 6.00±0.17 [c] |
| General acceptance | 6.00±0.12 [c] | 7.00±0.06 [a] | 6.00±0.12 [b] | 5.90±0.21 [c] |

## DISCUSSION

The proximate composition showed that crude protein was the major nutrient across all treatments, with the highest value in the control. This agrees with Effiong and Fakunle (2011), who reported that protein is usually the dominant component in fish dry matter. Moisture decreased in treated samples, while ether extract and ash were highest at 1.0%. Aloe vera, indicating better nutrient retention during smoking, supporting earlier reports on the preservative role of plant extracts (Oladipo and Bankole, 2013; Akinwumi *et al.*, 2019; Abdullahi *et al.*, 2019).

Weight loss after smoking was lowest in the 1.0% Aloe vera treatment (64%), suggesting improved retention of nutrients and water compared to the control. This is consistent with Adeparusi and Olowojuni (2015), who reported similar weight loss ranges in smoked C*larias gariepinus*. Microbial counts also reduced significantly in treated samples, with the lowest load at 1.0% by day 21, and sensory scores showed that 0.5% Aloe vera was most preferred. These findings confirm the preservative and quality-enhancing effects of Aloe vera, as also reported by Haruna *et al*. (2021).

## CONCLUSION

Pre-treatment of C*larias gariepinus* with Aloe vera extract prior to smoking improved microbial stability, reduced weight loss, and enhanced nutritional and sensory quality. The 1.0% concentration was most effective in preserving shelf life, while 0.5% improved consumer preference. Aloe vera extract is recommended as a natural preservative for smoked fish to reduce post-harvest losses and promote safe, eco-friendly fish processing.

## ACKNOWLEDGMENT

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# EFFECT OF GINGER AND GARLIC POWDER ON PROXIMATE COMPOSITION AND ORGANOLEPTIC CHARACTERISTICS OF SMOKED *Clarias gariepinus* AND *Heterotis niloticus*

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**ABSTRACT**
*Processing of fish is an important aspect of commercial fisheries in order to ensure freshness for long time and improve quality attributes. This study was conducted to determine the effect of Ginger and Garlic powder on the proximate composition and sensory qualities of smoked Clarias gariepinus and Heterotis niloticus. Forty-two (42) fish samples of mean weight of 450g was used for the study. The fish samples were grouped into batches T1, T2 and T3 were immersed in 5 % brine solution at ambient temperature of 30±2 0C. The batches were smoked using NIFRRI smoking kiln treatment; T1 was not treated (as control) (T2), 100% Ginger extract and (T3) 100% Garlic extract. The samples were subjected to proximate composition, and sensory evaluation. The highest protein value 68.50 was recorded for Clarias gariepinus (T2) and (T3) recorded 65.50 respectively. Lipid content was highest in C. gariepinusT1 (12.5) and lowest in T3 (6.51) while in H. niloticus recorded highest value in 0%=10.50 for T2 and lowest in 6.5 inT3. The two smoked fish species evaluated, without preservation. Ginger extract and Garlic powder. Improved Smoked fish proximate parameter while Garlic powder was most effective in improving the sensory parameters*

**Keywords:** Proximate composition, Sensory evaluation, Smoked fish, Ginger and Garlic powder

## INTRODUCTION

Processing of fish entails maintaining the desirable quality prior to marketing and consumption. Since fish are composed of perishable nutrients processing is therefore necessary to ensure safety and prolonged shelf life of fish, Different types of preservation methods employed to arrest fish spoilage include: drying, smoking, freezing, and brining (Kumolu-Johnson *et al.*, 2011). Smoking of fish is one of the most ancient processing technologies. It has been for centuries used for preservation, and is still widely used for this purpose among several communities in the third world where up to 70% of the catch is smoked for preservation (Kumolu-Johnson *et al.*, 2011). However, in industrialized countries, smoking of fish is done for enhancement of flavour and texture; often producing value added products whose preservation is achieved (Idris *et al.*, 2010). Heat generated as a result of smoking dehydrate, inhibits bacterial growth, retard enzymatic actions, add aroma, taste and colour on processed fish, but its quality can deteriorate during storage. Fish can be smoked whole, cleaned, split or filleted, depending on local preferences and the desired final product. An important fact is that the greater the surface area of the fish, the greater the amount of smoke particles which can be absorbed. Traditional smoked fish, though popular, suffer from some inherent problems, including un-even cooking of the product, scorching and burning due to direct heating, bitterness, unattractive appearance, rancidity development, limited shelf-life and insect infestation (ldris *et al.*, 2010).

Rancidity development may also affect the nutritional value, keeping quality, as well as consumer acceptance. Oikeh *et al. (*2013) reported fungal spoilage, lipid oxidation (production of off-flavours) and poor storage stability of smoked-dried fish as some of the problems of the fish industry in Nigeria. In other to eliminate much of the short comings associated with the use of synthetic insecticides and provide and an effective storage and preservation techniques, there have been in recent years an

increasing and concerted effort at developing plant base toxicants that are environmentally friendly. In the fish processing industry, replacement of synthetic antioxidants by plant is being widely encouraged by researchers and processors. Quality and shelf life of fish and fish products are often enhanced by using various food additives during handling, processing and storage. Due to potential health hazards synthetic additives are being replaced by their natural counter parts.

*Heterotis niloticus*, also called African bony tongue is readily accommodated in the fresh water bodies. It is available all year round with a large population of juveniles and adults due to its fast growth and versatile feeding habits. *H. niloticus* is one of the species that has great potentials for commercial aquaculture but associated with low acceptability *by consu*mers due to its poor taste, reducing its market value (Amuneke *et al.*, 2020). This commercial fish is a highly preferred source of food because of its high protein content and hardy flesh, thus forming a very important component in the diet of many Nigerians. Nutritional investigation shows that *Heterotis niloticus* contains 12.5g/100g fat, 61.2g/100g protein and 308.6 Kcal/g calculated caloric values (Adam Sulieman and Omer, 2021). African catfish (C*larias gariepinus*) is one of the most important fish species. There is paucity of information on the use of Ginger and Garlic extract treatment on smoked fish and this study aims to assess the effect of Ginger and Garlic extract on proximate and sensory property of smoked C*larias gariepinus* and *Heterotis niloticus*

C*larias gariepinus* is currently being cultured both inside and outside its natural range of tropical and subtropical environments (Adewolu *et al*., 2008). Positive attributes such as resistance to diseases, high fecundity, and ease of larval production in captivity make it of commercial importance in aquaculture. C*larias gariepinus* and *Heterotis niloticus* commercially important fish species in Nigeria with a high consumer acceptability. Food preservatives are used to increasing the shelf-life of food and improve food quality. The exploration of a safe, effective and acceptable natural treatments on fish is thus examined

## MATERIALS AND METHODS

### Study Area

This study was carried out at the processing Unit of Federal College of Freshwater Fisheries Technology Baga, Borno State, Nigeria temporarily relocated at NIFFR Zonal Office, Maiduguri located in North-Eastern part of Nigeria at latitude 11°51 and longitude 30°51 east at latitude 354m above sea level (Aluko, 1983).

### procurement and sample preparation

Twenty-one (21) freshly caught each of C*larias gariepinus* and *Heterotis niloticus* (Mean weight of 450 g) were bought from Gamboru fish market, Maiduguri, Borno State. Pre-dried Ginger and Garlic were obtained from Monday market Maiduguri Bornu state. c. Drained fish was skewered for smoking. The fish samples were smoke-dried using NIFFR smoking kiln for twelve hours for two days following the method describe by (Iheanacho *et al*., 2017). After smoking, the fish samples were collected randomly from each treatment and transported in separate carton to National Agency of Foods and Drugs Administration Control (NAFDAC), Maiduguri office for proximate analysis. The remaining fish were used for Sensory evaluation.

### Proximate Analysis of Smoked Fish Samples

The proximate analyses of the smoked fish samples were carried out according to AOAC (2006). Crude protein content of the various samples was determined by the Kjeldahl procedure; crude fibre was the trichloroacetic acid method; crude fat was by the soxhlet extraction procedure; ash (A) was carried out by incineration while, dry matter (DM) and Nitrogen Free Extracts (NFE) were calculated.

**Sensory Analysis of Smoked Fish Sample**

The determination of sensory attributes of the smoked fish products was evaluated. Panelists were chosen based on their familiarity and experience with smoked fish for sensory evaluation. Fish samples were represented in coded form and were randomly presented to the panelists. The panelists were provided with portable water to rinse their mouths between evaluations. However, a questionnaire describing the quality attributes (appearance, taste, texture, aroma and general acceptability) of the smoked fishes was given to each panelist. Each sensory attribute was rated on a 7-point Hedonic scale according to method described by Sogbesan and Ibrahim (2017).

**Data Analysis**

The data obtained was subjected to simple percentages, descriptive statistics and analysis of variance (ANOVA) using Statisticabl Package for Social Sciences (SPSS) version 16.1.

**RESULTS AND DISCUSSON**

From results of the proximate analysis (Table 1) the control sample (T1) recorded highest moisture content 12.00 and 13.50 in C*larias gariepinus* and *Heterotis niloticus* respectively with T2 recorded the lowest 10.50 crude protein a reduction in moisture, ash and crude lipid content recorded the highest for T1 and T2 for C*larias* and *Hterotis nilotics* respectively. The control samples recorded the lowest 1,05 Ash content in both C*larias gariepinus* and *Heterotis niloticus* while T2 recoded the highest 6.51. Nitrogen free extract recorded highest in T1 and lipid which could be attributed to weight loss to air (Davies and Davies 2009). The organoleptic test reveals that control in both fish species having the least general acceptance C*larias gariepinu* T2 was better in terms of aroma whileT3 recorded highest in appearance. *Heterotis niloticus*.

**Table 1:** Proximate composition of smoked *gariepinus Clarisas* and *Heteroti niloticus* treated ginger and garlic powder

| Fish species | Samples | | |
|---|---|---|---|
| | T1 | T2 | T3 |
| ***Clarias gariepinus*** | | | |
| Moisture | 12.0 | 10.51 | 11.0 |
| Protein | 66.12 | 68.51 | 65.25 |
| Crude Lipid | 12.5 | 7.011 | 6.50 |
| Ash | 5.01 | 6.04 | 2.05 |
| Nitrogen Free Extract (NFE) | 4.38 | 6.00 | 13.09 |
| ***Heterotis niloticus*** | | | |
| Moisture | 13.51 | 11.01 | 13.00 |
| Protein | 54.13 | 53.13 | 56.01 |
| Crude Lipid | 8.05 | 10.02 | 6.55 |
| Ash | 1.05 | 6.51 | 3.02 |
| NFE | 12.52 | 13.37 | 3.82 |

T1= Smoked Control (no treatment 0%); T2 = Smoked fish treated with 100% Ginger powder; T3 = T1= Smoked Control (no treatment 0%); T2 = Smoked fish treated with 100% Ginger powder; T3 = Smoked fish treated with 100% Garlic powder

| Parameters | Samples | | |
|---|---|---|---|
| | T1 | T2 | T3 |
| Appearance | 3.63 [a] | 4.20 [b] | 4.30 [d] |
| Texture | 6.20 [a] | 5.20 [de] | 5.45 [cd] |
| Taste | 5.3 [a] | 5.50 [cd] | 5.93 [df] |
| Odour | 5.95 [c] | 6.00 [b] | 5.90 [c] |
| General acceptability | 4.21 [a] | 5.55 [b] | 5.00 [c] |

**KEY**; T1= Smoked Fish Without treatment) =Smoked fish treated with 100% ginger powder and T3=Smoked fish treated with100% garlic powder.

**Table 3:** Effect of Ginger and Garlic powder on the Sensory Quality of smoked *Heterotis niloticus*

| Parameters | Samples | | |
|---|---|---|---|
| | **T1** | **T2** | **T3** |
| Appearance | 4.75 [a] | 6.20 [b] | 6.40 [d] |
| Texture | 6.30 [a] | 5.20 [de] | 5.35 [cd] |
| Taste | 6.35 [a] | 5.50 [cd] | 5.25 [def] |
| Odour | 5.95 [c] | 6.00 [b] | 5.11 [c] |
| General acceptability | 4.31 [a] | 5.55 [b] | 5.10 [c] |

**KEY**: T1= smoked without treatment, T2= smoked fish treated with 100% ginger powder. T3= smoked fish treated with 100% garlic powder t; Data with Different Superscript on the same column are significantly different at $p<0.05$

The crude protein (68.12%) boost in ginger powder treated fish in this study is in congruence with the findings of Agbabiaka *et al*. (2016) who reported increased protein contents in black pepper and ginger powder C*itharinus citharus*. Similar observation was also recorded by Ayeloja *et al*. (2013) in hot-smoked C*larias gariepinus* treated with different spices. T2 exhibited the lower moisture loss (10.5%) as compared to *H.niloticus* the control (14.5%) without any preservative which agrees with Assogba *et al*.(2019) that final product is dependent on the quality of raw material and time of smoking. Crude lipids showed that Control had the highest mean value of 12.61 %, while Treatment T3 recorded the lowest mean crude fat of (6.50%). %). Ash content ranged between 1.00% and 6.50% in all the treatments. The results show that the highest mean ash (6.50%) was obtained in Treatment T2, followed by Treatment T2 (1.50%), while Treatment T1 had the least (I.00%). Also, results showed that highest mean Nitrogen free powder value with 12,23.34 and 1.82% was obtained in Treatment T1. the lowest value of 1.80% was found at Treatment T1. This observation contradicts the result of Ayeloja *et al*. (2013) who studied effect of spices on the chemical properties of hot-smoked C*larias gariepinus*..These authors reported significant higher moisture content (6.18%), protein (79.44%), lipid (6.31%) and ash (7.04) for no spice-treated smoked African catfish, C*larias gariepinus* while ginger-spiced fish had markedly higher crude fibre (10.54%).

The results of sensory analysis of smoked C*larias gariepinus* and *H.niloticus* treated Ginger and Garlic powder is shown in table 2. The appearance in T3 (Control) was excellent (4.30) and (6.40) in table3 and 4 respectively significantly better than Treatments T2 6.22) and T1 (4.78). The better preference for acceptance of ginger extract reported by the sensory panelists in the present study agrees with earlier report by Adadu *et al*. (2021) which stated that treated smoked fish treated with oily substance shines brighter than untreated samples. Agbabiaka *et al.* (2012) reported that pre-treatment increase nutrient as additional nutrients are inherited. The sensory evaluation Table 2 and 3 recoded higher score in

appearance, aroma, colour and taste in both T2 and T3 than the control sample (T1) .Samples treated with Ginger and Garlic treated smoked fishes also recorded higher general acceptability than sample without preservation in in both C*larias gariepinus* and *Heterotis niloticus* (4.12) with 100% Ginger recorded highest acceptability. The present result is similar to those obtained by Ligia (20012) for blue striped catfish. In this study, C*larias gariepinus treated ginger* recorded higher crude protein Ash and Nitrogen free extract

## CONCLUSION

The Ginger and Garlic powder treatments have also shown a good potential in retaining proximate parameters. Smoked fish sensory parameters (taste, appearance, flavor and texture and general acceptability) have also shown improvement with the application of Ginger and Garlic powder. Garlic powder treatment is recommended when consumer's acceptability and nutrient retention is desired.

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# MICROBIAL LOAD AND SENSORY EVALUATION OF SMOKED CATFISH (*Clarias gariepinus)* USING DIFFERENT PACKAGING MATERIALS

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**ABSTRACT**

*The study investigated the types of materials to be used for packaging of dried fish in Nigeria. The study was conducted for 12 weeks. Envelop, Plastic and cellophane bag were selected and used as packaging materials. Catfish (Clarias gariepinus) of six months age weighing 6kg were killed, gutted, cleaned, salted, weighed and dried in an improved smoking kiln developed by Olayemi et al. (2013). The smoked dried catfish were removed from the smoking kiln cooled and packed in each of the three packaging materials. The samples were then stored in a shelf under ambient condition for one month. Envelope appeared to have the highest mean in appearance of 8.63±0.52, followed by the plastic material with the mean of 8.25±0.89 and least was cellophane bag with the mean value of 7.75±0.89 but with no significant difference respectively. For Aroma, envelope had the highest mean (8.50±0.76) followed by plastic material with the mean of (8.13±0.83) and the lowest mean recorded 8.00±1.41 in cellophane. The overall acceptability was highest in fish packaged in envelope with average mean value of (8.88±0.35). This was followed by fish packaged in plastic (8.25±0.87) and followed by fish packaged in cellophane bag with the least mean value (7.63±0.92) all with significant difference ($p<0.05$). The result concluded that appropriate packaging is necessary to maintain the quality of fishery products and customer satisfaction. In general, packaging requirement for fishery products vary according to the type of product whether fresh, frozen or processed, type of market, mode of storage and transportation. So also packaging material from envelope are generally more acceptable by the people in the study. Envelop is recommended for packaging smoked fish products for better shelf life.*

**Keywords**: Envelop, Cellophane bag, Plastic and *Clarias gariepinus*

## INTRODUCTION

Fish is one of the most important animal protein foods available in the Tropics. The Less Developed Countries (LDCs) capture 50% of the world's harvest and a large proportion of that catch are consumed internally. In Africa, 17.5% of the animal protein intake comes from fish while in Nigeria the proportion is 40%. Fish spoilage is high in the tropics due to lack o for appropriate handling and processing techniques.
A well dried fish product will go bad if it is not well packaged because of the hygroscopic nature and easy ability of fish to lose oil when exposed to the atmosphere. In Nigeria, smoked fish are not properly packaged and hence they are sold within a short period. This has made smoked fish business to remain at a small-scale level in the country. Fish smoking prolongs shelf life, enhances flavour and increases utilization in soups and sauces. It reduces wastages in time of bumper catches and/or harvest and allows storage for the lean season. It also increases protein availability to people throughout the year and makes fish easier to handle (pack, transport and market) (Akinola S*et al.*, 2015).

The packaging materials in use are still the indigenous ones that are not attractive, prone to easy entry of insects and rodents, thereby of no international appeals. The packaging materials only serve to hold the

fish products during handling, transportation and storage but offer little protection to the products from microbial, chemical, moisture intake, dusts and insect pests (Okonkwo *et al.*, 2016). The study aimed at investigating the storage of smoked catfish as affected by different composite packaging materials with a view to improving its quality, extend the shelf life and safeguard the health status of the consumers.

## MATERIALS AND METHOD

### Description of the Study Area

The experiment was carried out at the department of aquaculture and fisheries management farm, Faculty of Agriculture, Shabu-Lafia campus, Nasarawa state university, Keffi, Nigeria. Located at latitude 8.546 and longitude 8.534.

### Selection of Materials for Packaging

These materials ranked in the order of preference as follows: TRT1= Envelope TRT2= Plastic Material and TRT3= Cellophane bag. Based on this study, envelope, plastic and cellophane bag were used as packaging materials.

### Development of Composite Materials

Composite packaging materials were made from Polyethylene, transparent rubber and paper. The materials were then be laminated (putting layers of polyethylene on both surfaces) using Linea DH - 650laminating machine. The packaging materials to be used will be labeled as follows:
1. $TR_1$= Envelope. 2. $TR_2$= Carton. 3. $TR_3$= Cellophane bag

### Drying and Packaging of Fish

Catfish (*Clarias gariepinus)* of six months age were bought from Shabu, Lafia Local Government of Nasarawa State. The fish were killed, gutted, cleaned, salted, weighed and dried in an improved smoking kiln developed by Olayemi *et al*. (2013). After drying, the smoked dried catfish were removed from the smoking kiln cooled and packed in each of the three packaging materials. The samples were then stored in Ziplock bag on a shelf under ambient condition for one month.

### Microbial Analysis

The microbial analyses were carried out for the final quality of the dried fish after storage. The microbial loads were determined using methods described by AOAC (2002).

### Sensory Analysis

Sensory evaluation of the smoked dried samples of catfish in the different packaging materials were carried out using 10man trained panels for smell, taste, colour, texture and general acceptance on 9 points hedonic scale with score 9 having excellent attraction. Necessary precautions were taken to prevent carry-over flavour during the tasting by ensuring that each stage of sensory evaluation.

### Data Analysis

Data collected were analysed using one way analysis of variance (ANOVA) and descriptive statistics, such as frequencies, percentage and cumulative percentage and significant differences were separated at ($p>0.05$) probability level, using IBM SPSS statistical tool, version 20.0.

## RESULTS

### The storage of smoked catfish as affected by different composite packaging materials.

Result from Table 1 showed the acceptability of smoked catfish using different packaging materials. Envelope appears to have the highest mean in appearance with the mean of $8.63\pm0.52$, followed by the plastic material with the mean of $8.25\pm0.89$ and least was cellophane bag with the mean value of

7.75±0.89 but with no significant difference respectively. Cellophane material had the highest mean (8.13±0.99) acceptability on colour followed by envelope and plastic respectively. For Aroma, envelope had the highest mean (8.50±0.76) followed by plastic material with the mean of (8.13±0.83) and the lowest mean recorded 8.00±1.41 in cellophane. The overall acceptability was highest in fish packaged in envelope with average mean value of (8.88±0.35). This was followed by fish packaged in plastic (8.25±0.87) and followed by fish packaged in cellophane bag with the least mean value (7.63±0.92) all with significant difference at ($p<0.05$).

**Table 1:** Acceptability of smoked catfish using different packaging materials

| Packaging mater | Appearance | Colour | Aroma | Overall acceptability |
|---|---|---|---|---|
| Envelope | 8.63 ±0.52 [a] | 8.00±1.20 [a] | 8.50±0.76 [a] | 8.88±0.35 [a] |
| Plastic | 8.25±0.89 [a] | 8.00±0.93 [a] | 8.13±0.83 [a] | 8.25±0.87 [b] |
| Cellophane bag | 7.75±0.89 [a] | 8.13±0.99 [a] | 8.00±1.41 [a] | 7.63±0.92 [c] |

Note: [abcd] Mean carrying different superscripts are statistically different from each other ($p<0.05$)

**Occurrence of Bacteria Species from Smoked Catfish (*Clarias gariepinus*) spp from Different Packaging Materials.**

Table 2 results showed that fish packaged in envelope had highest occurrence of bacteria species (38.89%) followed by the cellophane bag with 33.33% of the bacteria species present while the plastic material had the lowest percentage occurrence of the bacteria species (27.78%) respectively.

**Table 2:** Occurrence of Bacteria Species from Smoked Catfish (*Clarias gariepinus*) spp from Different Packaging Materials

| Samples | Frequency of occurrence | Percentage (%) |
|---|---|---|
| Envelope | 7 | 38.89 |
| Plastics | 5 | 27.78 |
| Cellophane bag | 6 | 33.33 |

**Occurrence of Fungi Species from Smoked Catfish (*Clarias gariepinus*) spp from Different Packaging Materials.**

Table 3 result showed that envelope had the highest number of occurrence of fungi (*Aspergillus niger, Mucorsp, Aspergillus flavus* and *Cladosporium sp*) species with 40% level of occurrence while plastic and cellophane materials had the same level of fungi infestation (30%) (*Penicillium sp, Aspergillus niger, fusarium sp*) and (*Cladosporium sp., Aspergillus niger and Penicillium sp*) respectively.

**Table 3:** Occurrence of Fungi Species from Smoked Catfish (*Clarias gariepinus*) spp from Different Packaging Materials

| Samples | Frequency of occurrence | Percentage (%) |
|---|---|---|
| Envelope | 4 | 40 |
| Plastics | 3 | 30 |
| Cellophane bag | 3 | 30 |

**Total Fungal Mean Count of smoked *Clarias garepinus* using different packaging materials before storage**

Result in table 4 showed that the highest total heterotrophic count was observed in envelope ($6.7x10^{-6}$) and the lease was observed in plastic with the mean count ($5.7x10^{-6}$). Furthermore, the highest fungal mean count was observed in envelope materials with the mean value ($2.5x10^{-3}$) while least mean count observed was observed in plastic materials ($2.0x10^{-3}$).

**Table 4:** Total Fungal Mean Count of smoked C*larias gariepinus* of different packaging materials before Storage

| Packaging materials | Total Heterotrophic count | Total Fungal count |
|---|---|---|
| Envelope | $6.7x10^{-6}$ | $2.5x10^{-3}$ |
| Plastics | $5.7x10^{-6}$ | $2.0x10^{-3}$ |
| Cellophane | $6.0x10^{-6}$ | $2.3x10^{-3}$ |

Result in table 5 showed that there is reduction in the total heterotrophic count and fungal count after storage, the highest total heterotrophic count was observed in cellophane bag ($2.3x10^{-3}$) also the lease was observed in plastic with the mean count ($2.0x10^{-3}$). Furthermore, the highest fungal mean count was also observed in envelope bag materials with the mean count ($1.3x10^{-2}$) while least mean count observed was observed in plastic materials ($2.0x10^{-3}$).

**Table 5:** Total Fungal Mean Count of smoked C*larias gariepinus* of different packaging materials after Storage

| Packaging materials | Total Heterotrophic count | Total Fungal count |
|---|---|---|
| Envelope | $2.1x10^{-3}$ | $1.3x10^{-2}$ |
| Plastics | $2.0x10^{-3}$ | $1.4x10^{-2}$ |
| Cellophane | $2.3x10^{-3}$ | $1.9x10^{-2}$ |

## DISCUSSION

**Effects of different packaging materials on the acceptability and shelf life of smoked catfish (*Clarias gariepinus)***

The effects of different packaging materials on the acceptability and shelf life of smoked catfish (*Clarias gariepinus)* revealed that packaging material can influence quality of stored fish and hence the acceptability for human consumption (Kwangho, 2010) reported that food attributes are an important factor in predicting consumers' perceptions in food choices decision. Highest acceptability with the mean of 8.63±0.52 on appearance the same scenario goes to cellophane bag on color with the mean of 8.13±0.99, so also in terms of Aroma envelope is generally acceptable with the mean of 8.50±0.76. The trend also goes in overall acceptability there is significant different in enveloped with the mean 8.88±0.33 compared to other packaging materials. (Khanipour *et al.*, 2013) in their study reported that good packaging material will improve the storability of smoked dried fish by increasing the shelf life; this is better achieved by plastic as packaging material when compared with nylon.

The observed general decrease in sensory quality of the smoked fish samples over time is like that observed by many authors like (Ayeloja *et al.*, 2015) who also observed general significant decrease in aroma, texture, and color in hot smoked rainbow trout (Oncorhynchus mykiss) that was packaged using different packaging materials during storage. Occurrence of bacterial and fungal Species from Smoked Catfish (*Clarias gariepinus*) spp from Different Packaging Materials shows that bacteria species from envelope had 38.9% of the bacteria species hence envelop is prompt to bacteria compared to the other material also from the fungal species envelope had 40% level of occurrences compared other material

with 30% respectively. The presence of these microorganisms in the fish could put consumers at risk for their pathogenic nature known to man. Dutta *et al.* (2018) have reported both on total coliform and feacal coliform from smoked fish during storage which is in correlation with the report in this study. The variations of microbial counts and types from the fish samples could result from human handling, environment of storage, improper drying process and from culture ponds or tanks. However, lipid oxidation results in deterioration in food quality for off flavor and off-odor (Hus in't Veld, 1996). Ikutegbe and Sikoki, 2014) have reported that the decline in fish deterioration on storage time could be due to the underlying biological characteristics of the species analyzed and its susceptibility to fat oxidation. In conformity, higher microbial load was recorded from the fish samples, the result from total fungal mean count of smoked C*larias gariepinus* of different packaging materials revealed that enveloped had the highest mean count of $6.7x10^{-6}$ same goes to fungal count with the highest mean $2.5x10^{-3}$. From the microbial load perspective, coliform group of bacteria such as E. coli and the presence of afflatoxin producing fungus (*Aspergillus flavus*) were reported in increasing number during the storage period.

The microflora, *Staphylococcus aureus*, *Bacillus subtilis* and *Escherichia coli* encountered in smoked fish studied are common microflora associated with fish and are the same as those reported in smoked C*larias sp*. in Benin metropolis by Abolagba *et al* (2011) and Odu *et al* (2012) on smoke-dried mangrove oysters (C*rassos treagazar*) sold in Port Harcourt. The storage of the smoke-dried C. *gariepinus* and C. *nigrodigitatus* in the refrigerator and kitchen cabinet showed no significant growth of microorganisms throughout the storage period. The presence of *S. aureus*, *B. subtilis* and *E. coli* in the stored samples studied could be from the handling process; this calls for standard hygiene during fish handling and processing by the processors.

There was no significant increase in the bacterial load of the dried fish samples in the two storage facilities; the contamination of the samples by microorganisms did not increase indicating that the storage facilities were effective in storing the smoked fish. The highest total fungal count of ($2.5x10^{-3}$cfu/g) of the fish sample packaged in envelope was lower than the maximum recommended value of fungal counts for raw fish products, which is $1.7\times10^{2}$cfu/g according to International Commission on Microbiological Specifications for Foods (ICMSF 2002) and < 10 cfu/g by the Microbiological Guideline for Ready-to-eat-Food (2007). Contamination with *E. coli*, an enteric bacterium may have been introduced during smoking and preparation for storage. Olaleye and Abegund (2015) stated that the presence of *E. coli* in food may be because food handlers failed to observe basic sanitary rules. There was no growth of fungi in the samples, indicating the safety of the products. This showed that the storage facilities could prevent the growth of spoilage organisms.

## CONCLUSION

The result concluded that appropriate packaging is necessary to maintain the quality of fish and customer satisfaction. So also packaging material from envelope are generally acceptable by the people in the study but it is prone to bacterial and fungal growth and had the highest number of bacterial and fungal occurrence.

## RECOMMENDATION

From the result we can recommend that more research should be carried out on packaging materials to create room for further investigation on the effects of different packaging materials on the acceptability and shelf life of smoked catfish (C*larias gariepinus)* so that we can justified the result. Packaging material from envelope are recommended for use in fish.

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# SENSORY ASSESSMENT OF SMOKED AFRICAN CATFISH (*Clarias gariepinus*) PRESERVED WITH GROUNDNUT (*Arachis hypogea*) SKIN WASTE UNDER COLD STORAGE CONDITION.

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**ABSTRACT**

*The integration of multiple preservation methods is critical for extending the shelf life of fresh fish and ensuring availability during periods of scarcity. In Nigeria, seasonality strongly influences fish supply, as farmers align production cycles with market demand and management practices. However, there remains a gap in knowledge regarding the use of combined preservation methods for reducing post-harvest losses (PHL) during cold storage. This study evaluated the sensory properties of smoked African catfish (Clarias gariepinus) preserved with groundnut (Arachis hypogaea) (PS) skin waste under cold storage conditions. Results indicated that groundnut skin extracts improved consumer acceptability in terms of taste, aroma, and overall preference, with the PS250g treatment receiving the highest sensory ratings. Incorporating PS improves sensory attributes, particularly taste and aroma, but excessive amounts (325g) compromise texture and overall acceptability. The optimal level appears to be around 250g, balancing improved taste and aroma without major texture issues. These findings highlight the potential of integrating agro-waste products with cold storage to reduce PHL, enhance fish quality, and promote food security.*

**Keywords:** Cold storage, Groundnut skin, Sensory evaluation, Shelf life, Post-harvest loss

## INTRODUCTION

Fish is a highly perishable food commodity due to its biochemical composition, which makes it highly susceptible to rapid spoilage after harvest. Post-harvest loss (PHL) in the fisheries sector is particularly severe in tropical regions like Nigeria, where inadequate cold chain facilities limit storage potential (Xie *et al.*, 2023). Estimates suggest that Nigeria experiences 40–60% PHL due to poor preservation practices and unreliable electricity (AFSAA, 2024). Smoking remains a traditional preservation method widely practiced in Africa, as it improves flavor and shelf stability (Saliu, 2008). However, when combined with cold storage, smoking can further extend shelf life while maintaining quality (Toby, 2019; Takashima *et al.*, 2021). Shelf life extension reduce processors losses while factor of display and production distribution can hinder marketing if not adequately considered (Abouzied *et al.*, 2022).

Freezing preserves fish over extended storage period with minimum deterioration in sensory quality (Saliu, 2008). However, documentation on shelf life of fresh water fish in ice storage which can slows down PHL and extending shelf life of preserved fish is lacking (Ihuahi *et al.*, 2010). The development of solar energy equipment in reducing post-harvest loss resources will ensure availability of fisheries product with a blend of traditional and modern technologies will minimize PHL (Abdul *et al.*, 2014). PHL from catfish is 32% in Vietnam and occurs at processing and production stages from farms, fish smokers also incur losses in Ghana up to 17% as a result of haggling before fish are taken for processing (Toby, 2019). Takashima *et al.*, (2021) noted that storing products in cold storage facilities will reduce loss and waste of food worldwide. A criterion used in fish selection by consumers is freshness (Abouzied *et al.*, 2022).

Yamauchi and Takeshima (2023) reported the agrarian household in Nigeria lacks connection to electricity with only 30% connected to the grid. Xie *et al.*, (2023) noted that developing countries lack cold chain storage and distribution system and opined that storage in freezing system with other method of preservation need to be studied in detail. Solar power freezer project in small fishing communities in Fiji has improved the livelihood and social wellbeing of fisher folks (Datt *et al.*, 2023) with socio economic impacts on longer shelf life storage in freezer which has removed the need of smoking fish while noting that post deployment period of solar freezer increases to 50% for fisheries application and higher than other applications in the community. The World Bank (2023) stated that accessibility to fishery product is enhanced by cold storage as it reduces spoilage over time which allows for distribution expansion leading to increase income and food security. WWF (2023) reported that solar powered fridges and freezers can be cooperatively or individually owned, as they are technology which cools product keeping it fresh with low cost of operation in the long run. The use of root crop waste in fish production have been briefly elucidated bringing to fore the need to effectively make use of waste of little or no value in aquaculture/livestock production (Sule *et al.*, 2023b; 2023c). Solar powered cold storage will impact positively on reducing PHL while enhancing food security.

Groundnut skin (PS), a by-product of peanut roasting, is often discarded despite being rich in amino acids, fatty acids, and phytochemicals (Sule *et al.*, 2024). Its incorporation in fish preservation could provide an eco-friendly, low-cost solution to enhance quality while reducing waste. This study investigates the effect of groundnut skin waste on the sensory attributes of smoked African catfish stored under cold storage conditions for six months.

## MATERIALS AND METHODS

### Procurement and Preparation of Samples

The outer brown/red skin of groundnut after removing the haulms was obtained from local peanut roasters, dried, and milled into fine powder according to Sule *et al.*, (2024). Four concentrations were prepared by dissolving 62.5 g, 125 g, 250 g, and 325 g of PS powder in 1 L of water. Fifteen African catfish (*Clarias gariepinus*), averaging 1 kg each, were purchased live from a fish farm, gutted, and grouped into five treatments (n = 3 per treatment, including control). Fish samples were immersed in the solutions for 20 minutes, drained, and smoked for 10 hours to dryness. All samples were stored in a solar-powered deep freezer for six months (May 27–November 27, 2024). After storage, fish were thawed and cooked in unsalted water for five minutes before sensory evaluation.

### Sensory Evaluation

A panel of 10 trained assessors evaluated samples for taste, appearance, aroma, and texture using a 9-point hedonic scale (1 = dislike extremely; 9 = like extremely). Overall acceptability was derived from average scores.

### Statistical Analysis

Data were expressed as mean values. Descriptive analysis was used to compare treatment effects.

## RESULTS AND DISCUSSION

The sensory scores of the control and samples incorporated with varying levels of PS are presented in Table 1. Taste scores increased with PS addition, peaking at 250 g (6.90), which was higher than the control (5.90). However, further addition to 325 g did not sustain this improvement, suggesting that excessive PS may impart flavors less preferred by panelists. Appearance remained relatively constant across treatments (6.20–6.40), indicating that PS incorporation had little impact on the visual quality of the product. Aroma was significantly enhanced with PS addition, particularly at 125 g (7.70) and 325 g (7.30), compared to the control (5.80). This indicates that PS contributes volatile compounds or enhances aromatic perception, improving consumer appeal.

Texture scores declined as PS levels increased, with the highest value in the control (6.70) and the lowest at 325 g (5.30). This suggests that PS addition may have altered product structure, leading to a less desirable mouthfeel at higher concentrations. Overall acceptability was comparable between the control, 62.5 g, and 250 g samples (6.50), demonstrating that moderate incorporation of PS did not negatively affect consumer preference. However, a decline in acceptability was observed at 125 g (6.30) and became more pronounced at 325 g (5.90).

**Table 1:** Sensory scores of smoked catfish preserved with groundnut skin (PS) under cold storage

| | Taste | Appearance | Aroma | Texture | Acceptability |
|---|---|---|---|---|---|
| Control | 5.90 | 6.30 | 5.80 | 6.70 | 6.50 |
| PS 62.5g | 6.30 | 6.30 | 6.60 | 6.00 | 6.50 |
| PS 125g | 6.40 | 6.20 | 7.70 | 6.00 | 6.30 |
| PS 250g | 6.90 | 6.30 | 6.90 | 6.40 | 6.50 |
| PS 325g | 6.40 | 6.40 | 7.30 | 5.30 | 5.90 |

The findings indicate that PS positively influenced sensory characteristics, particularly taste and aroma, both critical factors in consumer acceptance (Abouzied *et al.*, 2022) but excessive addition compromised texture and overall acceptability. The most favorable balance was observed at 250 g, where improvements in taste and aroma were achieved without a significant reduction in acceptability These results are consistent with prior studies showing that smoking enhances sensory appeal (Saliu, 2008) and that natural additives such as onion peel (Sule *et al.*, 2023a) or garlic extracts combined with storage in ice on fish fillet for 18days (Jimenez-Ruiz *et al.*, 2023) and noted that texture is not affected by storing tilapia fillet in ice after garlic application. Hence autolytic process of enzymes was inhibited and degradation brought to halt which improves consumer preference. Importantly, the integration of GS waste provides a sustainable and low-cost option for reducing spoilage and enhancing food security. The combination of smoking, cold storage, and natural preservatives offers a viable strategy to mitigate PHL, extend shelf life, and enhance consumer acceptability of fish products. Cyprian *et al.*, (2013) panelist score on color parameter increase with storage time freshness and flavor decrease with increase storage time of fillet in modified atmospheric packaging and reported different results under chilled and super chilled cold storage conditions. Bastian *et al.*, (2016) stated that maximum shelf life of fish is 10 -15 days. Toby (2019) Advocated the use of cold storage noting that cold storage alone will not mitigate spoilage but makes product available. Jimenez-Ruiz *et al.*, (2023) noted texture of fish muscle in storage is related to degradation overtime and this can also be noticed on preserved fish products as muscle firmness is lost if processing and storage are inadequate.

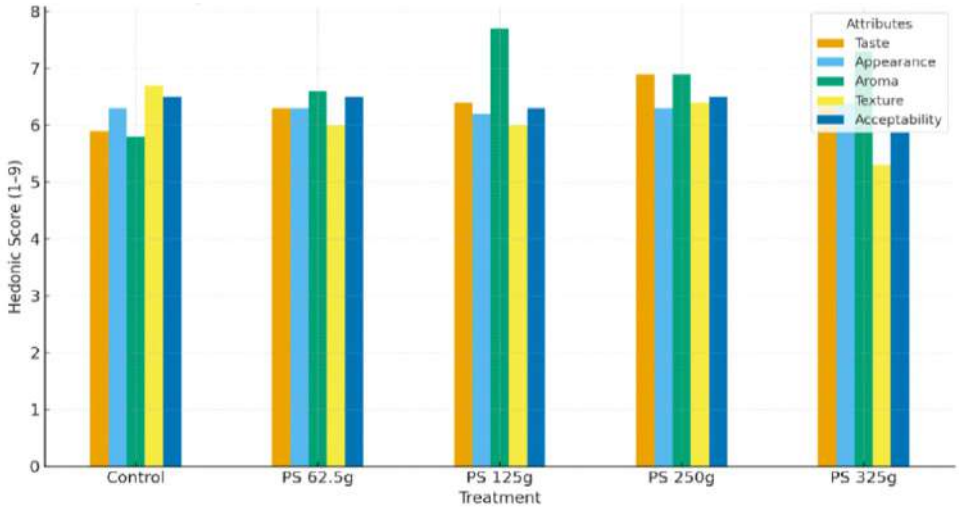



**Figure 1:** Sensory Evaluation of Smoked Catfish Preserved with Groundnut Skin

## CONCLUSION

This study demonstrates that groundnut skin waste can be effectively utilized to enhance the sensory qualities of smoked African catfish stored under cold and during cold storage. Treatments with PS, particularly at 125 g and 250 g, improved taste and aroma without compromising overall acceptability. The approach offers a sustainable means of reducing PHL, utilizing agro-waste, and improving fish quality for consumers. The valorisation of groundnut skin waste not only reduces environmental burden but also supports sustainable aquaculture and food security through reduced post-harvest losses.

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# COMPARATIVE ANALYSIS OF FATTY ACID PROFILE OF FISH OIL WITH OIL FROM OTHER SOURCES

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**ABSTRACT**
*This study compared the fatty acid composition of oils from marine fish (Trachurus trachurus), freshwater fish (Chrysichthys nigrodigitatus), chicken (Gallus domesticus), groundnut (Arachis hypogaea), and insect (Coptotermes formasanus). 3kg of Chrysichthys negrodigitatus, 3kg of Trachurus trachurus 2kg of Gallus domesticus, 1.2kg of Arachis hypogaea and 12.65g of Captotermes formasanus were collected using soxhlet extraction method. Fatty acid of oil collected were analysed using standard laboratory procedures, results obtained were subjected to appropriate statistical analysis using SPSS 16.0. Results showed significant differences ($p<0.05$) in lipid profiles, with saturated fatty acids (SFAs) dominating insect and animal oils, while groundnut oil contained the highest proportion of polyunsaturated fatty acids (PUFAs, 45.13%). Marine and freshwater fish oils were distinguished by elevated levels of long-chain omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), coupled with favourable n-6/n-3 ratios (<0.45). Groundnut oil, though PUFA-rich, lacked long-chain n-3 fatty acids, whereas insect oil was SFA-dense but offered sustainability advantages. These findings underscore the superior nutritional quality of fish oils, the complementary role of groundnut oil, and the emerging potential of insect oils for non-dietary applications. The study recommends promoting fish oils as key dietary n-3 sources while exploring oil blends for optimized nutrition.*

**Keywords:** Fatty acid profile, fish oil, groundnut oil, insect oil and chicken oil

## INTRODUCTION

Oil is an important part of our food as it serves many important physiological functions such as meeting energy requirement, being structural component of the cells, and starting component of various inflammatory mediators. It enhances the palatability of food, shelf life and makes food tasty (Bhushan, 2018). Oil are triglycerides that are liquid or clear liquid at room temperature. They contain a wide variety of nutrients and are part of the major three classes of food after carbohydrate and protein and also a good source of nutrient (Ogori, 2020). Edible oil is a fatty liquid that is physically extracted from several vegetables and in some animal tissues. Edible oils had made an important contribution to the diet of people in many countries serving as a good source of protein, lipid, and fatty acid for human nutrition including the repair of worn out tissues and new cells formation as well as a useful source of energy (Bello, 2011) Edible oils play an important role in the body as carriers of essential fatty acids (EFA). EFA are not synthesised in the body but are needed through the diet to maintain the integrity of cell membranes. They are also needed for the synthesis of prostaglandins which have many vital functions to perform in the body. Based on maintenance of good diet and control health issues like diabetes it has been essential to consume authenticated edible oils. Therefore, consumers need meaningful and honest information so that they can make an informed choice of their diet and the foods they purchase. Fish oil are an almost

unique source of EFA and especially n-3 HUFA, which comprise 10% to 25% of total fatty acid. Mainly due to their high nutritional value, Fish oil have, traditionally, been the major oil sources in aquafeeds especially for carnivorous species (Sargent and Tacon, 1999).

Generally, fish oil is more complex than vegetable oils due to long chain unsaturated fatty acids (Abdulkadir *et al*, 2010). Edible plant oil (EPO) is an indispensable nutritional resource for human health. It is obtained from seeds, pulps, fruits, and plumules of certain plants. Insect are in the class of in the class of invertebrate animals as a simple definition and are the largest group of organisms. Edible insect with the existence as huge number in nature become significant and popular in terms of for not only personal health but also the health and future of the planet Earth. Most attention on edible insects were attracted by their protein fraction. However, lipids as well represent a major component of edible insects. Edible insects have become one of the most attracted and attention-grabbing alternative food sources in recent years due to the constituents that include oils, proteins, carbohydrate, minerals and vitamins. The oil which is extracted from the processing or rendering of chicken is the chicken oil, it has high content of monosaturated fatty acid and also rich in linoleic acid which is an omega 6 fatty acid. In the work of (Negash *et al*, 2019) locally made edible oil have higher iodine value which makes it better for public consumption with respect to health risk. However, there is dart of information on the quality rating of oil extracted from different sources thus the need for this study which was aimed at comparing the chemical quality of oil extracted from fresh water fish (C*hrysichthys negrodigitatus*) marine water fish (*Trachurus trachurus*), chicken (*Gallus domesticus*), plant source (*Arachis hypogaea*) and insect oil (C*aptotermes formasanus*).

## MATERIALS AND METHOD

### Sample Collection

3kg of C*hrysichthys nigrodigitatus* (Silver catfish) was collected from New bussa, Niger state and transported within four hours in a frozen state in a polypropylene woven fabric to University of Ilorin, while 3kg *Trachurus trachurus* (Atlantic mackerel) was collected from the marine fish market in Lagos state and transported within nine hours in a polypropylene woven fabric. 2kg of life G*allus domesticus* (Chicken) was gotten from a local farmer in Ilorin. 1.2kg of *Arachis hypogaea* (Groundnut) was gotten from a local market in Ilorin, Kwara state. 12.65g C*optotermes formosanus* (termite) was collected from their nest in Ibadan, Oyo state and were transported in a plastic container within five hours.

### Oil Extraction Method and Free Fatty Acid Profile Determination

The extraction of the samples was done using soxhlet extraction method as described by Ahmed (2017). The free fatty acid profile (FFA) of the extracted oil were determined using Gas chromatography analysis. Samples were weighed and dried in the oven of 1200°C for 24 hours to remove moisture. The dried sample was then grounded to powdered form with mortar and pistol then it was wrapped in a filter paper and tied with thread. The sample was then placed in a thimble with 200ml of ethanol and ethyl acetate measured into a Soxhlet apparatus. The solvent was continuously boiled at 50°C to 60°C extracting the oil from the sample. The total time spent for the extraction process was 7 hours for the sample. The extracted oil was then collected in a flask and was decanted to separate the ethanol and ethyl acetate from the oil. The oil was placed in a water bath with a temperature of 90°C to allow evaporation of any remnant of ethanol and ethyl acetate.

### Statistical Analysis

Statistical analysis was performed using the SPSS 16.0 version. The difference of mean values were analyzed by one way analysis of variance (ANOVA) and significant means were separated using Duncan's multiple range test at 95% confidence value.

## RESULTS

### Fatty Acid Profile of the Oil

The fatty acid profiles of *Trachurus trachurus* (marine fish oil), C*hrysichthys nigrodigitatus* (freshwater fish oil), G*allus domesticus* (chicken fat), *Arachis hypogaea* (groundnut oil), and C*optotermes formasanus* (insect oil) revealed distinct differences in their composition (Table 1). It was observed that hexanoic acid (C6:0) was not detected in *arachis hypogaea* oil but *Trachurus trachurus* oil have significantly higher ($P<0.05$) hexanoic acid than other oil sources. Octanoic acid (C8:0) was not detected in *Trachurus trachurus* and *Arachis hypogaea* oil but G*allus domesticus* oil have significantly ($P<0.05$) higher octanoic acid than other oil sources. Decanoic acid (C10:0) was not detected in *Trachurus trachurus* and *Arachis hypogaea* oil but G*allus domesticus* oil have significantly higher decanoic acid than other oil sources. Dodecanoic (C12:0) acid was not detected in *Trachurus trachurus* and G*allus domesticus* oil but was significantly higher ($P<0.05$) in C*aptotermes formasanus* than the other oil sources. Tridecanoic acid (C13:0) was not detected in G*allus domesticus* and C*aptotermes formasanus* but *Arachis hypogaea* oil have significantly ($p<0.05$) higher tridecanoic acid than the other oil sources. Palmitic acid C16:0 was not detected in *Arachis hypogaea* but shows no statistically significantly different ($P>0.05$) in *Trachurus trachurus* and C*aptotermes formasanus* oil. *Arachis hypogaea* has a significantly higher heptadecanoic acid than other oil sources. *Arachis hypogaea* oil have significantly higher ($P<0.05$) Methyl stearate than other oil sources.

**Table 1:** Fatty acid profile of edible oil from different sources

| Compounds | Lipid Count | *Trachurus Trachurus* | *Chrysichthys nigrodigitatus* | Gallus domesticus | Arachis hypogaea | Coptotermes formasanus |
|---|---|---|---|---|---|---|
| Butanoic acid | C4:0 | N.D | N.D | N.D | N.D | N.D |
| Hexanoic acid | C6:0 | 5.897 ± 0.04 [a] | 4.328 ± 0.51 [c] | 5.054 ± 0.03 [b] | N.D | 4.09 ± 0.07 [c] |
| Octanoic acid | C8:0 | N.D | 4.211 ± 0.48 [b] | 4.965 ± 0.04 [a] | N.D | 4.127 ± 0.08 [b] |
| Decanoic acid | C10:0 | N.D | 4.978 ± 0.58 [b] | 5.869 ± 0.04 [a] | N.D | 4.677±0.022 [b] |
| Undecanoic acid | C11:0 | 2.869 ± 0.04 [a] | 2.139 ± 0.25 [c] | 2.541± 0.015 [b] | N.D | N.D |
| Dodecanoi c acid | C12:0 | N.D | 4.176 ± 0.48 [c] | N.D | 6.449±0.04 [b] | 15.865±0.61 [a] |
| Tridecanoic acid | C13:0 | 2.908 ±0.03 [b] | 2.134± 0.25 [c] | N.D | 3.301±0.02 [a] | N.D |
| Methyl myristoleate | C14:1 | 3.242± 0.09 [ab] | 2.693±0.52 [bc] | 2.781 ± 0.09 [bc] | 3.739±0.08 [a] | 2.503±0.05 [c] |
| Myristic acid | C14:0 | N.D | 4.148± 0.48 [c] | 4.889±0.03 [b] | 6.420±0.04 [a] | 3.920±0.03 [c] |
| Pentadecanoic acid | C15:0 | 2.906 ± 0.01 [b] | 2.126± 0.25 [d] | 2.516±0.015 [c] | 3.326±0.01 [a] | 2.023±0.01 [d] |
| 9-hexadecanoic acid | C16:1n -7 | 3.068± 0.17 [ab] | 3.207 ± 0.78 [ab] | 2.714 ± 0.06 [ab] | 3.611±0.11 [a] | 2.428±0.09 [b] |
| palmitic acid | C16:0 | 8.532±0.07 [a] | 6.257± 0.73 [b] | 7.425±0.04 [ab] | N.D | 7.551 ± 0.80 [a] |
| Cis -10-heptanoic acid | C17:1n -7 | 3.388±0.13 [abc] | 3.011±0.40 [bc] | 3.677±0.52 [ab] | 4.171±0.46 [a] | 2.472±0.036 [c] |
| Heptadecanoic acid | C17:0 | 3.044±0.03 [b] | 2.581± 0.25 [c] | 2.644±0.014 [c] | 3.454±0.025 [a] | 2.120±0.01 [d] |
| Gamma -linolenic acid | C18:3n -6 | 3.213 ± 0.11 [b] | 2.609 ± 0.10 [c] | 2.805±0.03 [c] | 3.712±0.04 [a] | 2.523 ± 0.18 [c] |
| 9,12 -octadecaienoic | C18:2n -6 | 3.177 ± 0.03 [b] | 2.690 ± 0.04 [cd] | 2.781 ± 0.03 [c] | 3.761 ± 0.19 [a] | 2.494±0.07 [d] |
| Methyl stearate | C18:0 | 5.893 ± 0.09 [b] | 4.681 ± 0.01 [d] | 5.140 ± 0.03 [c] | 6.689 ± 0.04 [a] | 4.050 ± 0.03 [e] |
| 5,8,11,14 eicosatetraenoic | C20:4n -3 | 3.639 ± 0.01 [a] | 3.158 ± 0.26 [b] | 2.992 ± 0.02 [b] | 3.938 ± 0.04 [a] | 3.009 ± 0.06 [b] |
| 8,11,14,17 eicosapentanoic | C20:5n -3 | 3.378 ± 0.02 [b] | 2.869 ± 0.15 [c] | 2.896 ± 0.02 [c] | 3.911 ± 0.05 [a] | 2.527 ± 0.08 [d] |
| 8,11,14 eicosatrienoic | C20:3n -3 | 3.321 ± 0.39 [b] | 2.493 ± 0.31 [d] | 2.870 ± 0.05 [c] | 3.743 ± 0.01 [a] | 2.323 ± 0.04 [d] |
| Cis -11 -eicosanoic acid | C20:1n -9 | 3.551 ± 0.13 [b] | 2.685 ± 0.16 [cd] | 2.896 ± 0.13 [c] | 4.144 ± 0.12 [a] | 2.501 ± 0.01 [d] |
| Eicosanoic acid | C20:0 | 5.933 ± 0.04 [b] | 4.942 ± 0.15 [d] | 5.261 ± 0.01 [c] | 6.835± 0. 03[a] | 4.178 ± 0.03 [e] |
| Heneicosanoic acid | C21:0 | 3.201 ± 0.02 [b] | 2.364 ± 0.25 [d] | 2.787 ± 0.04 [c] | 3.636 ± 0.03 [a] | 3.493± 0.24 [ab] |
| Docosahexanoic acid | C22:6n -3 | 4.362 ± 0.03 [a] | 4.933 ± 1.93 [a] | 3.800 ± 0.02 [a] | 4.790 ± 0.05 [a] | 3.066 ± 0.14 [a] |
| 13, docosanoic acid | C22:1n -9 | 3.804 ± 0.04 [b] | 3.604 ± 0.12 [bc] | 3.267 ± 0.08 [c] | 4.461 ± 0.33 [a] | 3.731 ± 0.03 [b] |
| Docosanoic acid | C22:1 | 6.283±0.07 [b] | 4.982 ± 0.01 [d] | 5.389 ± 0.03 [c] | 7.143 ± 0.16 [a] | 4.301 ± 0.02 [e] |
| Tricosanoic acid | C23:0 | 3.303 ± 0.01 [a] | 4.210 ± 2.10 [a] | 2.859 ± 0.01 [a] | 3.881 ± 0.21 [a] | 2.295 ± 0.02 [a] |
| 1,5 -tetraco senoic acid | C24:1n -9 | 4.550 ± 0.48 [a] | 3.029 ± 0.10 [b] | 3.579± 0.06 [b] | 4.884 ± 0.59 [a] | 3.132 ± 0.34 [b] |
| Tetracosanoic acid | C24:0 | 6.443 ± 0.03 [a] | 4.761 ± 0.49 [c] | 5.602 ± 0.01 [b] | N.D | 4.598 ± 0.21 [c] |

Values are expressed as mean standard deviation from duplicate determination. Different superscript, lowercase letters within columns indicates statistical significant difference ($P \leq 0.05$) N.D, not detected.

**Quality Determination of Fish Oil**

The result of the quality of the various oil extracted from different sources (Table 2) indicate that Saturated fatty acids (SFAs) were the dominant fatty acid across all oils, ranging from 43.99% in groundnut oil to 59.49% in insect oil. Among the SFAs, palmitic acid (C16:0), stearic acid (C18:0), and eicosanoic acid (C20:0) were particularly abundant in fish oils and animal fats, while dodecanoic acid (C12:0) and tetracosanoic acid (C24:0) were elevated in insect oil. Monounsaturated fatty acids (MUFAs) varied widely, with freshwater fish oil (C. *nigrodigitatus*) showing the highest proportion (27.89%), in contrast to insect oil which had the lowest (6.80%). Major MUFAs included palmitoleic acid (C16:1n-7), cis-11-eicosenoic acid (C20:1n-9), and docosenoic acid (C22:1). Polyunsaturated fatty acids (PUFAs) were most abundant in groundnut oil (45.13%), followed by marine and chicken oils (34.29% and 34.28%, respectively). Notably, essential omega-3 fatty acids such as eicosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3) were present in appreciable amounts in both marine and freshwater fish oils, with DHA concentrations reaching up to 4.93% in C. *nigrodigitatus*. In contrast, insect and plant oils contained lower levels of these long-chain n-3 PUFAs. The n-6/n-3 ratio, a critical index of nutritional quality, was lowest in marine fish oil (0.39) and highest in groundnut and insect oils (0.46). Values below 1 are considered beneficial for human cardiovascular and metabolic health.

**Table 2:** Quality determination of fish oil

| Fatty acids | Trachurus trachurus | *Chrysichthys nigrodigitatus* | Gallus domesticus | Arachis hypogaea | Coptotermes formasanus |
|---|---|---|---|---|---|
| ΣFA | 100 | 99.94 | 100 | 96.24 | 100 |
| ΣSFA | 58.04 | 51.03 | 57.55 | 43.99 | 59.49 |
| ΣMUFA | 7.67 | 27.89 | 8.17 | 10.88 | 6.80 |
| ΣPUFA | 34.29 | 25.42 | 34.28 | 45.13 | 30.21 |
| n-6 | 5.30 | 6.39 | 5.59 | 7.47 | 5.05 |
| n-3 | 13.45 | 14.70 | 12.56 | 16.38 | 10.93 |
| n-6/3 | 0.39 | 0.43 | 0.45 | 0.46 | 0.46 |

Values are expressed as mean from duplicate determination. SFA, saturated fatty acid; MUFA, monounsaturated, PUFA, polyunsaturated fatty acid

## DISCUSSION

The result of this study (Table 2) which show that there is relatively low n-6/n-3 ratios (<0.45) in fish oils compared with oil obtained from other sources indicate superior nutritional quality of fish oil compared to groundnut, chicken and insect oils, which had higher ratios as elevated n-6/n-3 ratios have been associated with chronic diseases, including obesity, cardiovascular disorders, and diabetes (Simopoulos, 2020). Marine (*T. trachurus*) and freshwater (C. *nigrodigitatus*) fish oils were rich in long-chain n-3 PUFAs, particularly EPA and DHA, which are critical for brain development, visual function, and reducing inflammation (Calder, 2022). In addition, high SFA content in both fish and insect oils suggests thermal stability, which may be advantageous for food processing but less desirable for cardiovascular health if consumed in excess (Micha et al., 2020). Conversely, groundnut oil, with its lower SFA proportion and higher PUFA content (45.13%), aligns with plant oil profiles known for cardioprotective properties (Chen *et al.*, 2021). High value of MUFA observed in C. *nigrodigitatus* oil (27.89%) a fresh

water fish indicate that oil extracted from this fish will be good in enhancing oxidative stability, suggesting that it has potential industrial applications in functional food formulations. MUFA-rich oils, particularly oleic acid dominant ones, have been linked to improved lipid metabolism and reduced risk of coronary heart disease (Schwingshackl *et al.*, 2021). Although C. *formasanus* oil showed relatively high SFA content (59.49%) and modest PUFA levels (30.21%), it represents a sustainable alternative fat source. Insect-derived lipids are gaining attention for their application in animal feed and as a sustainable food ingredient (Tzompa-Sosa & Fogliano, 2021). However, its high n-6/n-3 ratio compared to fish oils suggests limited direct nutritional advantage for human consumption unless blended with omega-3–rich oils. Groundnut oil stood out with the highest PUFA proportion (45.13%) and favorable MUFA/PUFA balance, making it valuable for cardiovascular health. However, it lacked significant levels of long-chain n-3 fatty acids (EPA, DHA), highlighting its complementary role rather than a substitute for fish oil in diets requiring omega-3 supplementation (Zhou *et al.*, 2022). This study generally indicate that fish oils remain the most nutritionally advantageous due to their high EPA, DHA, and favorable n-6/n-3 ratios. Groundnut oil also have its advantage as it could be very useful in improving cardiovascular health but it major limitation is the lack of essential long-chain omega-3s. Insect oil on the other hand presents a promising sustainable source but requires fortification or blending with fish oils to optimize its nutritional quality. These findings support the continued promotion of fish oils in human nutrition and aquaculture feed, while highlighting the complementary roles of plant and insect oils in sustainable food systems.

## CONCLUSION AND RECOMMENDATION

This study demonstrated clear compositional differences in the fatty acid profiles of oils from marine and freshwater fish, chicken, groundnut, and insects. Marine (*Trachurus trachurus*) and freshwater (*Chrysichthys nigrodigitatus*) fish oils were superior in nutritional quality, characterized by appreciable concentrations of long-chain omega-3 fatty acids (EPA and DHA) and favorable n-6/n-3 ratios (<0.45). Groundnut oil, while rich in total PUFAs, lacked these essential long-chain n-3 fatty acids, highlighting the superiority of fish oil compared with oil from other sources while oil from other sources can play complementary role rather than substitutive role to fish oils in human diets. Insect oil, though sustainable, was dominated by SFAs and showed limited nutritional benefits compared to fish and plant oils. It is therefore recommended that fish oil consumption should be prioritized in human diet than oil from other sources it (fish oil) remain the most nutritionally advantageous edible oil among the oil studied, while plant and insect oils can serve as supplemental or functional alternatives depending on dietary and industrial needs.

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# EFFECT OF SPICE TREATMENT ON THE PROXIMATE COMPOSITION OF FISH FLOSS FROM TILAPIA *(Oreochromis niloticus)*

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**ABSTRACT**

*This study investigated the production and proximate composition of fish floss from Nile tilapia (Oreochromis niloticus), with emphasis on the effects of spice treatments on nutritional quality and storage stability. Fresh tilapia samples were processed into floss using standardized methods, with four treatments: control (untreated), ginger, clove, and a ginger–clove combination. Proximate composition was analyzed following AOAC methods. Data collected were subjected to two-way ANOVA with significance at $P < 0.05$. Results showed that moisture content decreased significantly in the control samples but remained more stable in spiced treatments, suggesting improved shelf-life. Ash and crude fibre levels were higher in spiced treatments, indicating mineral and dietary fibre contributions from spices. Fat content was more stable in spiced floss, supporting the ant oxidative role of ginger and clove, while protein values were better preserved in spiced treatments compared to the control. Carbohydrate levels declined over storage, likely due to non-enzymatic browning and microbial activity. Overall, spiced tilapia floss demonstrated superior nutritional retention and stability compared to the un- spiced sample. The findings highlighted the potential of spice incorporation to enhance the nutrient quality, safety, and shelf-life of value-added fish products.*

**Keywords:** Production, Proximate Composition, Fish Floss, *Oreochromis niloticus* Spice Treatment

## INTRODUCTION

Tilapia (*Oreochromis niloticus*) is among the most important freshwater species in global aquaculture, providing a large share of affordable animal protein for low- and middle-income countries. Their rapid growth rates, adaptability to diverse culture systems, and widespread consumer acceptance have driven increases in production over the past decade (Barría *et al.*, 2023; Liu *et al.*, 2015).

Value-added processing of fish into shelf-stable, convenient products can reduce post-harvest losses, extend market reach, and increase incomes for small-scale producers and processors. One such product is fish floss, locally called "abon ikan" or shredded fish floss, a dried, seasoned fish product consumed as a condiment, snack, or protein topper. Its low moisture and concentrated nutrients make it attractive as a preservation and value-addition pathway for both tilapia and catfish (Nathalia, 2023).

"Dambun kifi" (fish floss) is a fish product produced mostly in the northern Nigeria by mainly the Hausas and Fulanis. It is a shredded or mashed fish meat/flesh cooked in spices, and then stir fried until the fish flesh is dry and powdery. Fish floss is quite different from other flosses, it has very nice and attracting aroma ahead of them. It is quite easier, though, it also requires time and energy, but fish due to its softness do not need grinding or beating with a wooden stick. It requires less oil than other flosses. (Lisa, 2019).

From a food security and livelihoods perspective, converting tilapia into fish floss also unlocks supply-chain resilience. Floss is lightweight, transportable, and less perishable than chilled fillets, permitting distribution to inland and off-season markets. Moreover, by transforming whole fish or by-products into shelf-stable products, smallholder fish farmers and microprocessors can capture additional value and reduce waste (Peñarubia *et al.*, 2023; Nathalia, 2023). The current study aims to produce fish floss from *Tilapia (Oreochromis niloticus)* and analyze the proximate composition to assess nutritional value.

## MATERIALS AND METHOD

### Study Area

The study was carried out in the Fish Processing Unit and the Hospitality Department of the Federal College of Freshwater Fisheries Technology (FCFFT), New Bussa, Niger State, Nigeria.

### Geographical Location

New Bussa is the headquarters of Borgu Emirate and Borgu Local Government Area in Niger State, Nigeria. It is geographically located at latitude 9°53′N and longitude 4°31′E (NIFFR Archives, 2023).

### Source of Experimental Fish

The experimental fish species and Nile *tilapia (Oreochromis niloticus)*, were purchased fresh from the Monday Market, New Bussa, Borgu Local Government Area, Niger State, Nigeria.

### Materials

The materials used in the experiment included fresh fish samples, sodium chloride (NaCl; table salt), ginger *(Zingiber officinale)*, clove *(Syzygium aromaticum)*, seasoning cubes, onion *(Allium cepa)*, pepper *(Capsicum annuum)*, vegetable oil, curry powder, thyme, lime *(Citrus aurantiifolia)*, stainless steel bowls, sharp knife, cutting slab, turning spoon, frying pot, packaging materials, weighing balance *(Diamond and Five Goats' Products)*, and a Smeg electric cooker.

### Experimental Design

A total of 20 kg of tilapia (*Oreochromis niloticus*) was processed. Three spice treatments were used: ginger, clove, and a combination of ginger and clove. Each treatment was replicated three times, giving a total of twelve (12) experimental samples.

### Procedure for Production of Fish Floss

The production of fish floss followed the method described by Isah (2018) with slight modifications. The fish samples were rubbed with lime juice to remove surface slime, washed thoroughly with clean water, descaled, degutted, and de-finned. Each 5 kg portion was weighed using a digital weighing balance. Ten grams (10 g) of table salt, five (5) seasoning cubes, two chopped onion bulbs, and 100 g of fresh pepper were added to each sample. The appropriate spice treatment (ginger, clove, or combination) was incorporated according to the design.

The fish was cooked at 63 °C for 30 minutes using a Smeg electric cooker, following FDA/USDA (2021) safe cooking guidelines, until the flesh became tender. After cooking, the fish was strained to reduce moisture (Winarni *et al.*,2021), deboned, and deskinned to obtain boneless flesh. The flesh was shredded into fine fibers and shallow-fried with two (2) tablespoons of vegetable oil at 150 °C for 30 minutes, until the moisture content reached a level suitable for shelf-life stability.

### Proximate Analysis

Proximate composition of the fish samples was determined following the methods of AOAC (2015).

**Moisture Content**
Moisture was determined using the oven-drying method. Two grams of fish sample were dried at 100 °C to constant weight and cooled in a desiccator before weighing.

$$\%Moisture = \frac{Loss\ in\ weight}{Sample\ weight} \times 100$$

**Crude Protein**
Protein content was determined by the Micro-Kjeldahl method. Total nitrogen obtained was multiplied by 6.25 to estimate crude protein.

**Ash Content**
Samples were ignited in a muffle furnace at 550–600 °C until a whitish-grey ash was obtained, cooled in a desiccator, and weighed.

$$\%Ash = \frac{Weight\ of\ ash}{Sample\ weight} \times 100$$

**Crude Fat**
Crude fat was determined by Soxhlet extraction using petroleum ether as solvent. The solvent was evaporated, and the flask dried and reweighed.

$$\%Fat = \frac{Weight\ of\ extract}{Sample\ weight} \times 100$$

**Crude Fibre**
Defatted samples were digested with dilute acid and alkali, filtered, dried, incinerated at 550 °C, and reweighed.

$$\%Crude\ Fibre = \frac{Residue - Ash}{Sample\ weight} \times 100$$

**Nitrogen-Free Extract (NFE)**
NFE was obtained by difference:
%NFE=100 − (%Moisture+%Protein+%Fat+%Fibre+%Ash)%

**Data Analysis**
Data obtained from the proximate composition of fish floss produced from *Tilapia* (*Oreochromis niloticus*) were subjected to two-way Analysis of Variance (ANOVA) using SPSS (Version 25.0). Treatment means were separated using Duncan's Multiple Range Test (DMRT) at a significance level of $p < 0.05$.

**RESULTS**
**Moisture Content of Fish Floss Produced from Tilapia**
In the un-spiced sample (T0), the moisture content started at $9.74\pm0.03^{a,B}$, decreased to $9.24\pm0.03^{a,B}$ in month 1, and further to $8.83\pm0.03^{a,c}$ in month 2. It then increased to $9.44\pm0.02^{a,B}$ in month 3, peaked at $10.32\pm0.03^{a,A}$ in month 4, remained high at $10.38\pm0.03^{a,A}$ in month 5, and finally settled at $9.29\pm0.03^{a,B}$ in month 6. Treatment T1 began at $5.08\pm0.03^{b,C}$, rose to $5.51\pm0.03^{c,c}$ in month 1, and to $6.07\pm0.03^{b,B}$ in month 2. The moisture peaked at $6.76\pm0.04^{c,B}$ in month 3, then rose to $8.88\pm0.03^{b,A}$ in month 4, slightly declined to $8.65\pm0.03^{b,A}$ in month 5, and ended at $8.35\pm0.03^{b,A}$ in month 6. In T2, the lowest starting value was $4.96\pm0.03^{c,C}$, which increased to $6.09\pm0.03^{b,B}$ in month 1 and to $6.53\pm0.03^{b,B}$ in month 2. The upward trend continued to $7.22\pm0.03^{b,A}$ in month 3, $7.67\pm0.03^{c,A}$ in month 4 and remained the same through months 5 and 6. Treatment T3 began at $5.13\pm0.03^{c,C}$, increased to $5.55\pm0.02^{c,C}$ in month 1, and to $6.28\pm0.03^{b,B}$ in month 2. The moisture content continued rising to $7.01\pm0.08^{b,A}$ in month 3, then reached $7.45\pm0.03^{c,A}$ in months 4 and 5, and slightly dropped to $7.22\pm0.03^{c,A}$ in month 6.

**The Percentage Ash Content of Fish Floss Produced from Tilapia**

In contrast, Table 4.2b presents the ash content of fish floss produced from tilapia from treatments T0 to T3. Initially, the un-spiced control (T0) had the lowest ash content at $3.92 \pm 0.03^{b'B}$, while T1, T2, and T3 had higher initial values of $4.67 \pm 0.03^{a'A}$, $4.37 \pm 0.03^{a'A}$, and $4.62 \pm 0.03^{a'B}$, respectively. Over time, T0 showed a steady increase, reaching $4.73 \pm 0.16^{a'A}$ at six months, with significant differences observed at various points, such as $4.33 \pm 0.03^{b'A}$ at month 3 and $4.64 \pm 0.03^{a'A}$ at month 4. T1 and T2 remained relatively consistent, with values ranging from $4.52 \pm 0.03^{a'A}$ to $4.82 \pm 0.03^{a'A}$, while T3 consistently showed the highest ash content, reaching $5.01 \pm 0.08^{a'A}$ at month 3 and maintaining high values like $4.89 \pm 0.03^{a'B}$ and $4.86 \pm 0.03^{a'B}$ toward the end. The different superscripts ($^{a}$/$^{b}$ and $^{A}$/$^{B}$/β) indicate that there were significant differences ($p < 0.05$) both among samples and across storage duration in the tilapia samples.

In summary, while the ash content in catfish fish floss remained statistically unchanged regardless of treatment or storage time, the tilapia fish floss showed significant variation in ash content, particularly between the control (T0) and the spiced treatments (especially T3), highlighting that spice type significantly influenced the ash content during storage.

**Percentage Fat Content of Fish Floss Produced from Tilapia**

The fat content of tilapia fish floss also varied with spice type and storage duration:
T0 (no spice) showed relatively stable fat content, starting at $15.47 \pm 0.03^{b'A}$ and ending at $14.30 \pm 0.03^{b'B}$, indicating significant change over time ($^{A}$ to $^{B}$), but not across spice types within months ($^{b}$ throughout).
T1 began with the lowest fat content at $14.41 \pm 0.03^{c'C}$ and rose to $15.97 \pm 0.03^{a'B}$ by month 6, with superscripts showing statistical differences both over time ($^{c}$ to $^{a}$) and across spice types ($^{c}$ to $^{B}$).
T2 maintained the highest and most stable fat content, ranging from $16.25 \pm 0.03^{a'A}$ initially to $15.58 \pm 0.03^{a'B}$ at month 6. The minimal change in superscripts ($^{a'A}$ to $^{a'B}$) suggests very stable fat content with no significant difference among spice types, and a slight change over time.
T3 showed steady fat values from $15.77 \pm 0.03^{b'B}$ to $15.90 \pm 0.03^{a'B}$, with only a minor statistical difference among spice types ($^{b}$ to $^{a}$), and no significant variation over time ($^{B}$ throughout).

**Percentage Crude Protein Content of Fish Floss Produced from Tilapia**

Treatment T0 started with 56.85% protein content but showed a steady decline over six months, ending at 56.60%.
Treatment T1 had an initial value of 59.47%, with some fluctuation but generally maintained protein content around 60% to 62% over the months, peaking at 62.00% at month 6.
Treatment T2 began at 58.16%, showing an increase to around 62.42% by month 1 and maintained values around 60.35% to 65.10% over the period.
Treatment T3 started at 59.90% and showed a slight variation but remained fairly stable, fluctuating around 60% to 60.50% throughout the six months.

**Crude fibre Content of Fish Floss Produced from Tilapia**

For treatment T0, crude fibre content started at $1.47 \pm 0.03^{a'A}$ and decreased to $1.26 \pm 0.03^{a,A}$ in month 1 and $1.15 \pm 0.03^{a'A}$ in month 2. It then increased to $1.20 \pm 0.01^{a'A}$ in month 3, followed by further increases to $1.51 \pm 0.03^{a'A}$ in month 4 and $1.49 \pm 0.03^{a,A}$ in month 5 , with a slight increase to $1.53 \pm 0.03^{a'A}$ in month 6.
For treatment T1, the initial value was $1.55 \pm 0.03^{a'A}$ which decreased through months 1 to 3 ($1.32 \pm 0.03^{a'A}$, $1.22 \pm 0.03^{a'A}$, $1.22 \pm 0.03^{a'A}$). It increased to $1.28 \pm 0.03^{ab'A}$ in month 4, then increased steadily to $1.35 \pm 0.03^{a'A}$ in month 5 and $1.47 \pm 0.03^{a'A}$ in month 6.
For sample T2, crude fibre started at $1.33 \pm 0.03^{a'A}$ and decreased consistently through months 1 to 3

(1.23±0.03$^{a,A}$, 1.06±0.03$^{a,A}$, and 1.28±0.04$^{a,A}$), then rose to 1.36±0.03$^{a,A}$ in month 4, 1.38±0.03$^{a,A}$ in month 5, and finally peaked at 1.47±0.03$^{a,A}$ in month 6.
For treatment T3, initial crude fibre was 1.41±0.01$^{a,A}$ and decreased slightly in months 1 and 2 (1.32±0.01$^{a,A}$, 1.14±0.03$^{a,A}$), then increased significantly in months 3 to 6: 1.29±0.07$^{a,A}$ 1.60±0.03$^{a,A}$ 1.33±0.03$^{a,A}$ and 1.55±0.03$^{a,A}$ respectively.

**Carbohydrate Composition of Fish Floss Produced from Tilapia**
For Treatment T0, the initial carbohydrate content was 12.53±0.13$^{c,D}$. It fluctuated during storage, reaching a high of 15.06±0.22$^{a,A}$ at month 3 and a low of 11.72±0.13$^{a,E}$ at month 5.
For Treatment T1, the initial carbohydrate content was 14.80±0.13$^{a,A}$. It decreased notably to 7.31±0.24$^{e,f}$ by month 6, with significant changes at months 2 (9.23±0.12$^{d,D}$), 4 (8.29±0.11$^{c,E}$), 5 (9.23±0.13$^{d,D}$), and 6. For Treatment T2, the initial carbohydrate content was 14.91±0.13$^{a,A}$. The values remained relatively stable throughout storage, ranging from 9.32±0.13$^{d,E}$ to 14.91±0.13$^{a,A}$.
For Treatment T3, the initial carbohydrate content was 13.19±0.12$^{b,A}$. There was a significant increase at month 1 (12.27±0.03$^{b,B}$) and a notable peak at month 3 (10.29±0.25$^{d,c}$), followed by slight fluctuations.

**Table 2:** Percentage Ash Content of Fish Floss Produced from Tilapia

| | Months | | | | | | |
|---|---|---|---|---|---|---|---|
| Treatment | Initial | 1 | 2 | 3 | 4 | 5 | 6 |
| T0 | 3.92±0.03$^{b,b}$ | 4.09±0.03$^{a,a}$ | 4.19±0.03$^{a,a}$ | 4.33±0.03$^{b,a}$ | 4.64±0.03$^{a,a}$ | 4.49±0.03$^{a,a}$ | 4.73±0.16$^{a,a}$ |
| T1 | 4.67±0.03$^{a,a}$ | 4.56±0.03$^{a,a}$ | 4.52±0.03$^{a,a}$ | 4.88±0.03$^{b,a}$ | 4.92±0.03$^{a,a}$ | 4.76±0.03$^{a,a}$ | 4.82±0.03$^{a,a}$ |
| T2 | 4.37±0.03$^{a,a}$ | 4.67±0.03$^{a,a}$ | 4.60±0.03$^{a,a}$ | 4.72±0.03$^{b,}$ | 4.75±0.03$^{a,a}$ | 4.75±0.03$^{a,a}$ | 4.79±0.03$^{a,a}$ |
| T3 | 4.62±0.03$^{a,b}$ | 4.81±0.01$^{a,b}$ | 4.87±0.03$^{a,b}$ | 5.01±0.08$^{a,a}$ | 4.89±0.03$^{a,b}$ | 4.89±0.03$^{a,b}$ | 4.86±0.03$^{a,b}$ |

Mean values in the same column carrying different superscripts differ significantly from each other at P < 0.05

**Table 3:** Percentage Fat Content of Fish Floss Produced from Tilapia

| | Months | | | | | | |
|---|---|---|---|---|---|---|---|
| Treatment | Initial | 1 | 2 | 3 | 4 | 5 | 6 |
| T0 | 15.47±0.03$^{b,a}$ | 15.47±0.03$^{b,a}$ | 15.05±0.03$^{b,a}$ | 14.23±0.03$^{c,b}$ | 14.17±0.03$^{c,b}$ | 14.38±0.03$^{b,b}$ | 14.30±0.03$^{b,b}$ |
| T1 | 14.41±0.03$^{c,c}$ | 14.41±0.03$^{c,c}$ | 15.17±0.03$^{b,b}$ | 15.51±1.15$^{b,b}$ | 16.32±0.03$^{a,a}$ | 15.79±0.03$^{a,b}$ | 15.97±0.03$^{a,b}$ |
| T2 | 16.25±0.03$^{a,a}$ | 16.25±0.03$^{a,a}$ | 16.15±0.03$^{a,a}$ | 15.48±0.08$^{b,b}$ | 15.49±0.03$^{b,b}$ | 15.49±0.03$^{a,b}$ | 15.58±0.03$^{a,b}$ |
| T3 | 15.77±0.03$^{b,b}$ | 15.78±0.02$^{b,b}$ | 15.43±0.03$^{b,b}$ | 16.08±0.08$^{a,a}$ | 15.74±0.03$^{b,b}$ | 15.74±0.03$^{a,b}$ | 15.90±0.03$^{a,b}$ |

Mean values in the same column carrying the same superscript do not differ significantly from each other, at P > 0.05

**Table 4:** Percentage Crude Protein Content of Fish Floss Produced from Tilapia

| | Months | | | | | | |
|---|---|---|---|---|---|---|---|
| Treatment | Initial | 1 | 2 | 3 | 4 | 5 | 6 |
| T0 | 56.85±0.03$^{c,c}$ | 58.07±0.03$^{d,a}$ | 55.97±0.03$^{d,d}$ | 55.75±0.17$^{b,d}$ | 55.00±0.03$^{b,e}$ | 57.52±0.03$^{b,b}$ | 56.60±0.03$^{c,c}$ |
| T1 | 59.47±0.03$^{a,c}$ | 59.97±0.03$^{c,c}$ | 60.42±0.03$^{b,b}$ | 60.70±0.13$^{a,b}$ | 60.30±0.03$^{a,b}$ | 60.20±0.03$^{a,b}$ | 62.00±0.03$^{a,a}$ |
| T2 | 58.16±0.03$^{b,c}$ | 62.42±0.03$^{a,b}$ | 65.10±0.03$^{a,a}$ | 60.50±0.12$^{a,b}$ | 60.50±0.03$^{a,b}$ | 60.72±0.03$^{a,b}$ | 60.35±0.03$^{b,b}$ |
| T3 | 59.90±0.03$^{a,b}$ | 60.28±0.01$^{b,a}$ | 59.97±0.03$^{c,b}$ | 60.32±0.03$^{a,a}$ | 60.10±0.03$^{a,a}$ | 60.38±0.03$^{a,a}$ | 60.50±0.03$^{b,a}$ |

Mean values in the same column carrying different superscripts differ significantly from each other at P < 0.05

**Table 5:** Percentage Crude Fibre Content of Fish Floss Produced from Tilapia

| | Months | | | | | | |
|---|---|---|---|---|---|---|---|
| Spice type | Initial | 1 | 2 | 3 | 4 | 5 | 6 |
| T0 | 1.47±0.03$^{a,a}$ | 1.26±0.03$^{a,a}$ | 1.15±0.03$^{a,a}$ | **1.20±0.01**$^{a,a}$ | 1.51±0.03$^{a,a}$ | **1.49±0.03**$^{a,a}$ | 1.53±0.03$^{a,a}$ |
| T1 | **1.55±0.03**$^{a,a}$ | **1.32±0.03**$^{a,a}$ | **1.22±0.03**$^{a,a}$ | 1.22±0.03$^{a,a}$ | **1.28±0.03**$^{ab,a}$ | 1.35±0.03$^{a,a}$ | **1.47±0.03**$^{a,a}$ |
| T2 | **1.33±0.03**$^{a,a}$ | **1.23±0.03**$^{a,a}$ | **1.06±0.03**$^{a,a}$ | 1.28±0.04$^{a,a}$ | 1.36±0.03$^{a,a}$ | 1.38±0.03$^{a,a}$ | **1.47±0.03**$^{a,a}$ |
| T3 | 1.41±0.01$^{a,a}$ | 1.32±0.01$^{a,a}$ | 1.14±0.03$^{a,a}$ | **1.29±0.07**$^{a,a}$ | **1.60±0.03**$^{a,a}$ | **1.33±0.03**$^{a,a}$ | **1.55±0.03**$^{a,a}$ |

Mean values in the same column carrying the same superscript do not differ significantly from each other, at P > 0.05

**Table 6:** Percentage Carbohydrates composition of fish floss produced from tilapia

| | Storage duration (months) | | | | | | |
|---|---|---|---|---|---|---|---|
| Treatment | Initial | 1 | 2 | 3 | 4 | 5 | 6 |
| T0 | **12.53±0.13**$^{c,d}$ | 11.85±0.13$^{c,c}$ | **11.85±0.11**$^{c,e}$ | **15.06±0.22**$^{a,a}$ | **14.32±0.16**$^{a,b}$ | 11.72±0.13$^{a,e}$ | 13.53±0.21$^{a,c}$ |
| T1 | 14.80±0.13$^{a,a}$ | **14.21±0.13**$^{a,b}$ | **9.23±0.12**$^{d,d}$ | 10.94±1.34$^{b,c}$ | **8.29±0.11**$^{c,e}$ | **9.23±0.13**$^{d,d}$ | **7.31±0.24**$^{c,f}$ |
| T2 | **14.91±0.13**$^{a,a}$ | **9.32±0.13**$^{d,e}$ | 10.22±0.11$^{b,c}$ | 10.79±0.01$^{c,b}$ | 10.22±0.11$^{b,c}$ | 9.97±0.13$^{c,d}$ | 10.12±0.13$^{b,c}$ |
| T3 | 13.19±0.12$^{b,a}$ | 12.27±0.03$^{b,b}$ | 10.19±0.13$^{b,c}$ | **10.29±0.25**$^{d,c}$ | 10.24±0.15$^{b,c}$ | 10.19±0.13$^{b,c}$ | 9.95±0.13$^{b,d}$ |

Mean values in the same column carrying the same superscript do not differ significantly from each other, at P > 0.05

## DISCUSSION

The results revealed that moisture content in tilapia fish floss varied with spice treatment and storage duration. The un-spiced sample (T0) maintained higher moisture levels throughout, having its peak at month 5 (10.38±0.03$^{a,a}$) before declining. In contrast, spiced treatments (T1–T3) consistently showed lower moisture contents, particularly at the initial stage, with T2 recording the lowest (4.96±0.03$^{c,C}$). This suggests that the addition of ginger, clove, and their combination aided in reducing water activity, possibly due to their hygroscopic and antimicrobial properties.

These findings align with Obi *et al*. (2015), who reported that spice incorporation into fish products reduces moisture levels by enhancing dehydration and inhibiting microbial growth. Similarly, Okoro *et al*. (2018) observed that clove and ginger-treated smoked fish had lower moisture content compared to un-spiced controls, which they attributed to improved preservative action of the spices. Maintaining lower moisture is beneficial since high moisture accelerates microbial spoilage and lipid oxidation in fish products.

Ash content increased significantly in spiced treatments compared to the control, with T3 (ginger–clove combination) consistently showing the highest values (up to 5.01±0.08$^{a,a}$). This indicates that spices contributed additional minerals and inorganic constituents. The steady rise in T0 (control) suggests concentration effects as moisture declined, but spice addition clearly enhanced mineral composition.

This agrees with Akinwumi (2014), who reported higher ash values in spice-treated catfish due to the mineral content of ginger and clove. Similarly, Fasakin *et al*. (2017) noted that plant-derived spices not only improve flavor but also contribute bioactive minerals that enrich proximate composition.

Fat content showed treatment-specific variations. T2 (ginger-treated floss) retained the highest and most stable fat levels (16.25±0.03$^{a,A}$–15.58±0.03$^{a,B}$), while T1 initially had the lowest but significantly increased during the storage period. The control (T0) declined gradually, suggesting higher susceptibility

to oxidative deterioration. The relative stability in T2 and T3 reflects the antioxidant potential of ginger and clove in retarding lipid oxidation.

This observation is supported by Onyeka *et al*. (2019), who found that ginger and clove extracts reduce peroxide values in fish-based snacks, thereby preserving fat content. Antioxidant spices inhibit rancidity, extending shelf stability and nutritional quality of fish products (Agbo *et al*., 2016).
Protein remained high across samples T1 and T2 showing slight increase during storage (up to $65.10\pm0.03^{a,A}$). The control (T0) recorded a slow decline, indicating that spice addition helped preserve protein integrity, possibly through reduced microbial degradation and antioxidative protection.
This aligns with Eyo (2001) and Nwanna *et al*. (2010), who emphasized that dried fish products maintain high protein values, but quality loss occurs during storage without preservatives. The protein stability in spiced floss suggests that ginger and clove enhance protein preservation, a result similar to findings by Adeleke & Abiodun (2015) in spiced fish crackers.

Fibre levels were generally low, as expected in fish products, but minor increases were noted in later storage months, particularly in spiced samples (T2 and T3). This may reflect the contribution of plant-derived spice residues, as ginger and clove contain crude fibre components.
Akinola *et al*. (2013) also observed slight increases in fibre content of spice-coated fish snacks, attributing it to dietary fibre inherent in plant additives.

Carbohydrate levels fluctuated across treatments, with T0 showing wide variation ($12.53\pm0.13^{c,D}$–$15.06\pm0.22^{a,A}$), while spiced treatments showed more stable trends. T1 declined sharply toward the end ($7.31\pm0.24^{c,F}$), whereas T2 maintained relative stability. The variations likely reflect residual glycogen breakdown and metabolic changes during storage.
This finding is consistent with Ikeme (2010), who noted that fish products show fluctuations in carbohydrate content due to enzymatic activity and storage conditions. The relative stability in ginger and clove-treated samples supports the view that spices reduce biochemical degradation during storage.

## CONCLUSION

The study revealed that both spice incorporation and storage duration had significant effects on the proximate composition of fish floss produced from catfish and tilapia. Moisture content generally decreased in un-spiced samples but fluctuated in spiced treatments, suggesting that spices play a role in moisture regulation and shelf stability. Ash content remained largely stable in catfish floss but varied in tilapia, indicating that spices may enhance mineral retention. Fat and protein contents were better preserved in spiced treatments, supporting the ant oxidative and antimicrobial benefits of spices, while un-spiced samples were more prone to lipid oxidation and protein degradation. The observed increases in crude fibre further emphasized the contributory role of spices, while the gradual decline in carbohydrate levels reflected storage-induced biochemical changes.

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# PROXIMATE, CHEMICAL AND SENSORY ASSESSMENT OF FRESH AND SUPER BRINED *Oreochromis niloticus* (*Linnaeus,* 1758) UNDER COLD STORAGE.

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**ABSTRACT**
*Salting and brining techniques in fish preservation have generally been applied since ancient days. This study examined the quality characteristics of fresh and super-brined Oreochromis niloticus under cold storage. Fresh samples of Oreochromis niloticus fish were treated with salt (super brined) labelled batch A while another set of fresh untreated fish as batch B, respectively. Both batches were stored in the cold store for 6 weeks at freezing temperature of -21°C. They were first analysed after 24hours of freezing and subsequently at two weeks interval for proximate, chemical and sensory attributes using standard measures. The results of all parameters for batches A and B differ but not significant ($p<0.05$). There was also positive linear correlation between the two fish sample batches for the measurable parameters. This study showed that brining has positive effects on fish under cold storage but did not significantly alter the nutrient and chemical composition.*

**Keywords**: Chemical composition, proximate composition, super brined, *Oreochromis niloticus*, sensory assessment

## INTRODUCTION

Fish is generally known to contain nutritious value and it is the main food source of protein in many countries including Nigeria (Umar, 2018). Fish and seafood products contain lipid, minerals and vitamins and protein which is made up of essential amino acids like lysine and methionine which are limited in other animals (Pasqualino *et al*., 2023). Fish is categorized as aquatic organism with high perishability features, and there is need for constant assurance of its characters in terms of safety, and extension of shelf-life (Fawole and Oyelese, 2019). Salting is a method of fish preservation in many countries of the world. Salting of fish removes water and lowers the water activity thereby reducing the water available to support microbial growth which causes spoilage (Oku and Amamakoromo, 2023). When fish is immersed with brine, the rate of salt penetration into the fish muscle is higher than that obtained by dry salting (Aberoumand and Ziaei-Nejad, 2015). According to Amaral *et al*. (2021), fresh fish is a perishable food with very short shelf life under refrigeration and several methods have been deployed to slow down its deterioration. This he said include chemical-based approaches for fresh fish preservation, applied either singly or in combination with chemical additives such as organic acids and natural extracts with icing systems. As observed by Ghosh *et al*. (2022), the food industry faces a conundrum because customers desire wholesome, nourishing cuisine that is both tasty and convenient. Therefore, this study sought to investigate the influence of brine salting on the nutrient composition and quality attributes of super brined and fresh tilapia fish (*Oreochromis niloticus*) under cold storage.

## MATERIALS AND METHODS

### Collection of Samples

Forty-eight (48) live samples of *Oreochromis niloticus* with average weight of 450gm were obtained from Asejire dam. It is located approximately on longitude 4º 7' 58.31" East of the Greenwich meridian and Latitude 7º 21' 46.47" North of the equator and 30 kilometers East of Ibadan, Oyo state, Nigeria. The fish

samples were kept in ice box and immediately transported to the laboratory of Aquaculture and Fisheries Management University of Ibadan. The fish were unlived and divided into two batches and put into separate bowls. Batch A was brined (super brined) and was treated with brine solution while Batch B (fresh) was left untreated. Super brining solution was prepared by allowing 350g of common salt (Sodium chloride) to be dissolved in one litre of water (Dobson, 1993). The sample A is then immersed in brine solution representing super brined and left for 6 hours. The brined sample A representing the super brined (treated), and fresh sample batch B (control), were kept in the cold storage at -21$^0$C for six weeks. Sampling was undertaken on the raw materials at week 0, 2, 4 and 6. Sampling at week 0 was carried out by withdrawing samples that had been frozen under brine or control conditions and analysed 24 hours after. Fish samples were subsequently withdrawn from the cold store bi-weekly to test for the proximate, chemical and sensory analysis. This is to determine any possible alteration in nutrient composition and quality attributes that might have taken place in the fresh and brined fish samples.

**Proximate analysis**
The proximate analysis which includes crude protein, crude ash, crude fibre and crude fat and moisture was determined according to the method of AOAC (2006).

**Chemical analysis**
Free Fatty Acid content (FFA) was analysed using method of AOAC (2006). Peroxide Value (PV) was determined according to method by Hasegawa (1987). The peroxide value was expressed as milliequivalents of free iodine per kg of the fish oil. TVB-N was determined using the titration method of Malle and Poumeyrol (1989) as outlined by EU/EC (1995). TVB-N content was expressed as mgN/100g of fish flesh.

**Organoleptic assessment**
Sensory assessment was carried out on the uncooked and the cooked frsh and super brined samples of Tilapia (*Oreochromis niloticus*) at the processing unit of the university fish farm by five trained students of the University of Ibadan. The assessment was based on the scoring system, on a 7-point Hedonic scale on the determination of characteristics according to Minim, (2006). Seven categories were ranked: very much liked (7), liked a lot (6), liked (5), liked and did not like (4), disliked (3), much disliked (2), very much disliked (1).

**Statistical Analysis**
T-test and correlation analysis (r) were used to compare the means for proximate composition, chemical indices and sensory score of fresh and super brined *Oreochromis niloticus* at cold storage condition.

## RESULTS AND DISCUSSION
The mean value for protein and fat as shown in Table 1 were higher for super brined than fresh *O. niloticus* which recorded higher ash, fibre and moisture content accordingly. There is however no significant difference ($p=<0.05$) in the values for both samples. There was also positive correlation (0.664-0.999) between the mean proximate concentrations for both samples. This indicates that the brining process did not significantly alter the nutrient composition of both samples. This result was supported by Binici and Kaya, (2018), who stated that brined fish often show variation in crude protein, lipid and moisture content. Pre-freezing treatment according to Yang *et al*. (2020), affects the degree of quality changes in fish. Pongsetkul *et al*. (2022) and Yu *et al*. (2024) in their findings also stated that protein content is largely retained numerically under frozen storage but protein quality declines as myofibrillar proteins undergo phosphorylation changes, sulfhydryl loss and fragmentation which affects functional value and texture.

**Table 1:** Mean proximate values and standard deviation (%) for fresh and super brined *O. niloticus*

| Fish sample | Protein (%) | Fat (%) | Ash (%) | Fibre (%) | Moisture (%) |
|---|---|---|---|---|---|
| Fresh | 19.32±0.17 | 6.55±1.09 | 2.52±0.06 | 0.55±0.12 | 71.07±1.11 |
| Super brined | 19.35±0.32 | 6.62±0.84 | 2.47±0.06 | 0.51±0.11 | 71.06±0.71 |

In Table 2, the mean chemical composition was higher in fresh samples than super brined *O. niloticus* for PV, FFA and TVBN. T –test however showed no significant difference ($p<0.05$) in the values for both fresh and super brined samples. There was a strong positive correlation (0.831-0.946) between the mean concentration of the chemical parameters for both fresh and brined samples. This indicates that the chemical composition of *O. niloticus* was not in any way altered by brining process. This result agrees with the findings of Mohamed *et al*. (2019) who stated that brined/frozen tilapia can be stored for months with slower biochemical change because freezing preserves nutrients but some biochemical markers still evolve slowly or become apparent after processing.

**Table 2:** Mean biochemical values and standard deviation for Fresh and Super brined *O. niloticus*

| Fish sample | Peroxide value (Meq/100g) | FFA (%) | TVBN (mg/100g) |
|---|---|---|---|
| Fresh | 1.34±0.05 | 1.33±0.04 | 3.33±0.05 |
| Super brined | 1.29±0.07 | 1.28±0.06 | 3.26±0.09 |

As shown in Table 3, the mean overall acceptability score by the taste panel for the uncooked super brined *O. niloticus* was 5.96±0.41 which is higher than that of uncooked fresh samples (5.71±0.52). The cooked super brined *O. niloticus* however recorded a lower mean overall acceptability score (5.81±0.50) than the cooked fresh *O. niloticus* with hedonic score of 5.88±0.58 (Table 4). The scores were however within tolerable limits of 4.0 as recommend by Minim, (2006). This shows that the fish is still acceptable at the end of the experimental period of six weeks for both super brined and the fresh samples. This result was supported by Hwang *et al*. (2020) who stated that brining of fish leads to higher salt content which enhanced preservation and also affect sensory qualities of the fish.

**Table 3:** Mean hedonic score for uncooked fresh and super brined *O. niloticus*

| Sample | Skin Pigment | Skin mucus | Eye tint | Gills tint | Gills colour | Eye shape | Overall acceptability |
|---|---|---|---|---|---|---|---|
| Uncooked fresh | 5.75±0.50 | 5.50±0.58 | 5.75±0.50 | 6.0±0.00 | 5.50±0.58 | 5.75±0.50 | 5.71±0.52 |
| Super brined | 6.0±0.00 | 6.0±0.00 | 5.75±0.50 | 6.0±0.00 | 6.0±0.00 | 6.0±0.00 | 5.96±0.41 |

**Table 4:** Mean hedonic score for cooked fresh and super brined *O. niloticus*

| Sample | Appearance | Taste | Odour | Texture | Overall Acceptability |
|---|---|---|---|---|---|
| Cooked fresh | 6.0±0.00 | 5.75±0.50 | 5.75±0.50 | 6.0±0.00 | 5.88±0.58 |
| Cooked Super brined | 6.0±0.00 | 5.75±0.50 | 5.75±0.50 | 5.75±0.50 | 5.81±0.50 |

## CONCLUSION

The findings of this study showed that brining process did not significantly alter the nutrient and chemical composition of fish after freezing storage. The proximate and chemical composition along with the sensory score of super brined and fresh tilapia fish *(Oreochromis niloticus*) after cold storage for six weeks were within acceptable international standard limits. All parameters measured in this study were within acceptable limits for fish consumption.

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# EFFECTS OF POLYCYCLIC AROMATIC HYDROCARBON: POTENTIAL RISK ON AQUATIC ORGANISM

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**ABSTRACT**
*Hydrocarbons (PAHs) are a class of chemicals that occur naturally in coal, crude oil, and gasoline. They also are produced when coal, oil, gas, wood, garbage, and tobacco are burned. PAHs generated from these sources can bind to or form small particles in the air. Fish is very important to human due to its high-quality protein as well as the essential amino acids needed by the body for growth and tissues maintenance. Around the world, fish protein makes up complete protein source in many people's diets and can also be used to maintain an active metabolism. This gave rise to this review, to ascertain the sources and effects of PAHs on processed fish and fish products. This review also helps to find out the risk of exposure of PAHs on human. There is no doubt that the exposure to PAHs can have adverse effects on humans by some of the PAHs being carcinogenic, causing skin and sight problems among others. It showed that fish product are exposed to various sources of PAHs through the use of direct firewood and charcoal during smoking, pyrolysis or combustion of coal. Exposure may also result from inhalation of engine exhaust and from use of products that contain PAHs in a variety of other industries, such as mining, oil refining, metalworking, chemical production, transportation, and the electrical industry. Adverse effects on these organisms include tumours, adverse effects on reproduction, development, and immunity. Human exposed to PAHs over long periods have developed lung cancer from inhalation, stomach cancer from ingesting PAHs in food, and skin cancer from skin contact.*

**Keyword:** Polycyclic Aromatic, Hydrocarbon, carcinogens, Fish products.

## INTRODUCTION

Polycyclic aromatic hydrocarbons (also called PAH, PAHs, PAH'S, polyaromates, polyaromatic hydrocarbons) are a group of over 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances like tobacco or charbroiled meat (Amoako *et al.*, 2011). PAHs are also manufactured for use in the pesticide, pharmaceutical and dye making industries; they are ubiquitous being present in soil, water air and food (Ni *et al.*, 2011) and pose a serious concern to the health of aquatic life and humans through bioaccumulation (Lee and Byeon, 2010). They are hydrophobic and can be readily adsorbed onto particulate matter, thus bio-accumulate in the environment; hence, coastal and marine sediments become the ultimate sinks for such compounds (Halek *et al.*, 2010). They are an important class of environmental pollutants that are potent mutagens and carcinogens and immunotoxic (Ni *et al.*, 2011). When in contact with the skin of mice, several carcinogenic PAHs have also been shown to interact with the immune system, stimulating immune responses and resulting in the development of antigen-specific T-cell mediated immunity. However, the effects of PAHs on both specific and non-specific immunity are contradictory and depend on the mode of exposure, the dose used or the species studied (Adekoya, 2016).

PAHs are produced by burning jet fuel and are also found in emissions from generators and motor vehicles (Kumar and Kothiyal, 2011). It is well known that PAHs are formed in large quantities as the result of

secondary thermochemical reactions at temperatures over 700°C. Also, the formation of these compounds during gasification and combustion have been reported. They generally occur as complex mixtures and some PAHs are manufactured. When pure, PAHs usually exist as colourless, white or pale yellow-green solids. PAHs are found in coal tar, crude oil, creosote and roofing tar but a few are used in medicines or to make dyes, plastics and pesticides. Others are contained in asphalt used in road construction. They can also be found in the environment, in the air, water and soil, hence are said to be ubiquitous and are found in almost all foods. Polycyclic aromatic hydrocarbons are produced when any incomplete combustion occurs. Thus, they are found in polluted air, cooking oil fumes, tobacco smoke, smoked foods, and foods cooked at high temperature. It has been noted that even air pollution usually contains many fewer PAHs than what a smoker breathes, and infact much less than the average level of PAHs in food. Even raw food can contain PAHs, due to air pollution (Magawata and Musa, 2015).

**Characteristics of Polycyclic Aromatic Hydrocarbon**

Polycyclic aromatic hydrocarbons have two or more single or fused aromatic rings with a pair of carbon atoms shared between rings in their molecules. The term "PAH" refers to compounds consisting of only carbon and hydrogen atoms. PAHs containing up to six fused aromatic rings are often known as "small" PAHs, and those containing more than six aromatic rings are called "large" PAHs (Olaniyi *et al.*, 2016). The majority of research on PAHs has been conducted on small PAHs due to the availability of samples of various small PAHs.

The general characteristics of PAHs are high melting and boiling points (therefore they are solid), low vapor pressure, and very low aqueous solubility, which both tend to decrease with increasing molecular weight, whereas resistance to oxidation and reduction increases (Ni *et al.*, 2011). PAHs are highly lipophilic and therefore very soluble in organic solvents. PAHs also manifest various functions such as light sensitivity, heat resistance, conductivity, emittability, corrosion resistance, and physiological action. PAHs possess very characteristic UV absorbance spectra. Each ring structure has a unique UV spectrum, thus each isomer has a different UV absorbance spectrum. This is especially useful in the identification of PAHs (Kumar and Kothiyal, 2011). Most PAHs are also fluorescent, emitting characteristic wavelengths of light when they are excited (when the molecules). Most polycyclic aromatic hydrocarbons (PAHs) with potential biological activity have been determined tohave a molecular structure that ranges in size from two to six fused aromatic rings (IARC, 2010).

The physicochemical properties of these PAHs that are critical to their biological activity vary greatly, because their molecular weights cover a vast range. Aqueous solubility of PAHs decreases approximately logarithmically with increasing molecular mass. Two ring PAHs, and, to a lesser extent, three-ring PAHs, dissolve in water; this makes them more readily available for biological uptake and degradation (Choi *et al.*, 2010). Furthermore, two- to four-ring PAHs volatilize sufficiently to appear in the atmosphere predominantly in gaseous form, although the physical state of four-ring PAHs can depend on temperature. In contrast, PAHs with five or more rings have low solubility in water and low volatility. They therefore occur predominantly in solid form, bound to particulates in polluted air, soil, or sediment (Choi *et al.*, 2010). In the solid state, these compounds are less accessible for biological uptake or degradation, which means that their persistence in the environment is increased. The properties that influence the biological activity of PAHs include their vapour pressure, their adsorption on surfaces of solid carrier particles, their absorption into liquid carriers, their lipid–water partition coefficient in tissues, and their limits of solubility in the lipid and aqueous phases of tissues. These properties are linked with the metabolic activation of PAHs, as well as their deposition and disposition. PAHs share a similar mechanism of carcinogenic action in both humans and experimental animals. This includes metabolic conversion to oxides and dihydrodiols, which in turn are oxidized to diol epoxides. These oxides and diol epoxides are the ultimate DNA-reactive metabolites of PAHs. The oxides form stable DNA adducts, and

the diol epoxides form stable adducts but also unstable adducts (so-called depurinating adducts) with DNA through formation of electrophilic carbonium ions (Olayemi *et al.*, 2011).

**Sources of Polycyclic Aromatic Hydrocarbon**

PAHs enter the air mostly as releases from volcanoes, forest fires, burning coal, and automobile exhaust. PAHs can occur in air attached to dust particles. Some PAH particles can readily evaporate into the air from soil or surface waters (Ioyerm, 2020). PAHs can break down by reacting with sunlight and other chemicals in the air, over a period of days to weeks. PAHs enter water through discharges from industrial and wastewater treatment plants. Most PAHs do not easily dissolve in water. They stick to solid particles and settle to the bottoms of lakes or rivers. Microorganisms can break down PAHs in soil or water after a period of weeks to months. In soils, PAHs are most likely to stick tightly to particles; certain PAHs move through soil to contaminate underground water. PAHs contents of plants and animals may be much higher than PAHs contents of soil or water in which they live (Eromosele, 2019). PAHs are not synthesized chemically for industrial purposes. Rather than industrial sources, the major source of PAHs is the incomplete combustion of organic material such as coal, oil and wood (Raufu *et al.*, 2014).

**Aquatic Environmental Fate and Ecotoxic Effects of PAHs**

PAHs are usually released into the air, or they evaporate into the air when they are released to soil or water. PAHs often adsorb to dust particles in the atmosphere, where they undergo photo oxidation in the presence of sunlight, especially when they are adsorbed to particles (Pena *et al.*, 2015). This oxidation process can break down the chemicals over a period of days to weeks. Since PAHs are generally insoluble in water, they are generally found adsorbed on particulates and precipitated in the bottom of lakes and rivers, or solubilized in any oily matter which may contaminate water, sediments, and soil. Mixed microbial populations in sediment/water systems may degrade some PAHs over a period of weeks to months (Shamsipur *et al.*, 2015).

**Exposure of PAHs to fish processors**

**Classification of PAHs**

The IARC Monographs Programme has reviewed experimental data for 60 individual PAHs (IARC, 2010). Of these 60 PAHs, one, benzo[a] pyrene, is classified as carcinogenic to humans (Group 1).

Other PAHs reviewed by IARC include cyclopenta[cd]pyrene, dibenz[a,h] anthracene, and dibenzo[a,l] pyrene, which are classified as probably carcinogenic to humans (Group 2A)

Dibenzo [a,h]pyrene, dibenzo[a,i]pyrene, indeno[1,2,3-cd]pyrene, and 5-methylchrysene, which are classified as possibly carcinogenic to humans (Group 2B).

The remaining 45 PAHs reviewed by IARC were acenaphthene, acepyrene (3,4-dihydrocyclopenta[cd] pyrene), anthanthrene, anthracene, 11H-benz[bc]aceanthrylene, benz[l] aceanthrylene, benzo[b]chrysene, benzo[g]chrysene, benzo[a]fluoranthene, benzo[ghi]fluoranthene, benzo [a]fluorene, benzo[b]fluorene, benzo[c]fluorene, benzo[ghi]perylene, and many more are classifiable as to their carcinogenicity to humans (Group 3), because of limited or inadequate experimental evidence (IARC, 2010).

**Routes of Exposure of PAHs**

The major route of exposure to PAHs in the general population is from breathing ambient and indoor air, eating food containing PAHs, smoking cigarettes, or breathing smoke from open fireplaces (Fagbote and Olanipekun, 2013). Tobacco smoke contains a variety of PAHs, such as benzo(a)pyrene, and more than 40 known or suspected human carcinogens. For non-smokers the main route of exposure is through food. PAH concentrations in foodstuffs vary. Charring meat or barbecuing food over a charcoal, wood, or other type of fire greatly increases the concentration of PAHs. Some crops, such as wheat, rye, and lentils, may synthesize PAHs or absorb them via water, air, or soil (Fagbote and Olanipekun, 2010).

Water can also contain substantial amounts of PAHs since those chemicals can leach from soil into water or they can enter water from industrial effluents and accidental spills during oil shipment at sea (Ogoko, 2014). Occupational exposure may also occur in workers breathing exhaust fumes, such as mechanics, street vendors, motor vehicle drivers, as well as those involved in mining, metal working, or oil refining. Routes of exposure include ingestion, inhalation, and dermal contact in both occupational and non-occupational settings. Some exposures may involve more than one route simultaneously, affecting the total absorbed dose (such as dermal and inhalation exposures from contaminated air).

**Uses of Polycyclic Aromatic Hydrocarbon**

There are a few commercial uses for many PAHs. They are mostly used as intermediaries in pharmaceuticals, agricultural products, photographic products, thermosetting plastics, lubricating materials, and other chemical industries (Tang *et al.*, 2013). General uses are (Snyder *et al.*, 2013):

i. Acenaphthene: manufacture of dyes, plastics, pigments, pharmaceuticals and pesticides
ii. Anthracene: manufacture of dyes and pigments; diluent for wood preservatives;
iii. Fluoranthene: manufacture of dyes, pharmaceuticals and agrochemicals.
iv. Fluorene: manufacture of dyes, pigments, pesticides, thermoset plastic and pharmaceuticals;
v. Phenanthrene: manufacture of pesticides and resins
vi. Pyrene: manufacture of pigments

**Effect of PAHs on Smoked Fish Product**

It has been established that there are two major sources of PAHs formation in foods. The first source is mainly due to the method of food preparation while the second major source of contamination of foodstuffs by contact with either petroleum products or coal tar products (Zhi *et al.*, 2015). Hence, the method of smoking the fish samples with charcoal and kerosene fraction of petroleum products, either way will contribute and result to increase in the level of PAHs in the smoked fish samples (Adekoya, 2016). The effect of smoking clearly showed that some of the PAHs are non-detectable in the wet samples, while some PAHs are found in smoked fish species. This means that smoking the fish samples definitely is responsible for the introduction of the various PAHs in the smoked fish (Akintola, 2020). Therefore, PAHs, which ordinarily would not have been contacted by eating the wet or fresh fish, now contains PAHs as a result of smoking. It was found that the method of cooking and length of time of smoking is a factor in the PAHs content (Eromosele, 2019).

**Acute or Short-term Healt of PAHs on fish and fish by products**

The effects on human health will depend mainly on the length and route of exposure, the amount or concentration of PAHs one is exposed to, and of course the innate toxicity of the PAHs. A variety of other factors can also affect health impacts including subjective factors such as pre-existing health status and age. The ability of PAHs to induce short-term health effects in humans is not clear. Occupational exposures to high levels of pollutant mixtures containing PAHs has resulted in symptoms such as eye irritation, nausea, vomiting, diarrhoea and confusion (Emoyan *et al.*, 2018). However, it is not known which components of the mixture were responsible for these effects and other compounds commonly found with PAHs may be the cause of these symptoms. Mixtures of PAHs are also known to cause skin irritation and inflammation. Anthracene, benzo(a)pyrene and naphthalene are direct skin irritants while anthracene and benzo(a)pyrene are reported to be skin sensitizers, i.e. cause an allergic skin response in animals and humans.

**Chronic or Long-term Health Effects**

Health effects from chronic or long-term exposure to PAHs may include decreased immune function, cataracts, kidney and liver damage (e.g. jaundice), breathing problems, asthma-like symptoms, and lung function abnormalities, and repeated contact with skin may induce redness and skin inflammation

(Ogungbuyi *et al.*, 2013). Naphthalene, a specific PAH, can cause the breakdown of red blood cells if inhaled or ingested in large amounts. If exposed to PAHs, the harmful effects that may occur largely depend on the way people are exposed.

**Carcinogenicity nature of PAHs on fish by products**

Although unmetabolized PAHs can have toxic effects, a major concern is the ability of the reactive metabolites, such as epoxides and dihydrodiols, of some PAHs to bind to cellular proteins and DNA. The resulting biochemical disruptions and cell damage lead to mutations, developmental malformations, tumors, and cancer. Evidence indicates that mixtures of PAHs are carcinogenic to humans (Chen *et al.*, 2013). The evidence comes primarily from occupational studies of workers exposed to mixtures containing PAHs and these long-term studies have shown an increased risk of predominantly skin and lung, but as well as bladder and gastrointestinal cancers.

**Teratogenicity**

Embryotoxic effects of PAHs have been described in experimental animals exposed to PAH such as benzo(a)anthracene, benzo(a)pyrene, and naphthalene. Laboratory studies conducted on mice have demonstrated that ingestion of high levels of benzo(a)pyrene during pregnancy resulted in birth defects and decreased body weight in the offspring (Delgado-Saborit *et al.*, 2011). It is not known whether these effects can occur in humans.

**Genotoxicity**

Genotoxic effects for some PAH have been demonstrated both in rodents and in vitro tests using mammalian (including human) cell lines (Babattuade, 2020). Most of the PAHs are not genotoxic by themselves and they need to be metabolised to the diol epoxides which react with DNA, thus inducing genotoxic damage. Genotoxicity plays important role in the carcinogenicity process and maybe in some forms of developmental toxicity as well (Adekoya, 2016).

**Immunotoxicity**

PAHs have also been reported to suppress immune reaction in rodents. The precise mechanisms of PAH-induced immunotoxicity are still not clear; however, it appears that immunosuppression may be involved in the mechanisms by which PAH induce cancer (Akintola, 2020).

## CONCLUSION

There is no doubt that the exposure to PAHs can have adverse effect on humans by some of the PAHs being carcinogenic, causing skin and sight problems among others. This review showed that fish product are exposed to various sources of PAHs such as use of direct firewood and charcoal during smoking, pyrolysis or combustion of coal. Exposure may also result from inhalation of engine exhaust and from use of products that contain PAHs in a variety of other industries, such as mining, oil refining, metalworking, chemical production, transportation, and the electrical industry. Adverse effects on these organisms include tumors, adverse effects on reproduction, development, and immunity. Human exposed to PAHs over long periods have developed lung cancer from inhalation, stomach cancer from ingesting PAHs in food, and skin cancer from skin contact.

## RECOMMENDATION

Further review needs to be done on determination of polyaromatic hydrocarbons in different fish species and commercial feeds as most of the unconventional resources used in feeds formulation undergoes processing through heating. Public education about the sources and health effects of exposure to PAHs should be improved. The risk of exposure to PAHs during processing of fish products should be stressed and measures taken to avoid it.

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# PROXIMATE AND SENSORY PROPERTIES OF CLUPEID (*Sierrathrissa leonesis*) FISH BASED SEASONING CUBE

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**ABSTRACT**

*Seasonings are commonly used to improve the taste of food and typically contain ingredients such as salt, spices, hydrogenated oils, and monosodium glutamate (MSG), however, many commercial seasonings pose health concerns due to their high MSG and salt content. Incorporating natural spices and protein-rich sources into seasonings may help mitigate these health risks. Sierrathrissa leonensis a mildly sweet, underutilized sardine species along with natural flavour enhancers like fermented locust beans (iru), ginger, alligator pepper, and salt, were used to develop a fish-based seasoning. The aim of the study is to produce, conduct proximate and sensory properties of clupeid fish-seasoning cube. The seasonings were subjected to proximate analysis. The sensory qualities of the seasonings were evaluated using 25 – member panel. The data obtained were subjected to statistical analysis using SPSS version 16.0 software. Statistical differences were performed using one-way analysis of variance followed by Duncan's Multiple Range Test ($p < 0.05$) to find the differences in the mean scores. The protein (42.20 to 57.91%), and the moisture content (2.95 and 3.72%) of the fish-based seasoning cubes were significantly higher ($p<0.05$) than the control (16.79, 1.48%) the sensory qualities (taste, flavour, colour, appearance, texture, and overall acceptability) than the control sample with (45% clupeid powder, 35% locust bean, 10% ginger, 5% alligator pepper and 5% salt) was the most acceptable product as it had the highest general acceptability score 8.76±1.09. It can be concluded that fish-based seasoning cubes with improved nutritional and sensory qualities that pose less health risks to consumers can be produced*

**Keywords**: Seasoning, *Sierrathrissa leonesis*, *iru*, spices

## INTRODUCTION

Seasonings are intricate blends of different substances used to improve the taste, smell, and overall appeal of food without altering its basic composition (Ugbabe *et al*., 2022). They can be sourced naturally from herbs, spices, and plants, or produced synthetically. Seasonings come in various forms, including powders or compacted into cubes. Seasoning cubes are widely used in global cuisines, especially across Africa and Asia, to enrich the flavour and aroma of meals (Ezekwe *et al.*, 2022). Common components include salt, spices, hydrogenated oils, and monosodium glutamate (MSG), along with optional ingredients such as crayfish, beef, chicken stock, and fish (Adjangba *et al*., 2020).

In Nigeria, various seasoning brands are produced in the form of bouillon cubes or as powdered seasonings. Popular examples include Star Maggi, Knorr Cubes, Royco, Onga, and Ajino-Moto. Bouillon cubes like Maggi and Knorr consist of dehydrated ingredients used to make broth or enhance flavour. Despite their convenience, these cubes often low in nutritional value have largely replaced traditional fermented seeds and products that once enriched African dishes with both flavour and nutrients. Research indicates that prolonged consumption of these cubes may pose health risks due to their high salt and monosodium glutamate (MSG) content (Umedum *et al*., 2013). Further studies have highlighted

concerns over MSG, a common ingredient in bouillon cubes, linking it to toxicity in various organ systems (Oode *et al.*, 2023). This study, therefore, focuses on developing a fish-based seasoning using these locally available ingredients, with the aim of enhancing nutrition as a way of addressing food insecurity in Nigeria.

## MATERIALS AND METHODS

Fish-based seasonings were made using ginger, cloves, alligator pepper, fermented African locust bean (iru), and clupeid fish (*Sierrathrissa leonensis*). The ingredients chosen for this project were relatively easy to access, affordable, and consisted of a short list of locally available resources.

### Raw Materials

Fresh clupeid fish (*Sierrathrissa leonensis*), fresh ginger, cloves, alligator pepper, fermented African locust bean (iru), and salt were sourced from Monday Market in New Bussa, Niger State. The ingredients were sun-dried for 4 to 5 days before being ground into powder. Figure 1 shows the methodological stage of fish-based seasoning

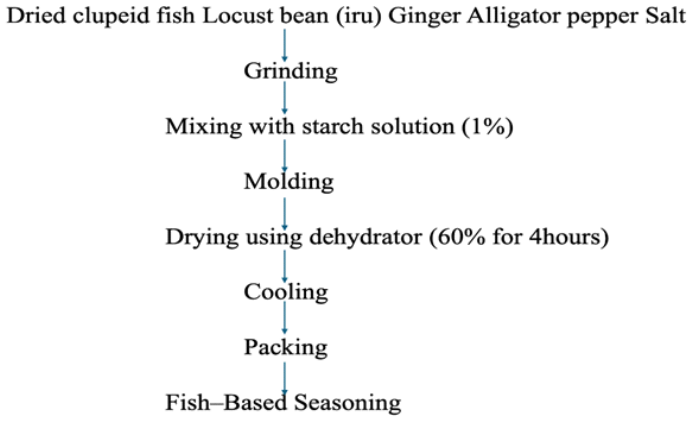



**Figure 1: Flow chart of fish based- seasoning**

### Study location and experimental site

The experiment was carried out at the National Institute for Freshwater Fisheries Research (NIFFR) in New Bussa, Niger State. Processes such as fish drying and the development of fish-based seasoning were conducted at the NIFFR Fisheries Technology Laboratory and Aviary, located between latitudes 9°51' and 10°55'N and longitudes 4°35' and 4°51'E. The institute is situated at an elevation of 110 meters above sea level, spanning 24 km in width and 136 km in length. It lies within Borgu Local Government Area, which covers an area of 11,579.786 km$^2$ and had a population of 172,835 as recorded in the 2006 census. The region receives about 950 mm of rainfall annually, with the highest monthly average in August. Temperatures in the area typically range from 27°C to 37°C, with peak temperatures reaching 40°C between February and March, and around 35°C during November and December (Mayomi & Olokor, 2014).

### Sample Preparation

The dried clupeid fish were cleaned and had their heads removed, then oven-dried at 50°C for 20 minutes to further reduce moisture content and facilitate easier grinding. Fresh ginger was cleaned, peeled, chopped, washed with potable water, and sun-dried. Fermented locust beans (iru) were sourced from a reliable vendor to ensure consistent quality. All seasonings were then ground and passed through a 2µm sieve to achieve a fine and uniform particle size.

**Seasoning Production**

The fish powder and other ingredients were weighed and blended based on the formulation outlined in Table 1. The mixture was combined with a 1% starch solution and molded into cubes using a cube cutter. These cubes were then dried in a dehydrator at 60°C for 3 hours, allowed to cool, and stored for later use. A commercial seasoning cube (Mr. Chef Dawa Dawa cube) served as the control sample for comparison.



a b c

**Plate 1a:** Raw material used, **b:** grinded raw material, **c:** Produced fished-based

**Table 1: Fish-seasoning formulation (%)**

| Samples | Fish powder | Fermented locust bean | Ginger | Alligator pepper | Salt |
|---|---|---|---|---|---|
| $C_0$ | - | - | - | - | - |
| $C_1$ | 45 | 30 | 10 | 10 | 5 |
| $C_2$ | 35 | 35 | 15 | 10 | 5 |
| $C_3$ | 40 | 30 | 20 | 5 | 5 |
| $C_4$ | 50 | 35 | 10 | 5 | 5 |
| $C_5$ | 70 | 10 | 10 | 5 | 5 |
| $C_6$ | 55 | 35 | 10 | 5 | 5 |
| $C_7$ | 60 | 10 | 15 | 10 | 5 |

The seasonings were analyses for their physicochemical properties (including acid value, peroxide value). Additionally, the sensory attributes of the fish-based seasoning soup including taste, colour, flavour, aroma, texture, and overall acceptability were assessed by a panel of 25 trained members.

The collected data were statistically analysed using SPSS version 16.0. One-way Analysis of Variance (ANOVA) was employed to identify significant differences, and Duncan's Multiple Range Test was applied to compare the mean values at a significance level of $p < 0.05$.

**Methods of Analysis**

Physicochemical, chemical, and microbiological parameters were determined according to the standard procedures outlined by the AOAC (2017).

**Proximate Analyses**

The proximate composition of the fish-based seasoning cubes—including moisture, ash, protein, fibre, and fat contents was determined on a dry weight (D/W) basis. These analyses were conducted following the procedures outlined by the AOAC (2010). All tests were carried out in the Analytical Laboratory of the National Institute for Freshwater Fisheries Research (NIFFR), New Bussa, Niger State.

**Determination of Protein Content**

To determine the protein content, 0.5 g of the sample was accurately weighed into a digestion flask. A

Kjeldahl catalyst tablet and 10 ml of concentrated sulfuric acid ($H_2SO_4$) were added, and the mixture was digested for approximately 4 hours until a clear blue-green solution was obtained. After digestion, the solution was cooled and transferred into a 100 ml volumetric flask, then diluted to the mark with distilled water. Next, 20 ml of boric acid solution was placed into a conical flask along with five drops of a suitable indicator and 75 ml of distilled water. Then, 10 ml of the digest was transferred to a Kjeldahl distillation flask. The distillation setup was assembled, and 20 ml of 2% sodium hydroxide (NaOH) was added to the digest through a funnel. Distillation began once the boric acid-indicator solution turned green, and it continued for 15 minutes. The distillate was then titrated with 0.05 N hydrochloric acid (HCl) until a pink endpoint appeared. A blank sample was also processed through the same procedure to ensure accuracy. The crude protein content was calculated by multiplying the percentage of nitrogen (%N) by a conversion factor of 6.25:

**% Crude Protein = %N × 6.25 % (%N)**

Titre Value x Atomic mass of nitrogen x Normality of Hcl used x 4

**Determination of Fat content**

Fat content was determined using the ether extraction method with a Soxhlet apparatus. One gram of the sample was weighed, wrapped in filter paper, and placed in a fat-free thimble, which was lightly plugged with cotton wool. The thimble was inserted into the Soxhlet extractor and extraction was carried out using petroleum ether (n-hexane) as the solvent for approximately 5 hours. Water and heat were applied to initiate extraction, and after 4–6 siphoning cycles, the ether was allowed to evaporate. The beaker was removed before the final siphoning.

The extracted fat was then transferred into a clean glass dish using ether rinses. The ether evaporated on a water bath. The remaining residue in the dish was dried in an oven at 105°C for 2 hours, then cooled in a desiccator and weighed. The fat content was calculated based on the weight of the residue.

**Determination of Ash content**

A clean, empty crucible was first heated in a muffle furnace at 600°C for one hour, then cooled in a desiccator and weighed (W). One gram of the sample was then placed into the crucible (W2), and the sample was ignited over a burner using a blowpipe until fully charred. The crucible was transferred to a muffle furnace set at 550°C and heated for 3–4 hours. The appearance of grayish-white ash indicated complete oxidation of organic matter. The crucible was cooled in a desiccator and weighed again (W3). The percentage ash content was then calculated based on the weight difference and is given as % ash content $= \frac{W3 - W2}{W1} \; x \; 100$

Where:

$W_3$weight of the sample with crucible before ashing

$W_2$weight of the sample with crucible after ashing

**Sensory Evaluation**

Sensory assessment was carried out following the procedure described by Iwe (2014) and Al-Subhi (2013), with slight modifications. A panel of 25 male and female students from the Department of Home Economics and Food Science, University of Ilorin, participated in evaluating the fish-based seasoning cubes. Soups were prepared using the different seasoning cube formulations, and the panelists who had received basic training assessed the samples based on taste, color, appearance, texture, flavor, and overall acceptability. Evaluations were conducted using a 9-point Hedonic Scale, where 9 indicated "extremely like," 1 meant "extremely dislike," and 5 represented "neither like nor dislike." Each soup sample was served on separate plates coded C0 to C7, and all samples were presented simultaneously.

**Statistical Analysis**
The data collected were analyzed using analysis of variance (ANOVA). Results were expressed as means ± standard deviation from duplicate tests. Mean differences were compared using Duncan's Multiple Range Test, with significance determined at $p \leq 0.05$. $W_1$ weight of the sample

## RESULTS AND DISCUSSION

**Proximate Composition of Fish-Based Seasoning Cubes**
The moisture content of the fish-based seasoning cubes ranged from 2.95% to 3.72%, significantly higher ($p < 0.05$) than that of the control sample, which recorded 1.48%. Ash content varied considerably among the samples, ranging between 11.03% and 43.51%. The control sample exhibited the highest ash content (43.51%), while $C_1$ had the lowest (11.03%).

Crude fibre content across the formulations was between 1.10% and 3.61%, with $C_6$ showing the highest fiber level (3.61%) and $C_5$ the lowest (1.10%). These differences were statistically significant ($p < 0.05$). Protein content varied markedly, from 16.79% to 57.91%, with $C_2$ having the highest protein level (57.91%) and the control sample the lowest (16.79%). Fat content ranged from 4.56% to 11.88%, with $C_1$ containing the highest fat content (11.88%) and $C_6$ the lowest (4.56%), showing significant differences across the samples ($p < 0.05$) as shown in Table 2

**Table 2:** Present the proximate composition of the seasoning cubes (%)

| Sample | MC | AC | CF | CP |
|---|---|---|---|---|
| $C_1$ | $3.63 \pm 0.33^{ab}$ | $11.03 \pm 0.23^{d}$ | $3.52 \pm 0.32^{a}$ | $42.20 \pm 1.27^{d}$ |
| $C_2$ | $3.72 \pm 0.26^{a}$ | $12.87 \pm 0.32^{b}$ | $1.75 \pm 0.09^{e}$ | $57.91 \pm 0.09^{a}$ |
| $C_3$ | $3.43 \pm 0.14^{abc}$ | $11.63 \pm 0.13^{c}$ | $2.24 \pm 0.15^{b}$ | $50.24 \pm 0.35^{c}$ |
| $C_4$ | $3.17 \pm 0.06^{cd}$ | $11.81 \pm 0.18^{c}$ | $2.42 \pm 0.08^{b}$ | $53.38 \pm 0.22^{b}$ |
| $C_5$ | $3.26 \pm 0.11^{bcd}$ | $13.12 \pm 0.33^{b}$ | $1.10 \pm 0.10^{d}$ | $46.17 \pm 0.20^{d}$ |
| $C_6$ | $2.95 \pm 0.24^{d}$ | $11.93 \pm 0.29^{c}$ | $3.61 \pm 0.16^{a}$ | $43.14 \pm 0.92^{e}$ |
| $C_7$ | $3.15 \pm 0.19^{cd}$ | $12.69 \pm 0.22^{b}$ | $3.39 \pm 0.19^{a}$ | $47.29 \pm 1.09^{d}$ |
| $C_0$ (control) | $1.48 \pm 0.09^{e}$ | $43.51 \pm 0.41^{a}$ | $1.89 \pm 0.18^{c}$ | $16.79 \pm 0.35^{f}$ |

*Values are mean± SD. Mean values in the same column different superscript are significantly different ($p<0.05$).*

$C_1$ (45% clupeid powder, 30% locust bean, 10% ginger, 10% alligator with pepper), $C_2$ (35% clupeid powder, 35% locust bean, 15% ginger, 10% alligator pepper), $C_3$ (40% clupeid powder, 30% locust bean, 20% ginger, 5% alligator pepper), $C_4$ (50% clupeid powder, 35% locust bean, 10% ginger, 5% alligator pepper), $C_5$ (70% clupeid powder, 10% locust bean, 10% ginger, 5% alligator pepper), $C_6$ (55% clupeid powder, 35% locust bean, 10% ginger, 5% alligator pepper), $C_7$ (60% clupeid powder, 10% locust bean, 15% ginger, 10% alligator pepper), 5% (salt is constant in all the samples), $C_0$: Commercial Seasoning (Mr chef Dawa-Dawa cube)

**Proximate Composition of Fish-Based Seasoning Cubes**
The moisture content of the fish-based seasoning cubes was lower than the values reported by Ndife *et al*. (2022), who found moisture levels ranging from 9.64% to 16.44% in seasoning cubes formulated with local spices. However, the values in this study were comparable to those recorded by Umedum *et al*. (2013), who reported moisture contents of 0.99% to 3.01% for three major commercial seasoning cubes in Nigeria. Differences in moisture levels may stem from variations in processing techniques and ingredient compositions. Seasonings with moisture content ≤ 12% are generally considered stable for

extended storage without spoilage.
The ash content in the fish-based seasonings was higher than the 6.83% to 7.33% range reported by Ndife *et al.* (2022). Variations in ash content can be attributed to differences in ingredient composition and processing methods. Akpanyung (2005) also documented high sodium concentrations (48.15% to 63.20% dry matter) in commercial bouillon cubes.
Ash represents the inorganic residue left after the complete combustion of organic matter, serving as a measure of total mineral content (Ayo-Omogie *et al.*, 2010). A higher ash value generally indicates greater mineral richness. Nutritionally, ash contributes to protein, carbohydrate, and fat metabolism (Okaka, 2005).

The crude fibre content observed in the fish-based seasoning cubes was comparable to the 1.35% to 2.01% reported by Umedum *et al.* (2013) for Nigerian commercial seasonings. The relatively higher fibre levels are likely due to the plant-based ingredients used in the formulations.
Dietary fibre plays an essential role in promoting gut health, regulating bowel movements, enhancing insulin sensitivity, and lowering the risk of chronic diseases like type 2 diabetes and cardiovascular ailments (Barber *et al.*, 2020). Although the fibre levels in this study are modest, they still contribute positively to dietary fibre intake.

However, the protein content in this study was lower than values obtained for tuna trimming powder (80.71%) by Ayomuo *et al.* (2006), and tilapia surimi powder (62.05%) by Ramirez *et al.* (1999). Nevertheless, the protein levels were significantly higher than the 9.29% reported by Keswet and Abia (2015) for pepper soup seasoning. Thus, regular consumption of these fish-based cubes could meaningfully contribute to daily protein requirements. Protein is vital for tissue repair, cellular structure, and supplying essential amino acids to the body.

The fat content in the samples ranged from 3.28% to 10.64%, higher than the 2.5% to 3.5% range reported by Umedum *et al.* (2013), but similar to the 4.38% to 11.31% found by Ndife *et al.* (2022). Traditional spices like *Tetrapleura tetraptera* have also been noted for their fat content (Agomuo *et al.*, 2006). Dietary fats enhance flavour by absorbing and retaining aroma, although excessive intake is linked to cardiovascular diseases. The moderate fat levels found in this study are acceptable and contribute to both flavour and energy value.

**Sensory Properties of fish-based seasoning**
Sensory quality characteristics (appearance, taste, texture, aroma, colour, and overall acceptability) of the fish-based seasoning are shown in Table 3. $C_4$ had the highest score in taste, aroma and overall acceptability (8.66, 7.96 and 7.76) respectively. However, $C_1$ had the highest score in texture and colour (8.88 and 8.48), followed by $C_4$ (7.68). Highest score was observed in $C_2$ for appearance (8.2) while control sample had the lowest score in all the sensory parameters.

The result of the sensory evaluation of the seasoning samples are presented in Table 4.8. The appearance score ranged from 6.10-8.20. $C_2$ had the highest appearance score (8.20) while $C_0$ had the least (6.10).
The scores for texture ranged from 5.44-8.88. $C_1$ had the highest texture score (8.88) followed by $C_4$ (7.38) while sample $C_0$ had the least value (5.44). However, the results revealed that, there was no significant difference in the texture of the samples and were all liked moderately except for sample $C_1$ and this could be due to the proportions of the ingredient used.

The taste score of the seasoning samples ranged from 4.92-8.36. $C_4$ had the highest taste score (8.36) followed by $C_2$ (8.28) while control $C_0$ has the least value (4.92). The taste of $C_4$ was preferred when compared to the other samples. The result of sensory properties of these findings are similar with the

findings of Fatima *et al*, 2023 appearance (7.11-8.18), taste (6.31-8.76) and general acceptability (6.27-8.22) on Seasoning Powders from Fermented African Locust Bean Chicken and Shiitake Mushrooms.

The aroma score of the samples ranged from 5.72 -7.96. $C_1$ had the highest (7.96) aroma score followed by $C_2$(7.72) while control $C_0$ had the least (5.72). Although, there was no significant difference ($p>0.05$) in the aroma of the samples except for $C_1$. The pungent aroma of ginger used in the fish-based seasonings could have been responsible for the lower scores in $C_3$ (20% ginger). The panelists had better preference for the aroma of $C_4$ than the other samples this could be due to moderate proportions of the ingredients used. The different proportions of the ingredients used for the formulations were associated with various aromas.

**Table 3:** Sensory Properties of fish-based seasoning

| Sample | Appearance | Texture | Taste | Colour | Aroma | Overall Accept |
|---|---|---|---|---|---|---|
| $C_1$ | $7.6 \pm 1.07^{ab}$ | $8.88\pm2.36^{a}$ | $7.6\pm1.35^{ab}$ | $8.48\pm2.51^{a}$ | $7.12\pm2.02^{ab}$ | $7.64\pm1.07^{a}$ |
| $C_2$ | $8.2 \pm 0.89^{a}$ | $7.28\pm 1.79^{b}$ | $8.28\pm1.30^{a}$ | $7.65\pm1.79^{b}$ | $7.72\pm0.954^{a}$ | $7.56\pm0.96^{ab}$ |
| $C_3$ | $6.7 \pm 1.78^{bc}$ | $6.08\pm 1.65^{b}$ | $6.76\pm1.50^{b}$ | $6.64\pm1.70^{b}$ | $6.76\pm1.562^{b}$ | $6.64\pm1.60^{b}$ |
| $C_4$ | $7.7 \pm 0.73^{ab}$ | $7.38\pm 1.79^{b}$ | $8.66\pm1.31^{ab}$ | $7.68\pm1.11^{b}$ | $7.96\pm1.091^{a}$ | $8.76\pm1.09^{a}$ |
| $C_5$ | $7.6 \pm 1.06^{ab}$ | $6.48\pm 1.26^{b}$ | $7.20\pm1.38b$ | $7.00\pm1.29^{b}$ | $7.08 \pm1.558^{bc}$ | $7.40\pm1.04^{ab}$ |
| $C_6$ | $7.3 \pm 1.38ab$ | $6.96\pm 1.27^{b}$ | $7.64\pm1.52^{ab}$ | $6.80\pm1.70^{b}$ | $7.24 \pm0.597^{ab}$ | $7.36\pm1.003^{b}$ |
| $C_7$ | $7.3 \pm 1.64^{b}$ | $7.08\pm 1.55^{b}$ | $6.96 \pm1.74^{b}$ | $7.36\pm1.99^{b}$ | $7.20 \pm1.708^{ab}$ | $7.52\pm1.53^{ab}$ |
| $C_0$ | $6.1 \pm 3.07^{c}$ | $5.44\pm 2.56^{b}$ | $4.92\pm3.01c$ | $5.20\pm2.38^{b}$ | $5.72 \pm2.407^{c}$ | $5.60\pm2.81^{c}$ |

Values are mean± SD. Mean values in the same column different superscript are significantly different ($p<0.05$).

C1 (45% clupeid powder, 30% locust bean, 10% ginger, 10% alligator with pepper), C2 (35% clupeid powder, 35% locust bean, 15% ginger, 10% alligator pepper), C3 (40% clupeid powder, 30% locust bean, 20% ginger, 5% alligator pepper), C4 (50% clupeid powder, 35% locust bean, 10% ginger, 5% alligator pepper), C5 (70% clupeid powder, 10% locust bean, 10% ginger, 5% alligator pepper), C6 ( 55% clupeid powder, 35% locust bean, 10% ginger, 5% alligator pepper), C7 ( 60% clupeid powder, 10% locust bean, 15% ginger, 10% alligator pepper), 5% (salt is constant in all the samples), C0: Commercial Seasoning (Mr chef Dawa-Dawa cube)

The general acceptability of the seasoning samples ranged from 5.60-8.76. Sample $C_4$ had the highest general acceptability score (8.76) followed by sample $C_1$ (7.64) while control $C_0$ had the least acceptance (5.60). The general acceptability rating implied that the sample $C_4$ was liked very much than other samples. This particular blend was therefore considered to be the most acceptable product.
Ndife *et al* 2022 on spice-mix seasoning cubes reported similar range in appearance, taste, texture, aroma, and general acceptability (6.30-8.05, 5.70-8.00, 6.50-7.80, 6.45-7.60, 6.50-7.90) respectively.

## CONCLUSION

This research work on proximate and sensory properties of clupeid (*Sierrathrissa leonesis*) Fish-Based seasoning cube**,** Fish-based seasoning cubes were produced and were subjected to proximate and sensory composition,. The sensory qualities (taste, colour, flavour, aroma, texture, and overall acceptability) of the seasonings were evaluated using 25 – member panel. The proximate composition of this finding, showed that the protein (42.20-57.91%), and the moisture content (2.95 and 3.72%) of the fish-based seasoning cubes were higher than the control (16.79, 1.48%) while the sodium content (0.92-1.67%) was lower than the control (9.26) also, fish-based seasoning cubes were higher in magnesium, zinc and calcium (67.29-224-73, 2.83-4.78 and 72.67-189.19%) respectively.

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# EFFECT OF DIFFERENT HEAT SOURCES ON THE NUTRIENT COMPOSITION OF AFRICAN CATFISH (*Clarias gariepinus*)

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**ABSTRACT**
*The present study investigated the effect of different heat sources on the nutritional qualities of African catfish (C. gariepinus). Thirty table-size catfish (500–600 g) were randomly assigned to three heat treatment groups: smoking with firewood, smoking with charcoal, and dehydration using an electric dehydrator. Each group contained ten fish samples which were analysed for proximate composition. Data generated was subjected to one-way ANOVA using a Completely Randomized Design (CRD), and means were separated with Duncan's Multiple Range Test at $p < 0.05$. Results revealed that evaluated the effect of different heat sources (firewood, charcoal, and electrical dehydrator) on the nutritional, microbial, and sensory qualities of C. gariepinus. Results of proximate analysis revealed significant differences ($p < 0.05$) across treatments. Moisture content was lowest in charcoal-smoked fish (5.33%) and highest in dehydrator-processed fish (10.45%), while crude protein was highest in charcoal-smoked fish (53.31%). Ether extract was highest in dehydrator-processed samples (33.81%), whereas crude fibre was lowest in charcoal-smoked fish (1.19%). Ash and nitrogen-free extract values also varied significantly among treatments. In conclusion, charcoal smoking provided the best balance of protein composition.*

**Keywords:** *Clarias gariepinus*, heat treatment, proximate composition

## INTRODUCTION

In an emerging economy like Nigeria, fish supply becomes a significant component of its overall food system; it plays a key role in economic development, and food security. Fish is renowned for its nutritional value such as high-quality protein, essential fatty acids (omega-3), and a broad spectrum of micronutrients including vitamin D, vitamin B12, iodine, calcium, and iron (FAO, 2021).

Among the numerous fish species cultivated and consumed in Nigeria, African catfish (C. *gariepinus*) is the most sought after which is due to its fast growth rate, high survival and ability to thrive under poor water quality among other qualities (Olaleye, 2020). However, like all animal protein food sources, fish is highly perishable and prone to spoilage due to its high moisture content and enzymatic activity (Oyebamiji *et al.*, 2018).
To increase shelf life, safety, and sensory appeal, various preservation techniques are employed using heat-based treatments such as boiling, smoking, frying, grilling and some value addition treatments as the most prevalent (Okafor *et al.*, 2021; Yusuf *et al.*, 2024).

As the demand for fish and fish products continues to rise, so does the need for proper post-harvest handling that will preserve the nutrition and sensory quality of harvested fish; however inappropriate processing techniques can lead to significant nutrient loss, making the fish less nutritionally beneficial

despite its wide sensory appeal (Nwankwo and Ajao, 2020). There is therefore the need to evaluate how the commonly used heat sources affect the quality of C. *gariepinus*, while understanding that this approach is essential for consumers, processors, nutritionists, and policy makers who aim to promote healthy and improved post-harvest fish processing standards. The objective of this study is to assess the effect of three different heat sources on the nutrient composition of C. *gariepinus*. As the demand for fish and fish products continues to rise, so does the need for proper post-harvest handling that will preserve the nutritional quality of harvested fish; however inappropriate processing techniques can lead to significant nutrient loss, making the fish less nutritionally beneficial despite its wide sensory appeal (Nwankwo and Ajao, 2020). There is therefore the need to evaluate how the commonly used heat sources affect the quality of C. *gariepinus*, while understanding that this approach is essential for consumers, processors, nutritionists, and policy makers who aim to promote healthy and improved post-harvest fish processing standards.

## MATERIALS AND METHOD

The study was conducted at the Department of Fisheries and Aquaculture, Federal University of Lafia, Nasarawa State, Nigeria. Lafia has a population of 339,712 inhabitants as of the 2006 Census. It is located at latitude $8^0$ $28^{'}$ N and Longitude $8^0$ 32' E and elevation of 158 metres above sea level (Ombugadu *et al.*, 2021).

### Procurement of Test Fish

Thirty pieces of 500 to 600g average weight table size of C. *gariepinus* was procured from Sunday Audu fish farm in Lafia and convened to the Department of Fisheries and Aquaculture where the processing took place.

### Experimental Setup and Design

The experiment was conducted using complete randomised design (CRD). Fish samples were treated using firewood, charcoal and electricity. Each treatment consists of ten fish samples: Treatment 1 (heat treatment by firewood) Treatment 2 (heat treatment by charcoal) and treatment 3 (heat treatment by electricity). Each treatment method was used to produce fish samples which were labelled and used for nutritional quality assessment.

### Heat treatment

Smoking was done at the Department of Fisheries and Aquaculture, Faculty of Agriculture, Federal University of Lafia, Nasarawa State, Nigeria, using firewood (10hrs), charcoal (18hours) and dehydration by electricity (15hrs), after which the treated fish samples were left to cool (1hour), packed and labelled for laboratory analysis of proximate assessments.

### Proximate Analysis

Fish samples were analysed for basic nutritional components like crude protein, ash moisture, ether extract and nitrogen free extract according to the method of (AOAC 2016)

## RESULTS AND DISCUSSION

The proximate composition of C. *gariepinus* smoked using different heat sources is presented in figures below. The result showed significant differences ($P<0.05$) in the values of percentage moisture content. The highest moisture was obtained in fish dried using electrical dehydrator (10.45%) followed by fish smoked using firewood heat (8.38%) while the lowest moisture was observed in fish smoked using charcoal heat source (5.33%) respectively.

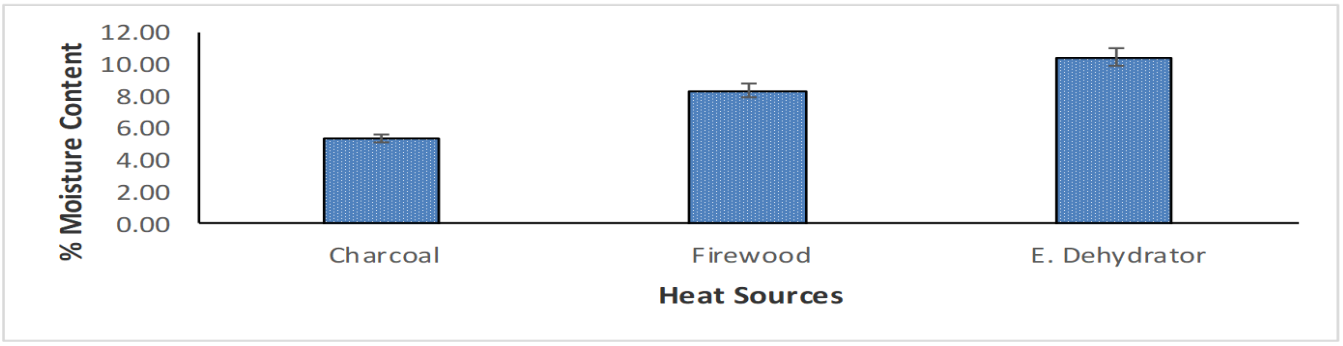



**Figure 1:** Percentage Moisture Content of C. *gariepinus* smoked using different heat sources

**Ash content of *Clarias gariepinus* smoked using different heat sources**

The result on percentage Ash content of fish smoked using different heat sources is presented in figure 2 below. The ash content showed significant differences ($P<0.05$) among heat sources. The highest ash content (8.29%) was recorded in C. *gariepinus* smoked using charcoal followed by firewood smoked fish (6.51%) while the lowest (4.93%) was recorded in C. *gariepinus* smoked using electrical dehydrator respectively. This study showed that heat had influence in the ash content of the fish.

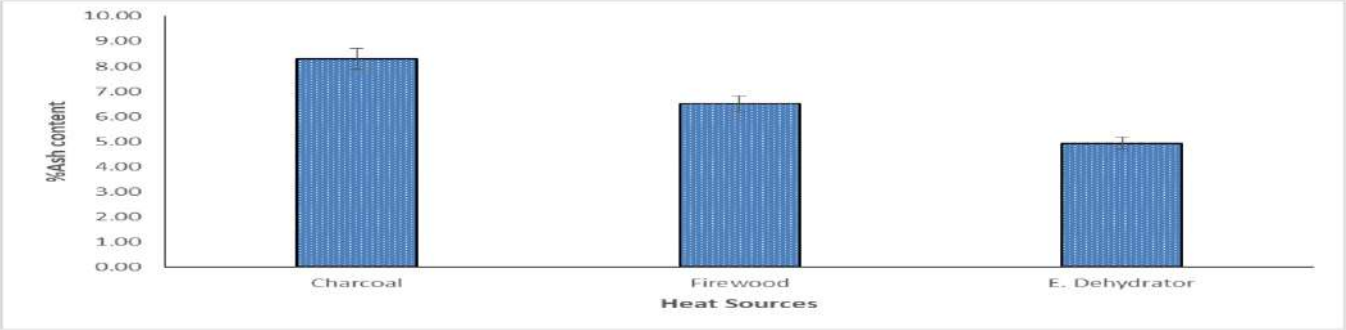



**Figure 2:** Percentage ash content of C. *gariepinus* smoked using different heat sources

Crude Protein of *Clarias gariepinus* smoked using different heat sources

The result of crude proteins of fish smoked using different heat sources is presented in figure 3 below. In this study, there was significant variations ($P<0.05$) in the value of crude protein obtained. Highest Crude protein value (53.31%) was obtained in C. *gariepinus* smoked using charcoal heat source which is significantly different from other heat sources followed by C. *gariepinus* smoked using firewood (45.90%) while the lowest was observed in the fish dried in electrical dehydrator respectively.

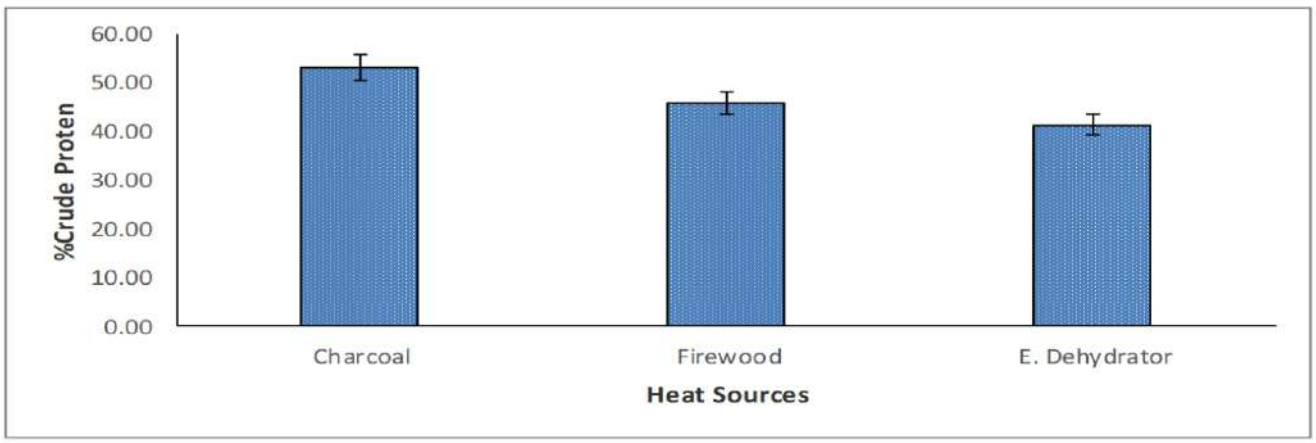



**Figure 3:** Crude Protein content of C. *gariepinus* smoked using different heat sources

**Ether Extract of *Clarias gariepinus* smoked using different heat sources**

The result in Figure 4 below showed the effect of different heat sources on the ether extract of fish (C. *gariepinus*). The content of ether extract was significantly different ($P<0.05$) from each other among heat sources. The highest values of ether extract were recorded in fish smoked using electrical dehydrator (33.81%) followed by firewood heat source (22.71%) while fish smoked with charcoal heat recorded the lowest (20.07%) respectively.

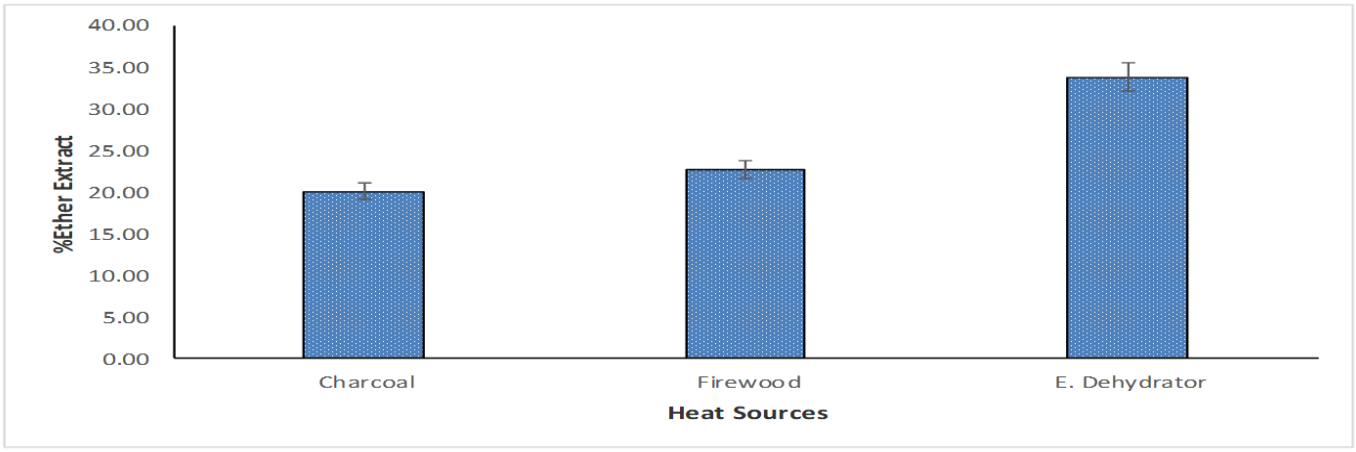



**Figure 4:** Effect of Different Heat Sources on the ether extract of C. *gariepinus*

Crude Fibre content of C*larias gariepinus* smoked using different heat sources

The values of crude fibre recorded for C. *gariepinus* smoked using different heat sources is presented in Figure 5 below. There were significant differences ($P<0.05$) in the values of crude fibre obtained in the study. The highest values of crude fibre were recorded in fish smoked using electrical dehydrator (8.75%) followed by fish smoked using firewood heat (5.57%) while the lowest value (1.19%) was recorded in fish smoked using charcoal heat.

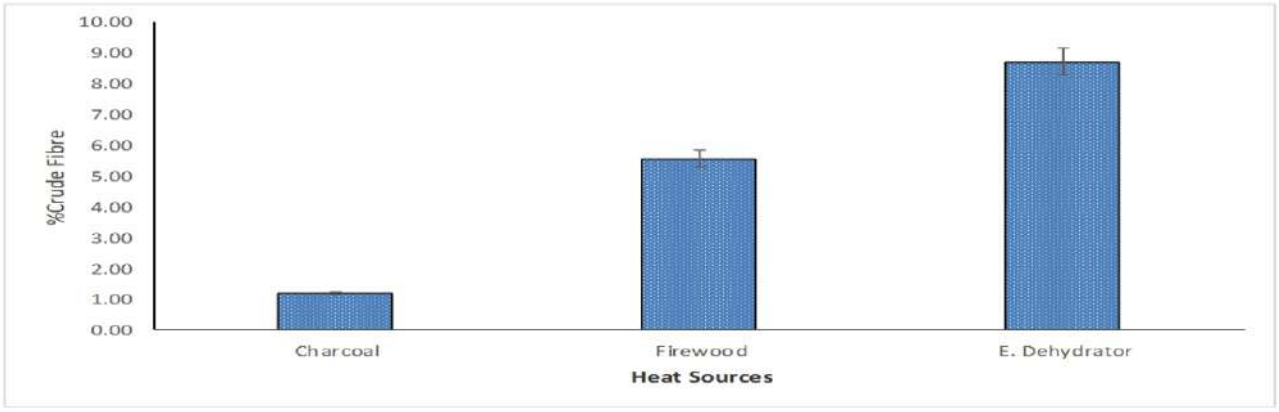



**Figure 5:** Crude Fibre content of C*larias gariepinus* smoked using different heat sources

**Nitrogen Free Extract of *Clarias gariepinus* smoked using different heat sources**

The result of nitrogen free extract obtained from C. *gariepinus* smoked using different heat sources is presented in Figure 6 below. The highest value of NFE was obtained in fish smoked using charcoal heat (12.14%) followed by fish smoked using firewood heat (10.93%) while fish smoked with electrical dehydrator (8.96%) recorded lowest.

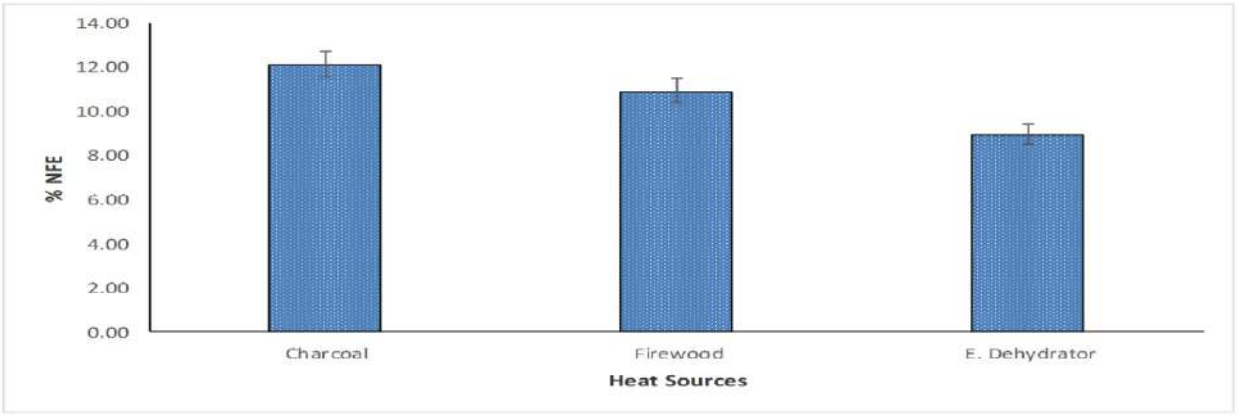



**Figure 6:** Nitrogen Free Extract of C. *gariepinus* smoked using different heat sources

## DISCUSSION

### Proximate Composition of *Clarias gariepinus* smoked using Different Heat Sources

The proximate composition of fish samples smoked using charcoal, firewood and dehydrator revealed that the various heat sources impacted on the nutritional value of the fish sample, which led to reduction of moisture.

The value of moisture recorded in this study ranged between 5.33% and 10.45%, which is within the acceptable level according to Olayemi *et al.*, (2011). Similarly, the findings in this study agreed with those of Yusuf *et al.*, (2025) and Ndife *et al.*, (2022) who recorded 10-13%; Ash content as obtained in fish smoked using charcoal is an indication that charcoal smoked sample dried better. The ash content obtained from firewood and electrical dehydrator are not significantly different. It could be concluded in the study that a well dried sample would produce high ash content than samples with high moisture content. The range of the ash content was an indication that the fish samples may be good sources of minerals such as calcium, potassium, zinc, iron and magnesium (Andrew, 2011). Crude protein of fish smoked with charcoal heat recorded slightly higher than fish dried using firewood and electrical dehydrator. The amount of crude protein recorded in the study is ideal for many freshwater fishes.

The result showed that the crude protein increased as the moisture reduces. Also, the range of the values recorded for protein in this study agreed with the observation (33.66 – 66.04) of Adebowale *et al.*, (2008), and Oyedokun (2020) in their independent studies on C. *gariepinus*. The value of the crude protein content in this study also shows the inverse relationship between the protein and moisture contents. Usman (2017) opined that the protein content of fish may be influenced by size, sexual maturation, water quality as well as feeding ration and frequency. The significantly high crude protein in the samples of the three heat sources makes it a better dietary protein source for human consumption. It was observed in the study that heat impacted on %EE in the smoked fish samples. This study suggests that a properly dried fish can maintain its lipid quality over time; as in the case of fish smoked using charcoal and firewood. The high lipid content of the samples is an indication that there was so high fat reserve in the muscle of the fish.

The result of the lipid content of catfish obtained from this study was higher than the report of Usman (2017) who recorded a range of 14.47 – 15.53 for smoked C. *gariepinus* sample in Lapai, Niger state, Nigeria. Also, there was no significant difference in the samples from charcoal and firewood heat except in the electrical dehydrator. Nitrogen free extract in the fish samples was significantly higher in fish samples smoked using charcoal than fish samples smoked using other heat sources which could be due to differences in the removal of moisture in the fish during smoking process.

## CONCLUSION

The results of the present study revealed that heat sources impacted on the proximate composition of C. *gariepinus* significantly. The study indicated high moisture content in fish samples smoked using electrical dehydrator compared to other heat sources while the lowest moisture content was obtained in fish smoked with charcoal heat. This study suggests that well dried fish can maintain its lipid quality over time as in the case of charcoal and firewood smoked fish. All the fish samples dried in the different heat sources showed a reduction in their crude fibre.

## RECOMMENDATIONS

1. To prevent waste and economic losses, fish handlers should take fish processing and preservation more seriously.
2. Further research should be carried out on the microbial qualities of the heat sources in Federal university of Lafia in order to achieve stable quality of smoked fish.

## ACKNOWLEDGEMENT

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# SHELF-LIFE EXTENSION OF CATFISH (*Clarias gariepinus*) USING JERUSALEM (*Cnidoscolus aconitifolus*) LEAF EXTRACTS

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**ABSTRACT**
*Ethanolic, hot water, cold water, and raw juice extracts of Cnidoscolus aconitifolius (commonly known as Jerusalem leaf) were evaluated for their effectiveness in preserving African catfish (Clarias gariepinus) post-slaughter. The study aimed to determine the potential of these natural extracts in extending the shelf life of the fish. Results indicated that the raw juice extract was the most effective, extending the shelf life from 20 hours in the unpreserved control sample to 28 hours post-slaughter, beyond which the fish was deemed unfit for consumption. In comparison, the hot water and cold-water extracts extended the shelf life to 24 hours each, while the ethanolic extract had no significant effect, preserving the fish for only 20 hours. Among the tested treatments, the raw juice extract demonstrated the highest efficacy, likely due to its ability to retain and release active phytochemicals more effectively than the other extraction methods. These findings suggest that raw juice extract of Cnidoscolus aconitifolius could serve as a promising natural preservative for short-term fish storage, particularly for Clarias gariepinus.*

**Keywords:** Jerusalem leaf, hot water extract, cold water extract, ethanolic extract, phytochemical compounds

## INTRODUCTION

Catfish are one of the oldest and most widespread fish species (Cecilia Snyder, 2023). Catfish as a group are of considerable commercial importance. Most catfish are bottom feeders. In general, they are negatively buoyant, which means that they usually sink rather than float due to a reduced gas bladder and a heavy, bony head. They are a diverse group of ray-finned fish. Catfish do not have scales; their bodies are often naked. In some species, their mucus-covered skin is used in cutaneous respiration, where the fish breathes through its skin (Bruton, 1996). C*nidoscolus aconitifolus, is a* plant which belongs to the family *Euphorbiaceae*. The plant is called 'chi da zugu' in Hausa language, Iyana Ipaja in Yoruba language while it is sometimes unconventionally referred to as 'Hospital is too far' by some other people. The leaves have active antimicrobial compounds such as alkaloids, saponins, flavonoids and tannins etc which are known for extending shelf life of food materials preserved by it (Wistar *et al*., 2012). C. *aconitifolus* locally prepared extract is a natural preservative which is able to provide natural anti-oxidant benefits and reduce microbial invasion in fish while extending the shelf life of food (Asguith and Butter, 1996). This study is therefore done to extend the shelf life of freshly slaughtered catfish preserved with extract of Jerusalem leaf and also to determine which method of extraction is best for the extraction of the antimicrobial compounds in it.

## MATERIALS AND METHOD

The catfish (C. *gariepinus*) samples were purchased from an artisanal fish seller in Kainji, Niger State. The fish were transported to the feed mill at Federal College of Freshwater Fisheries Technology, New Bussa, Niger State for the shelf life studies. There were five samples used for the experiment that were all gutted and placed in separate processing bowls.

**Collection of Plant Materials**
The plant materials (leaves) used were Jerusalem leaf; it was collected from the back of the Hospitality Department at Federal College of Freshwater Fisheries Technology, New Bussa, Niger State.

**Preparation of Extracts**
The Jerusalem leaf was washed clean with water to remove dirt and dust. This was then macerated and extraction done according to Ephraim (2010) as follows;

1. 300g of Jerusalem leaf was soaked in 150ml of cold-water for 24hours. The pulp obtained was left in a clean plastic container and shaken vigorously to allow for proper extraction. Filtration was done using a sterile muslin cloth after which the extract obtained was air-drained and stored at ambient temperature until it was used.
2. The raw juice extract was obtained by squeezing the leaf to obtain its juice, which was air dried and stored as done in (1) above. The hot water and ethanolic extracts were also prepared as done in (1) above.

**Preservation of Fish Using Extracts and Shelf Life Studies**
The fish samples were dipped inside the extracts in separate bowls and monitored for spoilage at an interval of 4 hours and the organoleptic characteristics were accurately noted and recorded.

**RESULTS AND DISCUSSION**
The results of this work showed a variation between C. *gariepinus* sample preserved with cold water, hot water, raw juice and ethanolic extracts of C. *aconitifolus* and the unpreserved sample. Natural preservation of fish, involves the use of plant parts i.e. leaves, stem, root, seeds etc, which contains active ingredients that slow down microbial growth and fat oxidation, so as to reduce the rate of spoilage and rancidity in fish (Andrew *et al.*, 2008). Jerusalem leaf extracts have been proven to contain active ingredients (flavonoids, tannins, saponins etc.) that delays microbial activities (deterioration) on fish (Pangha *et al.*, 2021). This work showed a variation between catfish preserved with cold water, hot water, ethanolic and raw juice extracts of C. *aconitifolus* from 20 hours as seen in the unpreserved sample (Table 1) to 28 hours in the raw juice extract (Table 2). It was also observed from the study that the raw juice extract was the best for preservation of catfish since it was found to extend the shelf life of fish to 28 hours compared to hot water, cold water and ethanoilic extracts. Ibekwe *et al.*, (2001) and Dutta (1993) had discovered ethanolic extracts to be more effective than the hot and cold water but had not compared it to the raw juice extracts, which proved more effective than the ethanolic extract in this study. The ability of Jerusalem leaf to preserve fish for 20 hours post-slaughter before spoilage began (Table 3) is not in line with the findings of Oladosu-Ajayi *et al.*, (2016) whose ethanolic extract of bitter leaf (*Vernonia amygdalina*) extended the shelf life of catfish for 36 hours post slaughter before spoilage could manifest and also that of Ajibola (2010) that the ethanolic extract of black pepper (*Piper nigrum*) which was preserved till 24-26 hours before spoilage set in. Catfish preserved with hot water extract of C. *aconitifolus* (Table 4) stayed for 24 hours post-slaughter before it was no longer fit for human consumption, and this was in line with the findings of Olateju (2010) whose hot water extract of grape fruit (C*itrus paradisi*) peel was able to extend the shelf life of catfish from 24-26 hours, but unlike that of Oladosu-Ajayi *et al.*, (2016) as the sample preserved with hot water extract only stayed till the 20$^{t}$ hour before spoilage began.

The inability of hot water to perform much is probably because some of the active ingredients like the glycosides, tannins, saponins, flavonoids, in C. *aconitifolus* (Egharevba *et al.*, 2014) are heat labile. The cold-water extract of C. *aconitifolus* only preserved catfish for 24 hours in Table 5 before it became unfit for consumption; this is not in line with the findings of Oladosu-Ajayi *et al.*, (2016) whose cold-water

extract only extended the shelf life of C. *gariepinus*) for 20 hours. It can thus, from this study be deduced that cold water could slightly liberate the antimicrobial compounds in C. *aconitifolus*. The unpreserved sample remained fit for (2010) and Oladosu-Ajayi *et al.*, (2016) as the unpreserved fish sample from these studies stayed till the 24 hour. The reason for these differences could be as a result of the ambient and environmental temperature as at the time of consumption for 20 hours before spoilage could set in. This is in line with the findings of Ajibola (2010) and Oladosu-Ajayi *et al.*, (2011) who monitored catfish at an ambient temperature but differed from that of the Ephraim experiment. The study carried out by Ephraim (2010) was in Abeokuta, Ogun state, that of Oladosu-Ajayi *et al.*, (2016) was New Bussa, in Niger State, showed a variation in environmental temperature while that of Ajibola (2010) and Oladosu-Ajayi *et al.*, (2011) might have as well resulted at a different ambient temperature as at the time the experimental work was carried out.

**Table 1:** Organoleptic characteristics of unpreserved *Clarias gariepinus*

| Hours | Eyes | Gills | Skin | Flesh |
|---|---|---|---|---|
| 0 | Convex | Reddish with fresh odour | Smooth and fresh with silvery colour at ventral region and darkly coloured at the dorsal region | Firm and elastic |
| 4 | Bulging black pupil | Less reddish, neutral odour | Smooth and fresh clear mucus and shinning | Firm and elastic |
| 8 | Black pupil and grey cornea, convex | Pale reddish and neutral odour | Tough, dry and shinning | Firm |
| 12 | Flat or concave, black pupils | Totally bleached neutral odour | The dorsal region totally black in colour, dry, the ventral region is darkly coloured | Firm |
| 16 | Flat, black pupil | Slightly brownish neutral odour | No mucus, dull, the ventral and dorsal region are darkly coloured | Firm |
| 20 | Sunken, opaque, black pupil | Brownish, sour odour | The dorsal and ventral regions are completely blackish in colour. Dull, tough | Less firm |
| 24 | Sunken, absence of cornea black pupil | Pale brownish, sour odour | The dorsal and ventral completely blackish, dull | Less firm and slightly not elastic |
| 28 | Sunken, opaque, black pupil, disappearance of cornea | Slightly greenish, rancid odour | The dorsal and ventral region are completely blackish, dull | Less firm, inelastic |
| 32 | Sunken, black pupil, disappearance of cornea | Less greenish rancid/offensive odour | Dull, rough, the dorsal and ventral regions are becoming reddish | Firm and inelastic |
| 36 | Sunken, black pupil, no cornea | Slightly greenish, rancid odour | The dorsal and ventral regions are slightly | Soft |

| | | | | |
|---|---|---|---|---|
| | | | changing to reddish colour, dull, rough | |
| 40 | Deeply sunken, black pupil, opaque | Slightly greenish pungent odour | The ventral and dorsal regions are minimally reddish, tough, dull | Flabby, soft |
| 44 | Flat eyes, opaque, black pupil | Greenish, ammoniacal odour | Blackish along ventral dorsal region | Swollen, soft |
| 48 | Deeply sunken, black pupil opaque | Pungent offensive odour | Slight blackish color along the dorsal region, slightly retain finger indentation | Soft. swollen |

**Table 2:** Organoleptic characteristics of *Clarias gariepinus* preserved with raw juice extract of Jerusalem leaf

| Hours | Eyes | Gills | Skin | Flesh |
|---|---|---|---|---|
| 0 | Convex, black pupil, grey cornea | Bright red with fresh odour | Smooth and fresh, darkly coloured at the dorsal region and silvery coloured at the ventral region | Firm and flexible |
| 4 | Convex, black pupil | Less reddish, fresh odour | No mucus on the skin, smooth and shining | Firm and flexible |
| 8 | Less protruded or flat, black pupil | Pale red and neutral odor | Partially reddish along the point below the lateral line (above the ventral region), no mucus on the skin, tough | Firm and hardened |
| 12 | Sunken, black pupil | Bleached neutral odour | Reddish colour along the entire ventral and dorsal region | Firm |
| 16 | Sunken, opaque, black pupil | Deeply bleached, cloudy, neutral odour | Dry, less shining, reddish along the ventral and dorsal region | Firm and inelastic |
| 20 | Sunken, opaque, black pupil | Brownish and cloudy sour odour | Blackish colour along the dorsal and reddish colour along the ventral, dull, tough | Firm and hard |
| 24 | Black pupil, Sunken, opaque | Brownish, sour odour | Presence of maggot, reddish colour along the ventral and dorsal region, dull | Firm, slightly not elastic |
| 28 | Opaque, black pupil, sunken deeply, maggot growth | Brownish, cloudy, rancid, odour | Wet belly, ventral and dorsal regions are reddish, dull | Less firm, inelastic |

| | | | | |
|---|---|---|---|---|
| 32 | Deeply sunken, black pupil, opaque | Pale brownish and cloudy, offensive odour | Dull, dry, dorsal and ventral regions are reddish | Soft and inelastic |
| 36 | Sunken, opaque, black pupil, disappearance of cornea | Pale brownish and cloudy, offensive odour | The dorsal and ventral regions are now bleached reddish, rough and dull | Soft and turgid |
| 40 | Deeply sunken, black pupil, maggot | Pale brownish, pungent odour | Reddish colour along the ventral and dorsal regions, tough, dull | Soft |
| 44 | Deeply sunken, black pupil, opaque | Pale brownish, offensive/pungent odour | Slightly reddish along the ventral and dorsal regions, rough and dull | Soft |
| 48 | Deeply sunken, black pupil opaque | Brownish and cloudy, offensive odour | Slightly retains finger indentation, dull, rough, slightly reddish along the ventral and dorsal regions, maggot growth | Soft |

**Table 3:** Organoleptic characteristics of *Clarias gariepinus* preserved with ethanolic extract of Jerusalem leaf

| Hours | Eyes | Gills | Skin | Flesh |
|---|---|---|---|---|
| 0 | Convex, black pupil, grey cornea | Reddish with fresh odour | Smooth and fresh, with silvery colour at the ventral region and darkly coloured at the dorsal region | Firm and flexible |
| 4 | Convex, black pupil | Pale reddish, with fresh odour | Smooth and freshly shining | Firm and flexible |
| 8 | Bulging, black pupil and grey cornea | Pale reddish, neutral odour | Slightly reddish along the ventral region and dark on the dorsal region, tough | Firm and hardened |
| 12 | Less convex | Bleached neutral odour | Darkly coloured at the dorsal region and silvery at the ventral part, tough | Firm |
| 16 | Flat, black pupil, opaque | Deeply bleached, neutral odour | Less shining, dull, silvery colour at the ventral region and blackish at the dorsal region | Firm |
| 20 | Flat, opaque, black pupil | Brownish and cloudy, sour odour | Light reddish along the ventral region and blackish along the dorsal region, dull and tough | Less firm |

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|---|---|---|---|---|
| 24 | Flat, black pupil, opaque, disappearance of cornea | Pale brownish, sour odour | Blackish on the dorsal region and slightly, reddish on the ventral part, dull, soft belly | Less firm |
| 28 | Flat, opaque, black pupil | Brownish and cloudy, rancid odour | Swollen, dull, reddish along the ventral region and blackish along the dorsal region, presence of maggots | Less firm and hardened |
| 32 | Flat, no cornea, black pupil | Pale brownish, cloudy, offensive odour | Swollen, dull, reddish along the ventral region and blackish along the dorsal parts, invasion of maggots | Soft |
| 36 | Flat, opaque black pupil | Slightly greenish, maggot appearance, rancid odour (offensive) | Highly swollen, rough dull, reddish ventral region and blackish dorsal part | Soft |
| 40 | Flat, black pupil, opaque | Slightly greenish with maggot growth, pungent odour | Slightly reddish along both the ventral and dorsal regions, swollen, rough and dull, maggot around the belly | Soft, flabby |
| 44 | Flat, black pupil, opaque | Pale brownish gills, offensive and pungent odour | Totally swollen, reddish along the dorsal and ventral portions, dull | Soft, retain finger indentation |
| 48 | Flat, black pupil | Greenish, offensive odour | Turgid, swollen, retains finger indentation, reddish along the ventral region, slightly blackish along the dorsal part | Soft, swollen flabby, appearance of finger indentation when touched |

**Table 4:** Organoleptic characteristics of *Clarias gariepinus* preserved with hot water extract of Jerusalem leaf

| Hours | Eyes | Gills | Skin | Flesh |
|---|---|---|---|---|
| 0 | Convex, black pupil, grey cornea | Bright red, fresh odour | Smooth and fresh, darkly coloured at the dorsal region and silvery coloured at the ventral region | Firm and flexible |
| 4 | Convex, black pupil | Pale red, fresh odour | Clear mucus, shining | Flexible and elastic |
| 8 | Convex, black pupil | Pale red, neutral odour | Tough, slightly reddish along the point immediately above the ventral region | Firm and hardened |

| | | | | |
|---|---|---|---|---|
| 12 | Less convex, partially sunken, black pupil | Partially Bleached neutral odour | Reddish colour along the ventral region, blackish colour along the dorsal region, less shining, tough | Firm and hardened |
| 16 | Flat, black pupil, opaque | Partially bleached, neutral odour | Dry, less shining, tough, reddish along the ventral region and blackish along the dorsal region | Firm |
| 20 | Flat, black pupil, grey cornea | Pale brownish, stale odour | Dull, tough, reddish colour along the ventral part and extending above the lateral line, soft along the belly region | Firm |
| 24 | Sunken, black pupil, presence of cornea, opaque | Pale brownish, sour odour | Reddish along and beyond the ventral region and extending beyond the lateral line, blackish along the dorsal region, dull | Less firm, and slightly inelastic |
| 28 | Deeply sunken, opaque, grey cornea, black pupil | Pale whitish, rancid odour | Blackish along the dorsal region, dull, tough, reddish along and beyond the ventral and dorsal region | Less firm, inelastic |
| 32 | Sunken, black pupil, opaque | Pale whitish, offensive odour | Dull, rough, slightly reddish along the ventral and dorsal region | Soft |
| 36 | Sunken, opaque, black pupil, maggot appearance | Pale whitish and cloudy, offensive odour | Reddish along the ventral region and blackish along the dorsal region, rough, dull | Soft |
| 40 | Sunken, opaque, maggot appearance, black pupil | Brownish and cloudy | Slightly reddish ventral and dorsal regions, rough, dull | Soft, flabby |
| 44 | Deeply sunken, maggot appearance, black pupil | Pale brownish, cloudy with offensive and pungent odour | Reddish along the ventral and dorsal region, dull | Soft |
| 48 | Sunken, black pupil, maggot appearance | Pale brownish, cloudy, pungent and offensive odour | Reddish along the ventral and dorsal region, dull, tough | Soft |

**Table 5:** Organoleptic characteristics of *Clarias gariepinus* preserved with cold water extract of Jerusalem leaf

| Hours | Eyes | Gills | Skin | Flesh |
|---|---|---|---|---|
| 0 | Convex, bulging | Reddish with fresh odour | Smooth and fresh, silvery colour at the ventral region and darkly coloured at the dorsal region | Firm and flexible |
| 4 | Bulging, dark pupil, brown cornea | Pale reddish, fresh odour | Clear mucus, shining and firm | Firm and elastic |
| 8 | Less bulging, black pupil, grey cornea | Pale red and neutral odour | Slightly reddish below the lateral line, tough and shinning | Firm |
| 12 | Less bulging, black pupil, grey cornea | Bleached neutral odour | Reddish colour along the ventral region and blackish along the dorsal region, less shining, tough | Firm |
| 16 | Flat, grey cornea, black pupil | Deeply bleached, neutral odour | Dull, less shining, reddish along dorsal region | Firm |
| 20 | Sunken, black pupil, opaque | Brownish and sour odour | Dull, tough, reddish along the ventral part, blackish on the dorsal region | Firm and hard |
| 24 | Sunken presence, maggot appearance, opaque, black pupil | Pale brownish with sour odour | Tough, blackish along the dorsal region, reddish along the ventral region, dull | Less firm |
| 28 | Sunken, maggot appearance | Pale brownish, rancid odour, maggot appearance | Dull, tough, blackish along the dorsal reddish along the ventral part | Less firm, inelastic |
| 32 | Sunken, total maggot invasion | Pale brownish, offensive odour | Dull, dry, reddish along the ventral region and blackish along dorsal region | Less firm and inelastic |
| 36 | Sunken, total maggot invasion | Pale brownish and cloudy, offensive odour | Blackish along the dorsal region and reddish along the ventral region, tough, dull | Less firm |
| 40 | Sunken, total maggot invasion | Pale brownish, cloudy, pungent odour | Dull, rough, slightly blackish along the dorsal region and reddish along the ventral part | Soft |

| | | | | |
|---|---|---|---|---|
| 44 | Deeply sunken, complete maggot invasion | Pale brownish with offensive and pungent odour | Slightly reddish along both the ventral and dorsal regions | Soft |
| 48 | Deeply sunken, complete maggot invasion | Pale brownish, presence of maggot, offensive odour | Rough, dull, slightly reddish along the ventral and dorsal region | Soft |

## CONCLUSION

It can thus be concluded from this study that raw juice extract of Jerusalem leaf is best for preserving catfish in order to extend its shelf life. C. *aconitifolus* was able to do this because of its preservative ability which stems from the phytochemical compounds present in it. It can also be found from this study that the phytochemical compounds of Jerusalem leaf cannot be easily liberated by ethanol. To this end, raw juice extracted from the Jerusalem leaf is the best preservative for catfish since it was able to reasonably extend its shelf life beyond that of unpreserved samples. After using Jerusalem leaf in soup preparation; its juice can be used by fish processors as a preservative instead of disposing of it. Fish may also be treated by immersion in the raw extract of Jerusalem leaf prior to smoking, in order to evaluate its potential for extending shelf life.

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# SENSORY QUALITY OF SMOKED-GUTTED AND DEGUTTED CATFISH (*Clarias gariepinus*, BURCHELL 1822) FROM TWO DIFFERENT SMOKING KILNS

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**ABSTRACT**

*Consumer's preference of eating smoked dried gutted and degutted was based on sensory profile a nd storage quality. This study assesses the sensory quality and shelf life of Clarias gariepinus using two different smoking kilns (FUTY and improved smoking kilns) Seventy two live Clarias gariepinus were procured, processed and grouped into two gutted and degutted sample. These sample were further grouped into four treatment representing gutted sample smoked in improved smoking kiln {GSSI) and FUTY smoking kiln (GSSF) while degutted sample were smoked in improved smoking kiln (DSSI) and FUTY smoking kiln as well (DSSF). Sensory quality of freshly smoked fish and preserved fish were taken following standard procedure. The statistical analysis of data was conducted by descriptive statistics and ANOVA at* $\alpha_{0.05}$. *The fish samples weighed between (0.6kg-1.2kg), with an average weight of 0.85kg, the type of smoking kiln and gut content significantly affected the sensory profile. T1 (Improved smoking kiln) had the highest at* $\alpha_{0.05}$. *value of 7.2+0.29, T4 (FUTY smoking kiln and gutted fish) had the least taste value of 6.1+0.8. T1 had the highest appearance value of 6.4+0.4, while the least appearance was in T3 (FUTY Smoking kiln and degutted) with 5.3+0 .56. The highest texture value was observed in T1 with 7.1+0.23, while the least was in T4 with 6.7+0.40. The least rancidity value found in T3 with 6.2+0.39. There were no significant differences in appearance, aroma, taste, and general acceptability across treatments. This study reveals that smoking kiln type and gut content significantly influence the sensory profile of freshly smoked fish, but this effect diminishes after three months of preservation.*

**Keywords**:
Sensory-profile, smoked dried fish, storage quality and African catfish

## INTRODUCTION

Fish makes up about 60% of world protein supply and developing countries derive more than 30% of their annual protein from fish (Kefas *et al.*, 2022)). Fish is low in fat and cholesterol; it is also rich in calcium, phosphorus, vitamins A and D (Khalili and Samples, 2018). Fish is highly perishable because it provides favourable medium for growth of micro-organism after death (Aliyu *et al*, 2012; Oparaku and Megbenka 2012). A number of processing techniques is in operation in Nigeria. These include chilling, freezing, salting, canning, drying and smoking. However, smoking is the most popular method of fish processing and among the several methods of long-term preservation of fish, smoking is perhaps the simplest method as it does not require sophisticated equipment or highly skilled workers (Olayemi *et al.*, 2011). Smoked-dried fish is the most acceptable form of fish product in Nigeria. Smoking is the oldest and most common method of fish preservation in many developing countries (Malgwi 2023). The smoke is produced by the process of incomplete combustion of wood in order to impart a characteristic flavour and colour to the fish (Kumolu-Johnson *et al.*, 2010). Hence this study is aimed to evaluate the sensory and storage quality of *Clarias gariepinus* using two different processors (Federal University of Technology, Yola and Improved smoking kiln)

## MATERIALS AND METHODS

The experiment was conducted in the dry laboratory of the Department of Fisheries, Modibbo Adama University Yola, Adamawa State. It is Located at Latitude $9^0$21'1'N to $9^0$21'20'N and longitude $12^0$28'45"E to $12^0$30'28"E. The Climate condition is characterized by dry and hot season with the hottest months being March and April and the coldest months being December and January**:** GIS Unit, Department of Geography MAUTECH, (2015) Minimum average
Temperature is 20.5 $^0$C and a maximum Temperature of up to 40 $^0$C (Adebayo and Zemba, 2020). The rainy season is usually short normally from the month of May to October with low relative humidity and average annual rainfall of 872.4mm.

### Treatment and Experiment Design

This research was conducted with a 2 x 2 x 3 factorial experimental design. Two treatments were used which were gutted and degutted C*larias gariepinus*.
Factor A Processors (Improved Smoking Kiln and Federal University of Technology, Yola (FUTY) Smoking kiln.
Factor B Treatments (Gutted and degutted C*larias gariepinus*).

### Sample Collection

Seventy-two table size (adult) C*larias gariepinus* samples ranging from 600g-1200g were purchased from a reputable Fish Farm in Jimeta-Yola, Adamawa state. The fish sample were transported live using three (3) 50 litres Jerricans to the dry laboratory of the Department of fisheries, Modibbo Adama University, Yola, Adamawa State. The Fish samples collected were washed and weighed to determine its average mean weight, thirty-six (36) were gutted and thirty-six (36) were degutted. Samples were dipped in a brine solution (5% NaCl) for 10 minutes then allowed to drain as suggested (Sogbesan *et al.* 2012).

### Preparation and processing of Fish Samples

Thirty-Six (36) Sample each of C*larias gariepinus* were gutted using a sharp Knife laterally from the end of the gill cover through the belly portion (Ventrally) to the Anus and eviscerated (entrails were removed). The degutted C*larias gariepinus* thirty-Six (36) were kept in a basin with water, Salt was applied to them and washed properly.

### Source of Fuel

One bag of charcoal was purchased from a charcoal seller in Sabon Gari and was transported to the dry laboratory of Department of Fisheries of Modibbo Adama University, Yola. The whole bag of the charcoal was used in smoking the fish samples, while little by little the charcoal was added as the smoking process was ongoing to maintain steady temperature. This lasted for 18hours.

### Fish Processing Procedure

The fish samples were processed using Federal University of Technology, Yola Smoking Kiln and Improved Smoking Kiln. The drying rate or moisture loss was measured at the end of the drying process, there was frequent checking of the fish in other to take precaution against charring of the fish product until the fish were completely smoked and dried. The fish were then allowed to cool at an ambient temperature before they were package using a polyethylene bag for preservation.

### Packaging Materials

Polyethylene packing rolls were obtained from Jimeta Modern Market, Adamawa state. The packaging material that was used for the period of 12 weeks (3 months) for preservation of the processed fish was

10×6 cm polyethylene and 12 x10 x 10 cm carton similar to Oluborode *et al*, (2013).

**Procedures for Sensory Evaluation**

Procedures and Methodology for Sensory Evaluation of C*larias gariepinus*.

Panel Selection: A panel of 10 trained sensory evaluators were selected based on their ability to detect differences in taste, texture, appearance, and aroma. Panelists couldn't consume food, beverages, or strong-smelling substances 30 minutes prior to the evaluation.

Evaluation Setup: The sensory evaluation was conducted in a controlled environment, typically in a well-lit, room with minimal distractions. Each panelist was provided with a randomized set of fish samples from both the gutted and degutted groups, smoked using both kilns.

Evaluation Criteria: The fish samples were evaluated based on the following sensory attributes using a 9-point hedonic scale (where 1 = dislike extremely, and 9 = like extremely):

Appearance: General visual appeal of the smoked fish, including colour uniformity, glossiness, and visual defects.

Texture: Mouthfeel, firmness, and chewiness of the fish flesh.

Flavour: Smokiness, fish flavour intensity, and any off-flavours.

Aroma: Smell of the smoked fish, intensity of smokiness, and overall pleasantness.

Overall Acceptability: General liking or preference for each sample.

**Sample Preparation**

Fish Collection: Fresh C*larias gariepinus* of mature size weighed between 600g - 1200kg were collected from a reliable source. All the fish were in good condition without signs of spoilage or physical damage.

Gutting and Degutting: The collected fish were into two groups. The first group were gutted (removal of internal organs), and the second group were degutted (complete removal of internal organs, head, and fins).

**Smoking Process**

Kilns Used: Two different smoking kilns were selected for the smoking process. The smoking kilns were Federal University of Technology, Yola and improved smoking kiln.

Preparation of Kilns: Both kilns were clean and ready for use.

**Smoking Procedures**

Federal University of Technology, Yola Kiln: The gutted and degutted fish were arranged on the rack of the traditional

Kiln and maintained a steady heat by using the appropriate amount of wood.

Improved Kiln: The gutted and degutted fish were arranged on trays in the improved kiln. The temperature was monitored using the built-in controls, ensuring a smoking temperature.

**Cooling and Packaging**

The fish were smoked, and allowed to cool before any sensory evaluation. After cooling, samples were packaged in clean, airtight polyethylene bags to prevent moisture and contamination before the evaluation begins.

**Organoleptic Assessment after Smoking**

**Sensory analysis**

Organoleptic attributes of taste, texture, colour, rancidity and general acceptability of the fish samples were evaluated by 10 trained panellists, which were selected among the lecturers from the department of Fisheries and Food Science Modibbo Adama University, Yola using a 9- point hedonic scale (Peryam and

Pilgrim, 1957).
Samples of fish and questionnaire were given to each of the panellists across the department of Fisheries and Food Science alongside with bottle water to rinse their mouth after tasting each sample to eliminate the taste of the previous fish sample (Peryam and Pilgrim, 1957).After three(3) month of preservation, sample of the fish were given to ten students from the department of Fisheries with sachet water for rinsing their mouth after tasting each sample of fish to remove taste of previous fish sample. Questionnaires were collected and subjected for analysis

**Mean Sensory Evaluation of Processed Gutted and Degutted *Clarias gariepinus* Using Improved and Federal University of Technology, Yola (FUTY) Smoking Kiln**

The study showed the sensory evaluation of processed gutted and degutted *Clarias gariepinus* immediately after processing. There was significant differences within the taste of all the treatments as T1 (Improved smoking kiln and degutted fish) to have the highest taste value of 7.2 ± 0.29followed by T3 (Federal University of Technology Yola (FUTY) smoking kiln and degutted fish) with a value of 6.5 ± 0.5 and the least taste was observed in T4 (Federal University of Technology, Yola (FUTY) smoking kiln and gutted fish) with the value of 6.1 ± 0.8.

**T1** = Degutted fish smocked with improved smocking Kiln. **T2** = Gutted fish smocked with improved smocking Kiln. **T3** = Degutted fish smocked with Federal University of Technology Yola smocking Kiln. **T4** = Gutted fish smocked with Federal University of Technology Yola smocking Kiln

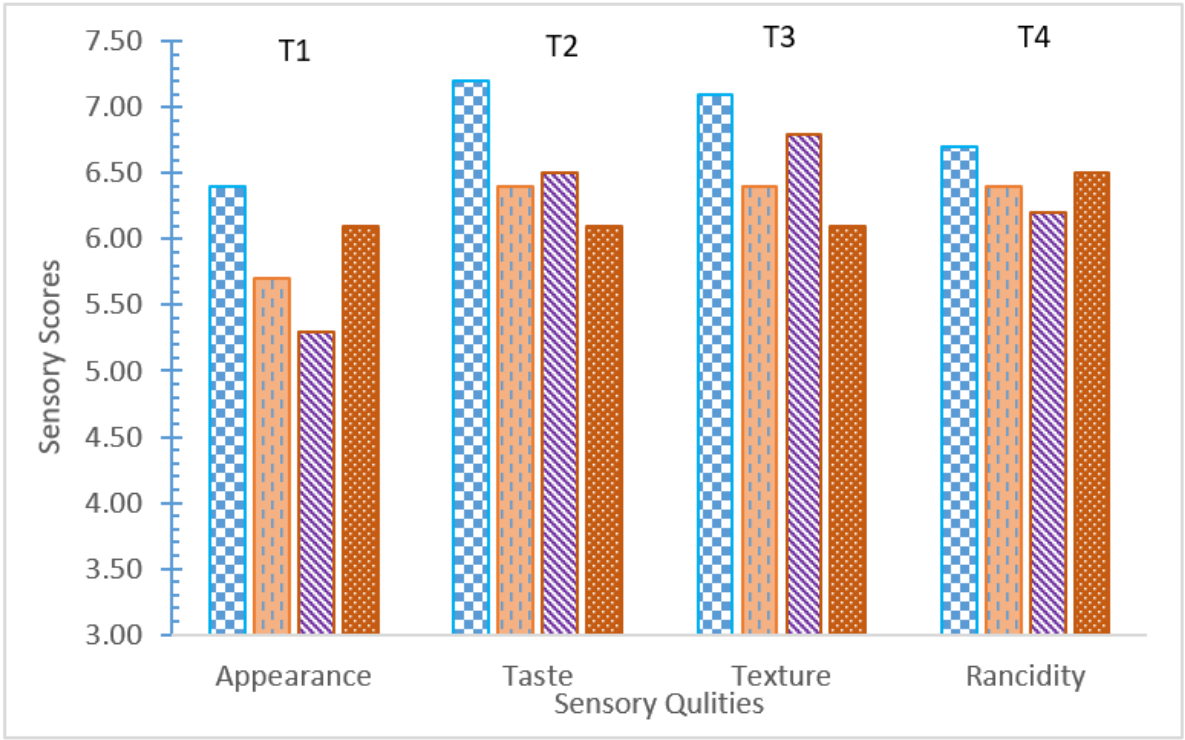



**Figure I:** Mean sensory qualities of processed Gutted and Degutted *Clarias gariepinus* using Improved and Federal University of Technology, Yola (FUTY),smoking Kiln.

The result also showed the appearance of the processed *Clarias gariepinus* before preservation which showed T1 (Improved smoking kiln and degutted fish) to have the highest appearance value after being smoked with a value of 6.4 ± 0.40 followed by T4(Federal University of Technology, Yola (FUTY) smoking kiln) with a value of 4.1 ± 0.67 and the least appearance was observed in T3 (Federal University of Technology, Yola (FUTY) smoking kiln and degutted fish) with the value of 5.3 ± 0.56 as seen in figure

1. The result also showed the texture of the processed *Clarias gariepinus* before preservation which T1 (Improvised smoking kiln) have the highest texture value of 7.1 ± 0.23 followed by T3 (Federal University of Technology, Yola (FUTY) smoking kiln and degutted fish) with a value of 6.8 ± 0.59 and the least texture was observed in T4 (Federal University of Technology, Yola (FUTY) smoking kiln and gutted fish) with the value of 6.1 ± 0.74. The result also showed the rancidity of the processed *Clarias gariepinus* before preservation which T1 (Improved smoking kiln) have the highest rancidity value after being processed with a value of 6.7 ± 0.40 followed by T4 (Federal University of Technology, Yola (FUTY) smoking kiln and gutted fish) with a value of 6.5 ± 0.64 and the least rancidity was observed in T3 (Federal University of Technology, Yola (FUTY) smoking kiln and degutted fish) with the value of 6.2 ± 0.3

**Mean Sensory Evaluation of Preserved Gutted and Degutted *Clarias gariepinus* Using Improved Smoking Kiln and Federal University of Technology, Yola (FUTY) Smoking Kiln Three (3) Months after Processing**

The study presented the sensory evaluation of preserved *Clarias gariepinus* three months after processing. Table 3 indicated that there were no significant differences in the appearance, aroma, taste, and general acceptability of all the treatments, as they all had a mean score of 1.25. The texture of the preserved *Clarias gariepinus* three months after processing was also assessed. T2 (Improved smoking kiln and gutted fish) was observed to have the highest texture value at 1.38, while the others had a texture value of 1.25. There were no significant differences ($p > 0.05$) as shown in table 1.

**Table 1:** Mean Sensory evaluation of preserved Gutted and Degutted *Clarias gariepinus* three (3) months after processed

| | N | T1 Mean | T2 Mean | T3 Mean | T4 Mean |
|---|---|---|---|---|---|
| Appearance | 8 | 1.25[a] | 1.25[a] | 1.25[a] | 0.00[b] |
| Aroma | 8 | 1.25[a] | 1.25[a] | 1.25[a] | 1.25[a] |
| Texture | 8 | 1.25[a] | 1.38[a] | 1.25[a] | 1.25[a] |
| Taste | 8 | 1.25[a] | 1.25[a] | 1.25[a] | 1.25[a] |
| General Acceptability | 8 | 1.25[a] | 1.25[a] | 1.25[a] | 1.25[a] |

Means with the different superscripts across the row are significantly different ($p > 0.05$)

**Key**
T1 = Gutted sample smoked with Improved smoking kiln
T2 = Degutted sample smoked with Improved smoking kiln
T3 = Gutted sample smoked with Federal University of Technology, Yola (FUTY) smoking kiln
T4 = Degutted sample smoked with Federal University of Technology, Yola (FUTY) smoking kiln
N = Means number of observations.

**Sensory Evaluation of Processed Gutted and Degutted *Clarias gariepinus* Using Improved and Federal University of Technology, Yola (FUTY) Smoking Kiln**

This study investigated the sensory evaluation of smoked African catfish (*Clarias gariepinus*) immediately after smoking but before preservation. The findings reveal significant differences in taste, appearance, texture, and rancidity scores among the treatments (smoking kiln type and gut content).

Degutted fish processed with the Federal University of Technology, Yola (FUTY) kiln (T1) received the highest taste score. This could be due to the Federal University of Technology, Yola (FUTY) kiln design which might promote better browning reactions during smoking, leading to more desirable flavours and also due to the absence of gut contents in degutted fish (T1 and T3) might eliminate any off-flavours associated with gut contents compared to gutted fish (T2 and T4). This agrees with the study of Ugochukwu *et al*. (2017) who investigated the sensory evaluation of hot-smoked C*larias gariepinus* processed with different wood sources and found that fish smoked with pepper wood received the highest overall sensory score. This highlights the influence of smoking wood on sensory characteristics

Similar to taste, degutted fish processed with the Federal University of Technology, Yola kiln (T1) received the highest appearance score. This could be due to more even browning or a more desirable smoked fish colour achieved by the Federal University of Technology, Yola (FUTY) kiln. This is similar to the study of Escapini *et al*. (2012) who studied the effect of smoking on the sensory properties of striped catfish (*Pseudoplatystoma reticulatum*) and reported that smoking time significantly affected the sensory scores, with longer smoking times leading to stronger smoked flavour and lower acceptability by panellists. This emphasizes the role of smoking duration in sensory perception.

Degutted fish processed with both kilns (T1 and T3) received higher texture scores compared to gutted fish (T2 and T4). This might be due to firmer texture resulting from better drying efficiency or the absence of gut contents affecting mouthfeel. Interestingly, minimal differences were observed in rancidity scores across treatments. This suggests that smoking duration or temperature might not have been sufficient to induce significant lipid oxidation at this stage. This aligned with the study of Ndiaye *et al*. (2013) who compared the sensory quality of fish jerky from round sardinella (*Sardinella aurita*) prepared using traditional and improved smoking methods and found that the improved method resulted in higher sensory scores for texture and overall acceptability. This reinforces the importance of optimizing smoking techniques for improved sensory qualities.

**Sensory Evaluation of Preserved Gutted and Degutted *Clarias gariepinus* Using Improved and Federal University of Technology, Yola (FUTY) Smoking Kiln for Three (3) Months**

This study examined the sensory evaluation of smoked and preserved African catfish (*Clarias gariepinus*) three months after smoking. The findings indicate a lack of significant differences in appearance, aroma, taste, and general acceptability across all treatments (smoking kiln type and gut content). However, a slight textural variation was observed as there were no significant differences in these sensory attributes (Appearance, Aroma, Taste, and General Acceptability) between treatments after three months of preservation. This suggests that both smoking methods and gut content may have minimal influence on these qualities after a prolonged storage period. The storage environment (temperature, humidity, and packaging) might have played a significant role in preserving the sensory characteristics of the fish across treatments. Storage conditions are crucial for maintaining the sensory quality of smoked and preserved C*larias gariepinus*. Processors and consumers should employ appropriate storage practices to minimize sensory deterioration. This is similar to the study of Bhargava *et al*. (2017) who investigated the effect of packaging materials on the sensory quality of smoked mrigal carp (C*irrhinus mrigal*) during storage and found that vacuum packaging significantly improved the shelf life and sensory attributes compared to traditional packaging methods. This highlights the importance of packaging in preserving sensory quality.

The gutted fish processed with the Federal University of Technology, Yola (FUTY) kiln (T2) had a slightly higher texture score compared to the other treatments. The reason for this difference is unclear and might require further investigation. The initial smoking process might have imparted a dominant smoke

flavor that masked any subtle variations between treatments after three months. While smoking kiln type and gut content might influence the sensory profile immediately after smoking, their impact might diminish over extended storage periods. Further research is needed to confirm this observation. This agrees with the findings of Jassim *et al.* (2016) who studied the sensory characteristics of hot-smoked Atlantic salmon (*Salmo salar*) during refrigerated storage and reported a decrease in overall acceptability scores over time, likely due to lipid oxidation and other quality changes. This suggests that even with smoking, some sensory deterioration can occur during storage.

**Comparing Sensory Evaluation of Smoked African Catfish (*Clarias gariepinus*) Between Freshly Processed and Preserved for Three Months.**

This study investigated the sensory evaluation of smoked African catfish (*Clarias gariepinus*) at two key points: immediately after smoking (freshly smoked) and three months after smoking (preserved). The findings reveal interesting changes in how smoking kiln type and gut content affect sensory perception over time.

Taste, appearance, and texture displayed significant differences between treatments. Degutted fish processed with the Federal University of Technology, Yola (FUTY) kiln generally received higher scores for taste and appearance, possibly due to better browning or absence of gut content flavours. Both degutted fish groups had higher texture scores compared to gutted fish, suggesting a firmer texture. Smoking parameters (potentially influencing browning and Maillard reactions), gut content flavours, and drying efficiency (affecting texture) likely play a more prominent role in sensory perception immediately after smoking. The findings agree with the study of Ugochukwu *et al*. (2017) who investigated the sensory evaluation of hot-smoked *Clarias gariepinus* processed with different wood sources and found that fish smoked with pepper wood received the highest overall sensory score immediately after smoking. This reinforces the influence of smoking parameters on freshly smoked fish sensory characteristics. Smoking kiln type and gut content have a stronger impact on the sensory profile of freshly smoked *Clarias gariepinus* compared to preserved fish stored for three months. Processors can leverage this knowledge to optimize smoking techniques for desired fresh-smoked qualities.

Findings from the result of preserved catfish (three months after smoking) shows that there were no significant differences in appearance, aroma, taste, and general acceptability across treatments. Only a slight textural variation was observed, with gutted fish processed with the Federal University of Technology, Yola (FUTY) smoking kiln having a slightly higher score. Which might be as a result of storage conditions likely played a significant role in homogenizing sensory attributes. The dominant smoke flavour might have masked any subtle variations between treatments. Additionally, some sensory characteristics might have dulled over time. This was also demonstrated in the study done by Jassim *et al.* (2016) who studied the sensory characteristics of hot-smoked Atlantic salmon (*Salmo salar*) during refrigerated storage and reported a decrease in overall acceptability scores over time, likely due to lipid oxidation and other quality changes. This aligns with the possibility of sensory attributes diminishing during storage observed in the current study. Also, Bhargava *et al*. (2017) investigated the effect of packaging materials on the sensory quality of smoked mrigal carp (*Cirrhinus mrigal*) during storage and found that vacuum packaging significantly improved the shelf life and sensory attributes compared to traditional packaging methods. This highlights the importance of optimized storage conditions for maintaining sensory quality over time

## CONCLUSION

The highest texture value was observed in T1 with 7.1+0.23, while the least was in T4 with 6.7+0.40. The least rancidity value found in T3 with 6.2+0.39. There were no significant differences in appearance, aroma, taste, and general acceptability across treatments. This study reveals that smoking kiln type and

gut content significantly influence the sensory profile of freshly smoked fish, but this effect diminishes after three months of preservation.

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# EFFECT OF CULTURING FACILITIES ON ORGANOLEPTIC PROPERTIES OF SMOKE-DRIED AND COOKED ADULT CATFISH *Clarias gariepinus* (Burchell, 1822)

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**ABSTRACT**
*This study evaluated the organoleptic properties of smoke-dried and cooked adult Clarias gariepinus reared in three different culture facilities: earthen pond, concrete pond, and plastic tank. Eighteen adult catfish were processed without spices to preserve their natural sensory characteristics. Six trained panellists conducted the assessment using structured questionnaires. Statistical analysis revealed significant differences ($p<0.05$) in taste, texture, fat content, and overall acceptability across the culture systems. Fish from earthen ponds, when smoked, exhibited superior taste, texture, and flesh integrity, with no vomiting sensation reported, making them the most preferred. Cooked fish from concrete ponds showed higher fat content, while those from plastic tanks were associated with increased vomiting sensation in both processing methods. Overall, earthen pond culture yielded the most organoleptically acceptable fish products, whether smoke-dried or cooked.*

**Keywords:** Culture media, processing method, organoleptic qualities and C*larias gariepinus*

## INTRODUCTION

The choice of fish culture facility; earthen pond, concrete pond, or plastic tank is influenced by factors such as budget, farm location, and production scale. Since fish is rarely consumed raw, various processing methods like boiling, frying, roasting, and smoking are used to enhance flavour, extend shelf life, and ensure safety. These methods can significantly affect the nutritional and organoleptic properties of fish (Olagbemide, 2015).

Fish is a vital source of high-quality protein, omega-3 fatty acids, and essential micronutrients, especially in food-insecure regions like sub-Saharan Africa, where over 200 million people face hunger (FAO, 2002). Nutritional evaluation of several species of marine and freshwater fishes has been reported. It is known that during heat treatments, the physicochemical property of fish undergoes significant changes (Akinwumi, 2014).

In Nigeria, fish accounts for 40% of animal protein intake due to its affordability and nutritional value (Omodara *et al.,* 2016). Processing methods not only improve taste and safety but also impact the physicochemical properties of fish, including fat content and digestibility (Jim *et al.,* 2017). To prevent spoilage and economic loss, effective fish processing and preservation are essential. Organoleptic qualities such as taste, texture, and aroma play a key role in consumer acceptance and must meet health and safety standards (Djopnang *et al.,* 2018). Poor sanitary practices in some culture systems affect product quality, yet many consumers prioritize quantity over safety. This study examines the organoleptic qualities of C*larias gariepinus* from earthen ponds, concrete ponds, and plastic tanks to assess how culture media influence consumer-acceptable fish quality.

## MATERIALS AND METHOD

### Study Area

The experiment was conducted in the wet laboratory of the Department of Fisheries and Aquaculture, Ebonyi State University, Abakaliki, located at latitude 6°20′N and longitude 8°06′E in South Eastern Nigeria. (Global Position System, 2018).

### Fish Procurement and Preparation

Eighteen live adult C*larias gariepinus* (average weight: 1000g) were sourced from FAQ Farm Complex of the Ebonyi State University, Abakaliki. Upon arrival, fish were washed to remove mucus, eviscerated, and cut into four parts. Samples were grouped for smoking and boiling, and further categorized based on culture media: earthen pond, concrete tank, and plastic tank.

### Smoking Procedure

Fish were sacrificed by head clubbing, gutted, washed, and smoked using a traditional drum kiln for 24 hours. Samples were turned periodically to prevent charring and cooled for 30–40 minutes at ambient temperature.

### Cooking Procedure

Fish cuts were washed, trimmed (tails discarded), and cooked without seasoning using standard utensils in the department's demonstration kitchen.

### Organoleptic Assessment

Six trained panellists from EBSU staff and secondary school evaluated the samples under controlled conditions. Fish were coded and served uniformly, with water provided for palate cleansing. Attributes assessed included taste, texture, fat level, colour, flesh compartment, vomiting sensation, and overall acceptability using a 5-point Hedonic scale (5 = Very Good to 1 = Very Poor), with 3.0 as the acceptability threshold (Munoz and King, 2007).

### Statistical Analysis

Data were analysed using One-way ANOVA, and significant differences ($p < 0.05$) were separated using Duncan's Multiple Range Test (DMRT).

## RESULTS AND DISCUSSION

Table 1 presents the organoleptic properties of Clarias gariepinus reared in three culture media and processed by smoking or cooking. Sensory scores for taste, texture, flesh compartment, vomiting sensation, fat level, and colour ranged from 5.00 ± 0.78 to 3.00 ± 0.40. Significant differences ($p < 0.05$) were observed across several parameters, particularly in taste, texture, and vomiting sensation.

Smoked fish from earthen ponds scored highest in taste (4.5 ± 0.65), flesh compartment (5.0 ± 0.78), and had no vomiting sensation, indicating superior quality. In contrast, cooked fish from plastic tanks had the lowest ratings, especially for vomiting sensation (3.5 ± 0.45). Fat levels were highest in cooked fish from concrete ponds (4.0 ± 0.58), while colour remained statistically similar across all treatments.

The observed differences may be attributed to both the culture environment and processing methods. Proper handling and hygiene likely contributed to the overall acceptability of the samples. The lack of significant variation in colour suggests effective preservation across all treatments.

**Table 1:** Organoleptic properties of *Clarias gariepinus* reared in three different culture media

| Parameters /Culture media | Taste | Flesh Compartment | Vomiting Sensation | Texture | Fat level | Colour |
|---|---|---|---|---|---|---|
| Concrete pond smoked | $4.0\pm0.58^{a}$ | $4.0\pm0.58^{a}$ | $1.0\pm0.00^{b}$ | $3.0\pm0.40^{a}$ | $4.0\pm0.58^{a}$ | $2.5\pm0.30^{a}$ |
| Earthen pond smoked | $4.5\pm0.65^{a}$ | $5.0\pm0.78^{ab}$ | $0.0\pm0.00^{b}$ | $3.5\pm0.45^{a}$ | $3.0\pm0.40^{b}$ | $2.5\pm0.30^{a}$ |
| Plastic tank smoked | $3.5\pm0.45^{c}$ | $3.5\pm0.45^{c}$ | $2.0\pm0.30^{ab}$ | $3.0\pm0.40^{c}$ | $2.5\pm0.30^{a}$ | $2.5\pm0.30^{a}$ |
| Concrete pond cooked | $3.0\pm0.40^{c}$ | $3.5\pm0.45^{c}$ | $3.0\pm0.40^{c}$ | $2.5\pm0.30^{a}$ | $3.0\pm0.40^{b}$ | $2.5\pm0.30^{a}$ |
| Earthen pond cooked | $3.0\pm0.40^{c}$ | $3.5\pm0.45^{c}$ | $3.0\pm0.40^{c}$ | $3.0\pm0.40^{c}$ | $3.0\pm0.40^{b}$ | $2.5\pm0.30^{a}$ |
| plastic tank cooked | $3.0\pm0.40^{c}$ | $3.0\pm0.40^{c}$ | $3.5\pm0.45^{c}$ | $2.5\pm0.30^{a}$ | $3.0\pm0.40^{b}$ | $2.5\pm0.30^{a}$ |

Figures with the same alphabet in superscript are not statistically different f($P<0.05$).

## CONCLUSION

From the organoleptic assessment, smoked fish from earthen pond had better taste, texture, flesh compartment and no vomiting sensation and general acceptability than other culture media as revealed by the panellists. Fish reared in concrete pond and processed by cooking had higher fat level than others, were those cultured in plastic tank had higher vomiting sensation for both smoked and cooked as revealed by the panellists. With the results of the assessment of the panellists, fish cultured in earthen pond is adjudged to better and generally accepted when smoke-dried or cooked.

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# FUNGAL ANALYSIS OF SMOKED CATFISH (*Clarias gariepinus*) FROM KITA, DONGA LOCAL GOVERNMENT AREA, TARABA STATE, NIGERIA

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**ABSTRACT**

*The study examines fungal contamination in smoke-dried Clarias gariepinus (African catfish). Using standard microbiological techniques, the study isolated and identified Aspergillus niger with the highest colony count ($5.0 \times 10^5$ CFU/g), followed by Aspergillus flavus, Penicillium sp., and Mucor sp. These fungi are known to produce mycotoxins, which can lead to severe health complications such as food poisoning and long-term organ damage. The high level of fungal contamination suggests that inadequate drying methods, unhygienic handling, and poor storage conditions contribute significantly to microbial growth in smoke-dried fish. The findings highlight the urgent need for improved fish processing and storage practices to minimize fungal contamination and ensure food safety. The study recommends adopting proper hygiene during fish smoking and handling, monitoring storage conditions, and enforcing stricter food safety regulations. Regular microbiological assessment of dried fish products is also necessary to prevent the consumption of contaminated fish and reduce health risks among consumers.*

**Keywords:** Fungal Analysis, C*larias gariepinus*, *Aspergillus niger*, *Aspergillus flavus*, *Mucor sp.*,

## INTRODUCTION

Fungi, moulds and bacteria are the agents responsible for various types of food spoilage and food borne intoxications (Haque *et al.*, 2021). Fish is one of the major sources of proteins upon which a large number of Nigerian populations depend. In Nigeria, fish and fish products constitute more than 60% of the total protein intake in adults. The problem of fish in Nigeria however, is its high rate of perishability especially since the relative ease of preservation is not readily attainable, hence the difficulty in handling.

Preserving fish involves processes that impede growth of microorganisms either by the addition of growth inhibiting ingredients or adjusting storage conditions by freezing or drying (Akise *et al.*, 2013). Processing methods affect the microorganisms in fish in different ways, resulting in different types of micro-flora and different risks from spoilage organisms and pathogens. Generally, the different preservation methods are: drying, smoking, freezing, chilling and brining. However, despite the fact that smoking is the most common method of fish preservation in Nigeria (Adeyeye and Oyewole, 2016), its effectiveness as an international source of foreign exchange is gradually losing ground (Ayodeji, 2020).

Fishes are susceptible to diseases caused by a large number of infectious agents including viruses, bacteria, true fungi, fungi-like microorganisms, other Protists and metazoans (Rodolphe *et al.*, 2014). In general, the number of reported fungi and fungi-like pathogens responsible for diseases in animal is on the increase globally (Gozlan *et al.* 2014). Mycotic infections of fishes by Oomycetes are wide spread in freshwater and represent the most important fungal group affecting wild and cultured fishes. This study is aimed at analysing the fungal species commonly found on smoked catfish (*Clarias gariepinus*) from Kita, Donga Local Government Area, Southern Taraba State.

## MATERIALS AND METHODOLOGY

### Area of Study

Kita Stream, Donga Local Government Area, Taraba State. Donga is a local Government Area in Taraba State, Nigeria. Its' headquarter is in the town of Donga on the Donga River at 7º 48` 00``N 10º 03` 00``E and 7.71667º 10.05000ºE. It has an area of about 3,420 km$^2$. It is a commercial centre which attracts people from many parts of neighbouring local government of the state like Takum, Wukari, Bali, Gassol. The Donga River arises from the Mambilla Plateau in Eastern Nigeria, form part of the international border between Nigeria and Cameroon, and flows northwest to eventually merge with the River Benue (Figure 1)

### Sample Collection and Preparation

A total of Ten (10) samples of Fresh Catfish (C*larias gariepinus*) were collected from Kita stream and was smoked by the Researcher, the smoked fish were placed in a sterile specimen bag and labelled. The total weight of the samples was measured in grams.

### Moisture Analysis

About 10 grams of the samples were added to pre-weighed aluminium foil and total weight was recorded. Samples were placed in 105$^0$C oven and dry for one hour to constant weight. Percentage moisture was computed as weight lost divided by sample weight multiplied by 100.

$$\% \text{ moisture} = \frac{\text{weight loss}}{\text{sample weight}} \; x \; 100$$

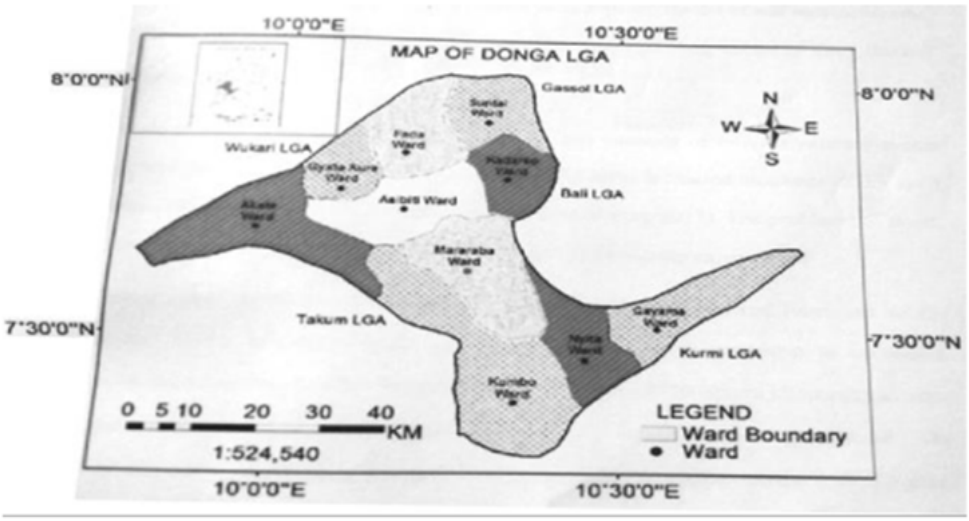



**Figure 1:** Map of Donga Local Government; Source: Ministry of land and survey, Taraba State (2019)

### Isolation of Fungi

***Dilution (Spotting) method***

Ten grams (10g) of each sample were aseptically weighed into a sterile bottle containing 90 ml of sterile peptone water. The mixture was shaken vigorously using vortex mixer to dislodge all fungal contaminants, 5-fold serial dilutions were prepared to $10^5$ (Samson *et al.*, 2010). One millilitre of each dilution is dispensed in duplicate in sterile Petri dishes. Molten Saboraud dextrose agar to which Chloramphenicol (0.5g/l) are added to the Petri dishes, which are gently rotated to ensure even dispersion. The plates were allowed to solidify and be incubated at ambient temperature (room temperature) for 3-7 days.

The cultures were examined for growth at regular intervals and all observed colonies are sub-cultured to

obtain pure colonies, which were subsequently isolated and identified using morphological characteristics, spore formation, the production of fruiting bodies and biochemical reactions (Alkenz *et al.*, 2015) and compares with mycology colour atlas.

**Identification of Fungi**

***Macroscopy***

The growth rate, colour, texture, colonial morphology and diffusible pigments of each sample were examined macroscopically.

***Microscopy***

A drop of lactophenol cotton blue stain was placed on a clean grease-free slide. A small fragment of (vegetative) colony, woolly or powdery colony was picked using a sterile needle and teased in the stain until a homogenous blue mixture of stain and culture is obtained. A clean cover slip was applied avoiding air bubbles. Excess stain was removed with blotting paper and the preparation was examined using X10 and X40 objectives of the microscope respectively.

***Grams Staining***

Suspected yeast colonies were stained using Gram's Method as described by Forbes *et al*. (2007).

***Fermentation test***

Fermentation test was carried out on suspected yeast organism with sucrose, lactose, glucose and maltose, as described by Forbes *et al.* (2007).

**RESULTS**

Table 1 presents the identified fungal species include *Aspergillus niger*, *Aspergillus flavus*, *Mucor sp.*, and *Penicillium spp*. These fungi are known contaminants of smoked fish. The results indicate that *Aspergillus niger* was the most prevalent fungus, accounting for 47.1% of the total isolates, followed by *Penicillium sp.* (23.5%), *Aspergillus flavus* (17.6%), and *Mucor sp.* (11.8%). The presence of these fungi in smoke-dried catfish suggests significant contamination, which could pose risks to food safety and public health (Table 2)

Table 3 presents the fungal load in smoke-dried *Clarias gariepinus*. The results indicate that *Aspergillus niger* had the highest fungal colony count ($5.0 \times 10^5$ CFU/g), followed by *Aspergillus flavus* ($2.0 \times 10^5$ CFU/g), *Penicillium sp.* ($2.0 \times 10^5$ CFU/g), and *Mucor sp.* ($1.5 \times 10^5$ CFU/g).

**Table 1:** Morphological characteristics of isolated fungi on saboraud dextrose agar

| Fungi | Morphology | Mycelia |
|---|---|---|
| *Aspergillus niger* | Dark appearance | Present |
| *Aspergillus flavus* | Dark green appearance | Present |
| *Mucor* spp. | White/grey appearance | Present |
| *Penicillium* spp. | Pale green | Present |

**Table 2:** Distribution of isolated fungi from smoke-dried catfish (*Clarias gariepinus*) samples

| Fungi | Number of fungi isolate | Total number of isolates | Percentage (%) |
|---|---|---|---|
| *Aspergillus niger* | 2 | 10 | 17.6 |
| *Aspergillus flavus* | 5 | 10 | 47.1 |
| *Mucor* spp. | 1 | 10 | 11.8 |
| *Penicillium* spp. | 2 | 10 | 23.5 |

**Table 3:** Number of fungi isolates from smoke-dried catfish (*Clarias gariepinus*) samples

| Fungi | Number of fungi isolate | Mean colony (CFU/gram) |
|---|---|---|
| *Aspergillus niger* | 2 | $2.0 \times 10^5$ |
| *Aspergillus flavus* | 5 | $5.0 \times 10^5$ |
| *Mucor* spp. | 1 | $1.5 \times 10^5$ |
| *Penicillium* spp. | 2 | $2.0 \times 10^5$ |

## DISCUSSION

The findings of *Aspergillus niger* in the present study agrees with studies that have reported *A. niger* as a common fungal contaminant in smoked fish, often due to inadequate drying and exposure to humid storage conditions. Dutta *et al.* (2018) also observed *A. niger* in stored smoked fish, where it contributed to spoilage. Similarly, Adamu *et al.* (2020) documented *A. niger* in freshwater fish samples from Nasarawa State, linking its presence to unhygienic handling and poor storage. The isolation of *Aspergillus flavus*, which is in line with the reports of Ike *et al.* (2020) who identified *A. flavus* as a predominant contaminant in smoked fish from Aba, Nigeria, emphasizing its association with poor drying and exposure to moisture. Otu *et al.* (2021) also reported *A. flavus* in smoked fish from Abuja, Nigeria. *Mucor sp.*, which was also detected in the present study was reported earlier by Bernal *et al.* (2018) who found *Mucor* in dried seafood sold in local markets in the Philippines, highlighting its role in food spoilage. The presence of *Mucor* in smoked fish suggests possible contamination from environmental sources during handling or storage, as also noted by Adamu *et al*. (2020).

The final fungal isolate, *Penicillium spp.*, was characterized by a pale green appearance with mycelial growth. *Penicillium* species are known producers of mycotoxins such as patulin and citrinin, which have been linked to kidney and liver toxicity. Dutta et al. (2018) found *Penicillium* species to be major contaminants in stored smoked fish, indicating that post-smoking handling and storage conditions play a critical role in fungal proliferation. Otu et al. (2021) also documented *Penicillium* in smoked fish sold in Nigerian markets, attributing its presence to poor post-harvest handling and prolonged storage. The finding discovered the predominance of *Aspergillus niger* (47.1%) aligns with previous studies that identified *A. niger* as a major contaminant in smoked and dried fish. According to Ike et al. (2020), *A. niger* was the most frequently isolated fungus in smoked catfish sold in Nigerian markets, contributing to food spoilage and potential mycotoxin production. Similarly, Adamu et al. (2020) reported that *A. niger* was among the dominant fungal species in freshwater fish from Nasarawa State, Nigeria, further confirming its prevalence in fish products. While *A. niger* is not the most potent mycotoxin producer, it has been associated with ochratoxin contamination, which has nephrotoxic and carcinogenic effects.

## CONCLUSION

The high fungal load observed in the samples suggests that factors such as moisture retention, inadequate drying, and exposure to environmental contaminants contributed to the contamination. The fungal counts recorded in this study exceed microbiological safety limits, indicating potential risks to consumers. The results underscore the importance of understanding the microbiological quality of

smoked fish, as contamination with toxigenic fungi can have significant health implications.

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# SUSTAINABLE INLAND, COASTAL AND MARINE AQUACULTURE DEVELOPMENT - SICMA

# SOCIO-ECONOMIC CHARACTERISTICS AND CONSTRAINTS TO SUCCESSFUL FISH FARMING IN DUTSE METROPOLIS JIGAWA STATE, NIGERIA

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**ABSTRACT**
*This study assessed the socio-economic characteristics and constraints confronting successful fish farming in Dutse metropolis Jigawa State, Nigeria. Targeted population were fish farmers whose sources of livelihood were from fish farming activities in the study area. Structured questionnaires were administered in a random sampling procedure within a period of four months (June - September 2024). Data from the study were analysed using Statistical Package for Social Sciences (SPSS) software version 22.0. The results obtained indicated that majority (64.70%) of the fish farmers were male indicating gender disparities which may be due to land tenure system. The active workforce is within the age bracket of 41-50 years (47.06%). Majority of the farmers were married (47.05%). It was also observed that (35.29%) of the fish farmers possess tertiary education. However, fish seed availability, water quality management, inadequate technical expertise, high feeding costs, marketing and disease infestation, was a major constraint. While Pest/predator attacks is classified as "minor constraints and theft, water availability and poor feed quality was ranked as not constraints. Efforts should be intensified on different areas of fish farming development.*

**Keywords**: Constraints, fish farming, Dutse metropolis, Livelihood

## INTRODUCTION

The fish farming industry, which accounts for over 50% of global fish production, is the fastest-growing food-producing sector (FAO, 2016). Nigeria, farming development has been driven by social and economic objectives, such as nutrition improvement in rural areas, generation of supplementary income, diversification of income activities, and the creation of employment (Anthony & Richard, 2016). The contribution of aquaculture to fish supply in Nigeria is an indication of growth in fish production activities as a result of global decline in supply of ocean fisheries associated with pressure on fishing, habitat destruction and environmental pollutions (Adedeji et al., 2011). Fish farming generates employment directly and indirectly in terms of people employed in the production of fishing output and other allied business, it also generates income for all categories of people involved in fish farming and thus contributes to the national income (Ogunremi et al., 2022). When compared with livestock, it requires less space, time, money and has a higher feed conserving rate (Nwakuche et al., 2019). Fish farming is regarded as a key agricultural and food-producing sector throughout the world. Ogunremi et al.(2022) reported that fish farming like any other area of agriculture is constrained by factors which hinder maximum productivity for meeting the protein demand and income generation of the populace. Hence this study was carried out therefore, to assess the socio-economic characteristics and the constraints affecting fish farmers in the study area.

## MATERIALS AND METHOD

### Study Area

The study was conducted in some farms in Dutse Metropolis, the capital city of Jigawa State, located in the northwestern region of Nigeria. Dutse lies between latitude 11°45′N and longitude 9°20′E, and it is characterized by a semi-arid climate with distinct wet and dry seasons. The average annual temperature ranges between 26°C to 39°C, and the rainy season typically spans from May to October (Barau, 2015).

Dutse Metropolis hosts several small- to medium-scale fish farms due to increasing interest in aquaculture as a means of livelihood and food security. These farms predominantly culture *Clarias gariepinus* (African catfish) due to its high tolerance to varying environmental conditions, rapid growth rate, and consumer preference.

**Data collection**
The qualitative data was collected through informant interview with various fish farmers. Data was collected through interviews of fish farmers using structured questionnaires on socio demographic characteristics of the respondent, and constraints of successful fish farming in Dutse within a period of four months (June - September 2024).

**Data Analysis**
Data was presented using a simple percentage and frequencies and proportions to summarize variables, using SPSS (version 22.0) statistical package software for analysis.

**RESULTS**
The age distribution of farmers showed that the majority are aged 41-50 years (47.06%) and only 5.88% of participants are above 51 years. Fish farming in Dutse is predominantly male-dominated, with males comprising 64.70% of the farmers. Females, at 35.30%, show moderate representation. Married farmers make up 47.05%, while single individuals represent 29.41%. Education levels among farmers reveal that 17.65% have primary education and 47.06 % have secondary education. Tertiary education is represented by 35.29%. Response on years of experience in fish farming indicated that 65.70% had 1-5years and 23.52% had 6-10 years of experience. 70.59% have not received any training on fish farming only 29.41% have being trained (Table 1).

The constraints confronting fish farmers in the study area is shown in Table 2. Pest/predator attacks and water availability was classified as "minor constraints," with mean scores of 1.67. Fish seed availability, water quality management, inadequate technical expertise, high feeding costs, and Disease infestation, was ranked as "major constraints" with mean scores of 2. Pest/predator attack is term as minor constraint. However, theft, water availability in terms of quantity and poor feed quality was ranked as not constraints with mean score of 1. Among, those fish seed availability was particularly notable and ranked 1. Following by high cost of feeding. Theft was considered not constraint with mean scores of 1 and ranked number 10. (Table 2).

**Table 1:** Socio-demographic Characteristics of Respondent

| Variable | Categories | Frequency | Percentage (%) |
|---|---|---|---|
| Age | 21-30 | 3 | 17.65 |
| | 31-40 | 5 | 29.41 |
| | 41-50 | 8 | 47.06 |
| | >51 | 1 | 5.88 |
| Gender | Male | 11 | 64.70 |
| | Female | 6 | 35.30 |
| Marital status | Married | 8 | 47.05 |
| | Single | 5 | 29.41 |
| | Divorced | 2 | 11.76 |
| | Windowed | 0 | 0 |
| Educational status | Qur'anic | 0 | 0 |
| | Primary | 3 | 17.65 |
| | Secondary | 8 | 47.06 |

| | | | |
|---|---|---|---|
| | Tertiary | 6 | 35.29 |
| Year in practice | 1-5 | 11 | 65.70 |
| | 6-10 | 4 | 23.52 |
| | >11 | 2 | 11.70 |
| Do you get any training for fish farming? | Yes | 5 | 29.41 |
| | No | 12 | 70.59 |
| Land ownership | Owned | 12 | 70.50 |
| | Leased | 5 | 29.41 |
| No of employee in the farm | 1-5 | 13 | 76.47 |
| | 6-10 | 4 | 23.53 |

**Table 2:** Constraints to fish farming in Dutse metropolis

| Constraint | Severe | Mild | Not constraint | Score | Mean Score | Overall Rating | Rank |
|---|---|---|---|---|---|---|---|
| Disease infestation | **4** | 12 | 1 | 37 | 2 | Major constraint | 6 |
| Pest/predator attack | 1 | 16 | 0 | 35 | 1.67 | Minor constraint | 7 |
| Theft | **0** | 5 | 12 | 22 | 1 | Not constraint | 10 |
| Water availability in terms of quantity | **0** | 10 | 7 | 27 | 1 | Not constraint | 9 |
| Water quality management | **9** | 6 | 2 | 41 | 2 | Major constraint | 4 |
| Inadequate technical expertise | **9** | 7 | 1 | 42 | 2 | Major constraint | 3 |
| Marketing | **6** | 10 | 1 | 39 | 2 | Major constraint | 5 |
| High Cost of feed | **11** | 5 | 1 | 44 | 2 | Major constraint | 2 |
| Poor Feed quality | **0** | 16 | 1 | 33 | 1 | Not constraint | 8 |
| Fish seed Availability | **15** | 1 | 1 | 48 | 2 | Major constraint | 1 |

Note: Mean score ≥2-major constraint, 1.5 to 1.9 – minor constraint, <1.5 not a constrain, Severe =3.0 point, Mild= 2.0 point, Not a constraint=1.0 point

## DISCUSSION

Socio-economic characteristics of the respondents in Dutse metropolis revealed that 47.06% are aged 41-50 years. This result agrees with the findings of Agbabiaka and Okeke, (2024), who observed the same trend among fish farmers in three Agricultural Zones of Imo State, Nigeria. This result indicates that most of the respondents were within the economically active population and therefore constitute a good labour force for fish farming industry (Olawumi, et al., 2020).

In this study, the percentages of the male and female respondents were 64.70% and 35.30%, respectively. It is evident that males were more represented in the production of fish in both earthen fish ponds and concrete tanks (i.e. the farmers are gender biased). This result can be justified by the assertion of Agbabiaka and Okeke, (2024) that fishery activities are mostly dominated by men. However, aquaculture

practices are not limited to a particular gender (Agbabiaka & Okeke, 2024). Both male and female farmers are engaged in fish farming to increase fish production, improve food security, reduce hunger and also to increase their incomes (Olaoye et al., 2023). The significant male dominance in fish farming aligns with broader trends in fisheries, highlighting persistent barriers faced by women due to discriminatory land tenure systems and social norms (Agbabiaka & Okeke, 2024). However, education is an important factor which can influence farm productivity and determines farmers' access to loans. Level of education, according to the study, showed that most of the fish farmers are learned which is expected to facilitate higher output and efficiency in fish production. These findings are in line with findings by Agbabiaka and Okeke, (2024) who relatively revealed high proportion of farmers with HND/BSc qualifications. However, continuous training and extension services are needed to enhance skills and knowledge transfer across the sector. This is so because fish farming requires a lot of technical and scientific knowledge to be successfully undertaken. The inability of the aquaculture sector to exploit growth opportunities rests on numerous constraints that hold back the aquaculture nationally and in other areas as well (Adegbite & Oluwalana, 2021).

In this study, farmers reported that Fish seed availability, water quality management, inadequate technical expertise, marketing, high feed costs, and Disease infestation, was ranked as "major constraints" confronting fish farming operations in the study area with mean scores of 2. Considering the mean ranking of the constraints, the most critical constraint fish farmers faced in the study area was fish seed availability which was particularly notable and ranked 1 and the second was high cost of feed and ranked 2. These results are almost similar with the findings by Ogunremi et al. (2022), Ajayi and Egwere (2021) and Doyi et al., (2024), who reported similar findings. However, Theft was considered not constraint and ranked 10 which is contrast to the findings by Ogunremi et al. (2022) who reported theft as a major constraints in his work, Assessment of Fish Farming Practices, Development and Constraints among Fish Farmers in Ibi Local Government Area, Taraba State, Nigeria. In a similar study Nwakuche et al. (2019) identified the major problem to fish farming as water shortages during dry season, lack of capital, disease and pest infestation and high cost of fish feed. These constraints are capable of hindering the expected high return from fish farming in the country.

## CONCLUSION

From the findings fish seed availability, water quality management, inadequate technical expertise, high feeding costs, marketing and disease infestation, was ranked as "major constraints. Pest/predator attacks is classified as "minor constraints while theft, water availability and poor feed quality was ranked as not constraints. The most critical constraint fish farmers faced in the study area was fish seed availability and high cost of feed. Therefore, it is recommended that policies be directed to establishment of commercial pelleted and floating feed mills; Modern hatcheries; Provision of credit facilities and Provision of adequate infrastructural facilities.

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# POST-FLOOD ASSESSMENT OF THE PHYSICO-CHEMICAL PARAMETERS OF TROPICAL MAN-MADE LAKE IN NORTHEASTERN NIGERIA

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**ABSTRACT**
*This study evaluated key physico-chemical parameters of Lake Alau, Borno State, Nigeria, to assess its suitability for fisheries and domestic use. Samples were collected fortnightly from May to June 2025 between 7:00 and 9:00 am at three fixed stations using one-liter PVC bottles. In-situ measurements of temperature and pH were taken with a Hanna HI98129 Portable Multi-Parameter Meter, while other parameters were analyzed at FCFFT Baga using standard AOAC, APHA, and WHO methods. Parameters analyzed were dissolved oxygen, carbon dioxide, biological oxygen demand, alkalinity, nitrate, phosphate, turbidity, total dissolved solids, and conductivity. Data were statistically analyzed using ANOVA and Duncan's Multiple Range Test (DMRT) at $p < 0.05$ via Statistix 10.0. Results (mean ± SE, range) indicated: temperature (26.1 ± 0.4 °C, 25.5–26.7 °C), depth (3.4 ± 0.2 m, 3.1–3.6 m), pH (7.4 ± 0.1, 7.2–7.6), dissolved oxygen (6.2 ± 0.3 mg/L, 5.8–6.6 mg/L), BOD (3.1 ± 0.2 mg/L, 2.7–3.4 mg/L), nitrate (1.8 ± 0.2 mg/L, 1.5–2.1 mg/L), phosphate (0.35 ± 0.05 mg/L, 0.30–0.40 mg/L), turbidity (12.4 ± 1.2 NTU, 11.0–13.8 NTU), TDS (225 ± 15 mg/L, 210–240 mg/L), and conductivity (390 ± 25 µS/cm, 360–420 µS/cm). Temperature correlated positively with most parameters ($r = 0.52–0.78$, $p < 0.05$). This baseline indicates Lake Alau's continued suitability for fisheries and domestic use.*

**Keywords:** Post-flood, Lake Alau, Physico-chemical, Northeastern

## INTRODUCTION

Lake Alau, formed by the Alau Dam on the Ngadda River in Borno State, Nigeria (Latitude 11°51′43″ N, Longitude 13°13′36″ E), plays a pivotal role in regional agriculture, fisheries, and domestic water supply (Mohammed *et al.*, 2017; Wikipedia, 2025). Its multifaceted function necessitates regular monitoring of its physico-chemical characteristics, as water quality is intrinsically linked to ecosystem health, fish biology, and human use (APHA, 2012; Despite its importance, monitoring data for Lake Alau have largely depended on sporadic studies; the most recent comprehensive survey dates back to 2017 (Mohammed *et al.*, 2017), highlighting a need for up-to-date assessments.

Physico-chemical parameters including temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), nutrients (nitrate, phosphate, $CO_2$), total dissolved solids (TDS), turbidity, alkalinity, and conductivity are critical indicators of water suitability for both aquatic life and human consumption (APHA, 2012; WHO, 2011; FAO, 2018). Temperature affects solubility of oxygen and biochemical rates, while pH influences nutrient availability and metal toxicity. DO and BOD are key indicators of organic pollution and habitat suitability (Mohammed *et al.*, 2017). Nutrient levels (nitrate, phosphate) reflect external inputs such as agricultural runoff, which may lead to eutrophication (Mohammed *et al.*, 2017; Fabian *et al.*, 2023). TDS, turbidity, alkalinity, and conductivity relate to dissolved mineral and particulate matter important in determining potability and fish growth potential (FAO, 2018). In Nigeria, national water standards (Standards Organization of Nigeria, SON) complement WHO and FAO guidelines in defining safe usage thresholds. Research elsewhere in the region, such as assessments of Gubi Dam (Haruna, 2025) and Zobe Reservoir (Nababa *et al.*, 2024), has shown that while most

parameters fall within acceptable limits, localized nutrient enrichment and sedimentation are recurring concerns, attributed to agricultural runoff and hydrological changes. These findings underscore the importance of frequent, high-resolution monitoring.

Given Lake Alau's collapse in September 2024 and its subsequent ecological and hydrological impacts, this study undertakes an 8-week weekly (fortnightly) monitoring of key parameters from May to June 2025, offering a timely update. Studies like Mohammed *et al*. (2017) and Fabian *et al*. (2023) provide useful baselines; however, this research expands temporal resolution and incorporates extensive statistical analysis, including Pearson's correlations among variables. By comparing data against FAO, SON, and WHO standards, this study aims to deliver a nuanced evaluation of Lake Alau's current water quality, and its viability for fisheries, irrigation, and domestic use.

## MATERIALS AND METHODS

### Study Area

This study was conducted at Lake Alau, Lake Alau was created in 1987 on River Ngadda for the purpose of supplying portable water to Maiduguri metropolitan as well as for irrigating over 8,000 ha of farm lands in the catchment area of the reservoir Odunze *et al.*, (1995). Lake Alau is located on latitude 11° 51′43″ N and longitude 13° 13′36″ E on the South Eastern (SE) part of Maiduguri (Fig. 1), capital of Borno State, Nigeria (Idakwo and Abu 2004; Google Earth 2008). The lake supplies the municipal water treatment plant, the major source of drinking water supply to the capital, apart from sporadic water obtained from boreholes. The lake also gives room to a significant number of agricultural activities for an estimated population of 521,492, 211,204 and 156,564 in Maiduguri, Jere and Konduga respectively (FRN 2007).

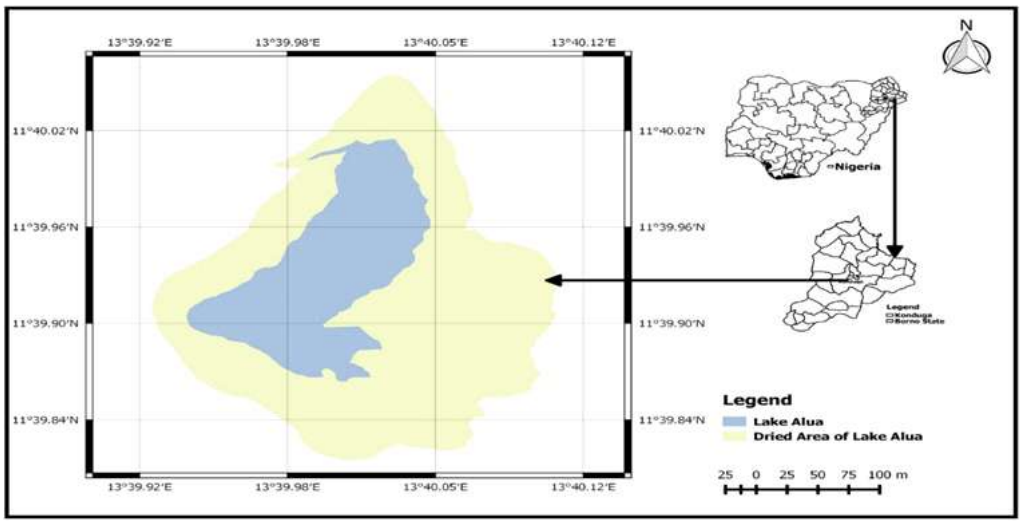



**Figure 1:** Map of Lake Alau, Maiduguri, Nigeria

### Water sampling Periods

Between May and June 2025, weekly water sampling was conducted at three consistently identified sites across Lake Alau: upstream, central lacustrine zone, and downstream near the dam wall. Sampling occurred between 7:00 and 9:00 am to avoid diel fluctuations in water chemistry. Surface water was collected into one-liter PVC bottles which were rinsed three times with lake water before sampling. Temperature pH and depth were determined in situ. The filled bottles were labeled, placed in coolers with ice packs, and transported within two hours to the Department of Fisheries at FCFFT Baga for analysis.

**Water sampling and Procedures**

Temperature and pH were measured using a Hanna HI98129 Portable Multi-Parameter Meter. A HACH 2100P turbidimeter recorded turbidity in Nephelometric Turbidity Units (NTU). TDS and conductivity were measured using a Wag Tech portable meter calibrated with known standards. Dissolved oxygen was determined using the modified Winkler titration method. Samples were fixed on-site and titrated in the laboratory according to APHA (2012) procedures. Carbon dioxide content was determined by titrating acidified samples against 0.05 M sodium hydroxide with phenolphthalein. Alkalinity was measured using gran titration through addition of 0.02 M HCl. BOD was assessed via a 5-day incubation of sealed, dark bottles at 20 °C. Nitrate was measured at 220 nm using a UV-Vis spectrophotometer (JASCO V-730), and phosphate concentration was determined by the ascorbic acid colorimetric method at 880 nm. Algal screening and duplicate analyses-maintained data integrity and accuracy.

**Data Analysis**

Data from all sampling events were log-transformed where necessary and analysed using Statistic 10.0. Weekly means of the three stations were compared using one-way ANOVA, and where significance ($p < 0.05$) was detected, Duncan's Multiple Range Test was applied. Pearson correlations assessed interdependencies among measured parameters. All results were compared against FAO fisheries, SON potable water, and WHO drinking water benchmarks.

**RESUTS**

The table 1 below presents the observed range, mean values, and standard errors of various physico-chemical parameters of Lake Alau water, benchmarked against internationally and nationally recognized permissible limits set by FAO, SON, and WHO. The temperature of the lake ranged from 25.5 to 26.7°C, with a mean of 26.1 ± 0.4°C, which falls within the acceptable range for aquatic life (20–30°C as per FAO and 25–30°C as per WHO). The depth of the lake varied slightly from 3.1 to 3.6 meters, with no specific standard limits, but such stable depth indicates good water retention capacity of the dam during the sampling period. The pH ranged from 7.2 to 7.6 with a mean of 7.4 ± 0.1, reflecting neutral to slightly alkaline conditions, which is suitable for aquatic life and within all regulatory limits (6.5–8.5). Dissolved oxygen (DO) values (5.8–6.6 mg/L; mean 6.2 ± 0.3 mg/L) were sufficient to support fish and other aquatic organisms, surpassing the minimum requirement of 5 mg/L recommended by FAO and WHO.

The biological oxygen demand (BOD) ranged from 2.7 to 3.4 mg/L (mean 3.1 ± 0.2 mg/L), indicating low organic pollution within the permissible limit of 5 mg/L (FAO) and 4 mg/L (SON). Nitrate and phosphate concentrations were low (mean 1.8 ± 0.2 mg/L and 0.35 ± 0.05 mg/L respectively), suggesting minimal nutrient enrichment and risk of eutrophication, falling well below the acceptable limits (≤10 mg/L for nitrate and ≤0.5 mg/L for phosphate). Turbidity averaged 12.4 ± 1.2 NTU, slightly above WHO's ideal limit for potable water (≤5 NTU) but within SON's acceptable limit for surface waters (≤25 NTU), indicating moderate suspended solids likely due to rainfall or runoff. Total Dissolved Solids (TDS) and conductivity were also within permissible limits, averaging 225 ± 15 mg/L and 390 ± 25 $\mu$S/cm respectively, reflecting low salinity and good water quality. The physico-chemical characteristics suggest that Lake Alau's water quality during the study period was suitable for fisheries, aquatic life sustenance, and possibly irrigation, with minimal contamination risk.

**Table 1.** Physico-Chemical Parameters of Lake Alau (July–August 2025)

| Parameter | Range | Mean ± SE | Maximum permissible limits in water | | |
|---|---|---|---|---|---|
| | | | FAO | SON | WHO |
| Temperature (°C) | 25.5–26.7 | 26.1 ± 0.4 | 20–30 | – | 25–30 |
| Depth (m) | 3.1–3.6 | 3.4 ± 0.2 | – | – | – |
| Ph | 7.2–7.6 | 7.4 ± 0.1 | 6.5–8.5 | 6.5-9.2 | 6.5–8.5 |
| DO (mg/L) | 5.8–6.6 | 6.2 ± 0.3 | ≥5 | ≥4 | ≥5 |
| BOD (mg/L) | 2.7–3.4 | 3.1 ± 0.2 | ≤5 | ≤4 | ≤3 (potable) |
| Nitrate (mg/L) | 1.5–2.1 | 1.8 ± 0.2 | ≤10 | ≤10 | ≤50 |
| Phosphate (mg/L) | 0.30–0.40 | 0.35 ± 0.05 | ≤0.5 | ≤0.5 | ≤0.3 (ideal) |
| Turbidity (NTU) | 11.0–13.8 | 12.4 ± 1.2 | ≤5 | ≤25 | ≤5 (with filtration) |
| TDS (mg/L) | 210–240 | 225 ± 15 | ≤1000 | ≤1000 | ≤1000 |
| Conductivity (μS/cm) | 360–420 | 390 ± 25 | ≤1000 | ≤8000 | ≤2500 |

FAO = Food and Agriculture Organization; SON = Standards Organization of Nigeria;
WHO = World Health Organization

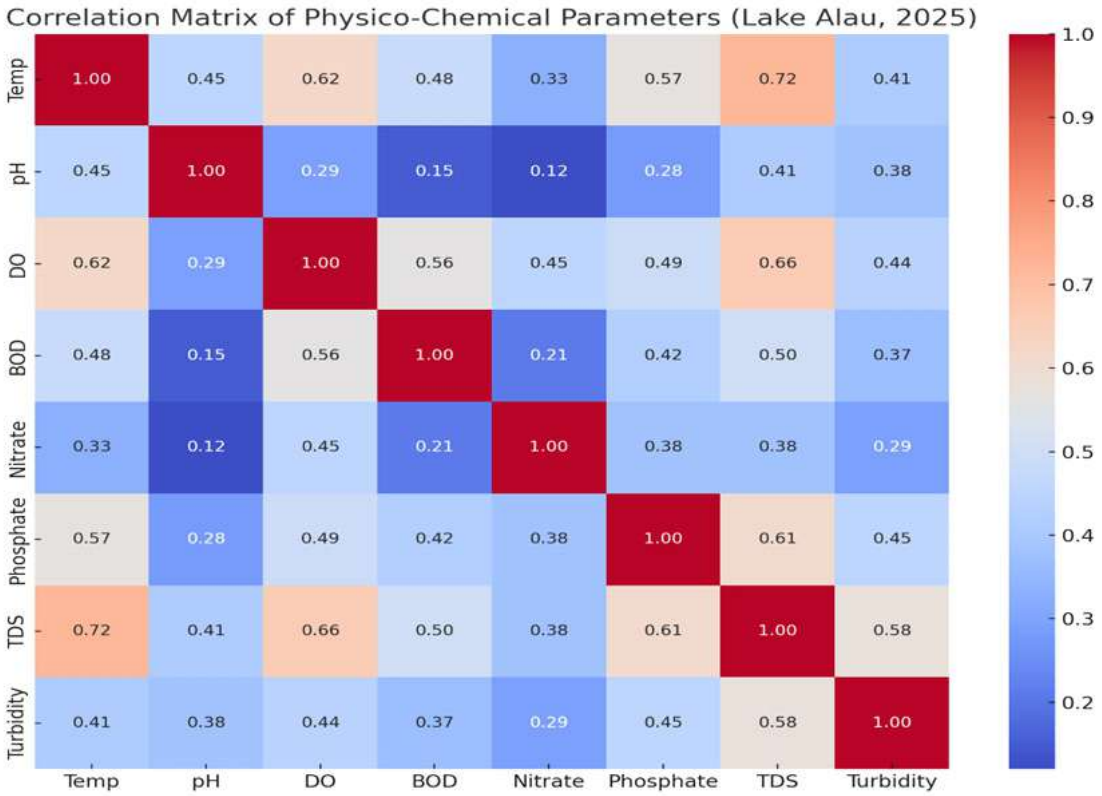



**Figure 1:** Correlation matrix of Physico-chemical parameters of Lake Alau

The figure 1 above shows the correlation matrix of physico-chemical parameters measured in Lake Alau during the 2025 study period. The color gradient indicates the strength and direction of correlation between parameters, where red shades represent strong positive correlations (closer to +1) and blue shades represent weaker or negative correlations (closer to 0). Temperature showed strong positive correlations with Total Dissolved Solids (TDS) (r = 0.72) and moderate positive correlations with Dissolved Oxygen (DO) (r = 0.62), Phosphate (r = 0.57), and Biological Oxygen Demand (BOD) (r = 0.48). This suggests that increases in temperature tend to increase these parameters, possibly due to enhanced microbial activity and mineral dissolution at higher temperatures. Additionally, temperature showed a weaker correlation with pH and Nitrate, indicating lesser direct influence on these variables.

Total Dissolved Solids (TDS) was strongly and positively correlated with DO (r = 0.66), Phosphate (r = 0.61), and Turbidity (r = 0.58), implying that increases in dissolved solids are associated with higher levels of these parameters, potentially reflecting runoff inputs or sediment disturbances. pH had low to moderate positive correlations with most parameters but showed weaker association with Nitrate (r = 0.12) and BOD (r = 0.15), suggesting pH stability despite organic pollution or nutrient fluctuations. Nitrate showed generally weak correlations with most parameters except Phosphate (r = 0.38) and TDS (r = 0.38), indicating nutrient loads may come from similar sources. This matrix highlights interdependencies among lake parameters that are critical for aquatic ecosystem balance and supports water quality management decisions.

## DISCUSSION

The weekly data reveal that Lake Alau's general water quality remains favorable for fisheries and domestic use, with most parameters within FAO, SON, and WHO limits. Observed temperature ranges (25.5–26.9 °C) align with optimal conditions for tropical freshwater fish (Mohammed *et al*., 2017). The neutral pH and high DO confirm a healthy aquatic environment conducive to fish growth, supporting conclusions by Boyd (1979Mohammed *et al*. (2017).

The mean BOD value of 3.0 mg/L lies below thresholds that signify organic loading and resembles earlier findings from Alau (Mohammed *et al*., 2017), indicating continued ecological resilience. However, phosphate concentrations occasionally exceeded WHO potable standards. This may indicate anthropogenic inputs likely agricultural or domestic runoff consistent with patterns seen in Gubi Dam (Haruna, 2025) and Zobe Reservoir (Nababa *et al*., 2024). Positive correlations between temperature and phosphate, TDS, and DO suggest linked thermal activity, nutrient mobilization, and mineral dissolution after dam restructuring.

The correlation analysis presented in Table 2 reveals important relationships among the key physico-chemical parameters measured at Lake Alau. Temperature demonstrated a strong positive correlation with Total Dissolved Solids (TDS) (r = 0.72), indicating that as water temperature increased, the concentration of dissolved solids also tended to rise. This is consistent with findings by Wetzel (2001), who noted that higher temperatures often promote the dissolution of minerals and salts into aquatic systems. Temperature was also moderately correlated with Dissolved Oxygen (DO) (r = 0.62), reflecting the influence of temperature on the solubility of oxygen in water; however, the relationship was not as strong as typically expected, possibly due to biological oxygen demand (BOD) activities that simultaneously consume oxygen. The temperature-BOD correlation was 0.48, indicating that temperature may indirectly influence the microbial oxygen demand through enhanced microbial activity at higher temperatures. TDS and conductivity were closely linked (r = 0.66), reflecting mineral content as documented by FAO (2018). Significant positive correlations among nutrients, BOD, and DO demonstrate the interconnected chemical cycles in the lake.

Conversely, pH, alkalinity, and conductivity often showed negative relationships during high-temperature periods, potentially due to increased respiration and nutrient uptake by primary producers, a trend documented in several African reservoirs (Okayi *et al*., 2013). The negative associations of alkalinity with nutrients suggest dilution or consumption by phytoplankton. Taken together, collective findings indicate Lake Alau maintains good water quality, but moderate nutrient enrichment necessitates catchment management, especially to control agricultural runoff a measure supported by both FAO and SON guidelines.

Dissolved Oxygen (DO) itself was strongly correlated with TDS (r = 0.66) and BOD (r = 0.56), signifying that oxygen dynamics in the lake are likely affected by the concentration of dissolved ions and

organic matter requiring oxidation. This pattern aligns with studies by Jhingran (1991), where nutrient loading and organic pollution were shown to significantly impact DO levels. Turbidity exhibited a moderate positive correlation with TDS (r = 0.58), which is logical since particulate matter contributes to both parameters. Turbidity also correlated with phosphate (r = 0.45), indicating potential nutrient loading from agricultural runoff, a phenomenon similarly reported by Okayi *et al*. (2013) in Nigerian inland water bodies.

Interestingly, nitrate showed only weak correlations with most other parameters, possibly reflecting rapid biological uptake or denitrification processes in the dam environment. Phosphate, in contrast, showed moderate correlations with TDS (r = 0.61) and DO (r = 0.49), suggesting potential links with eutrophication processes. These relationships are significant as elevated phosphate levels can promote algal growth, thus altering oxygen regimes and water quality (APHA, 2012). The correlation matrix underscores the interconnected nature of physico-chemical variables in Lake Alau, with implications for water quality management. For example, managing TDS and nutrient inputs could simultaneously improve DO levels and reduce turbidity, enhancing the aquatic habitat's suitability for fish and other biota.

## CONCLUSION

This study provided an in-depth assessment of the physico-chemical properties of Lake Alau over an 8-week period during May and June 2025. Key parameters such as temperature, DO, BOD, TDS, turbidity, nitrate, phosphate, and pH exhibited significant variations and interrelations. Lake Alau's water remains largely healthy and suitable for fisheries and basic domestic applications. Physical and chemical parameters show regular variation consistent with tropical seasonal patterns. The observed strong correlations between temperatures, DO, TDS, and phosphate suggest that these factors collectively influence the ecological health of the lake. Most measured values remained within the permissible limits set by FAO, WHO, and SON; however, nutrient loading indicators like phosphate and nitrate require closer monitoring to prevent potential eutrophication. The findings serve as critical baseline data for sustainable water quality management and fisheries development in Lake Alau.

## RECOMMENDATIONS

Based on the findings of this study, it is recommended that regular monitoring of Lake Alau's physico-chemical parameters be sustained, particularly for nutrients such as phosphate and nitrate, to prevent the risk of eutrophication and subsequent degradation of water quality. The slight elevation in phosphate concentration, though marginal, signals the need for community-based pollution control measures, including proper agricultural runoff management and public awareness campaigns on responsible waste disposal around the lake catchment area. Additionally, collaborative efforts between local fisheries authorities, environmental agencies, and stakeholders should be strengthened to implement integrated lake management practices that ensure the sustained suitability of Lake Alau for fisheries production and domestic uses, while preserving its ecological integrity for future generations.

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# HATCHABILITY, SURVIVAL AND GROWTH OF AFRICAN CATFISH (*Clarias gariepinus*, Burchell 1822) FRY RAISED IN WHITE AND BLACK CULTURE ENCLOSURES

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**ABSTRACT**
*The hatchability, growth, and survival of Clarias gariepinus were investigated in white and black concrete and plastic tanks. Two gravid each of females (1.70±0.28 kg) and males (1.70±0.57 kg) of C. gariepinus brooders were used for the breeding experiment following standard procedure. Duplicate groups of 5 grams of fertilized eggs were incubated in white concrete (WCT), black concrete (BCT), white plastic (WPT) and black plastic (BPT) tanks. Hatchability, growth, and survival rates were calculated following the standard formula. Data were analysed using descriptive statistics and ANOVA$\alpha_{0.05}$. The percentage hatchability of eggs and growth performance of fish fry were significantly ($p<0.05$) highest in BCT (77.82±5.91 %) and BPT (2.64±0.68g), respectively. The percentage survivability of fry was significantly ($p<0.05$) highest (85.60±5.64%) in WCT. The results from this study clearly indicate that BCT and BPT are both preferred for hatchability and fry growth in C. gariepinus, while survivability is better in WCT.*

**Keywords**: *Clarias gariepinus*, brood stocks, induced breeding, incubation trough, tank colours.

## INTRODUCTION

African catfish (C*larias gariepinus*), a unique and commercially important tropical aquaculture species is undoubtedly a preferred fish choice for Nigeria fish farmers. It is especially appreciated for its biological, nutritional, and economic qualities (Williams *et al*., 2008). Catfish aquaculture development in Nigeria have spanned four decades but the rate of development has been very slow in Northeast region as compared to other parts of the country. However, in recent times, catfish farming is expanding rapidly in Maiduguri metropolis probably due to insurgency that prevents access to fishing areas. The disruption of fish supply from natural waterbodies has therefore paved way for aquaculture expansion in this socio-economically challenging period in Borno State, Nigeria. The growing demand for African catfish as high-nutritional food fish may be another reason for the rise in aquaculture in the area.

The expansion in aquaculture has led to an upsurge in demand for high-quality fish seeds for pond stocking to ensure sustainable fish production (Williams *et al*., 2008). Thus, this had spurred interest in seeking for safe and better means to produce fast-growing fingerlings in large quantities. The breeding protocol and mass production of African catfish fry/fingerlings have been standardized over the years, which resulted in the unprecedented growth witnessed in Catfish aquaculture in Nigeria (Olanrewaju *et al*., 2015). Catfish fingerlings are usually produced in indoor hatchery through hypophysation techniques. Despite remarkable breakthroughs recorded in catfish breeding, the hatchability and larval rearing in the hatchery still pose some challenges. The challenges range from low hatching rate, poor growth, and survival of fry. This, however, could be related to the selection of appropriate hatching trough colour for breeding and larval fry rearing (Olanrewaju *et al*., 2016).

The hatching troughs commonly used are mainly concrete and plastic but with varying colours. Tank colour has been shown to affect growth and survival, stress response, and reproduction in fish under

culture condition (El-Sayed and El-Ghobashy, 2011). It is clear, therefore that hatching and larval rearing in different enclosures of different background colours may be of interest in aquaculture practice, especially for their effect on hatchability and fish growth. However, the compatibility of culture tanks and their colour with fish growth has been largely neglected, especially in indoor hatchery. It has been established that ensuring optimal breeding conditions is a basic precondition for successful hatching and larva rearing (De Graaf *et al*., 1995).

Although several studies on different rearing enclosures (Olanrewaju et al., 2016; Oti and Nwani, 2007), enclosure colour (Dada, 2007; Alabi and Ocholi, 2018), photoperiod, and light intensity effects (Adebayo, 2018) on hatching and survivability of C*larias gariepinus* eggs and larvae had been conducted. However, there is sparse information on the combined effects of tank varieties and background colour on hatchability, growth, and survival of C. *gariepinus* fry. This study therefore evaluates the hatchability, growth, and survival rates of C. *gariepinus* in white and black concrete and plastic tanks in indoor hatchery. The findings of this study will provide useful information on the production of C. *gariepinus* fry/fingerlings using various tanks and background colours in an indoor hatchery.

## MATERIALS AND METHODS

### Study area

The study was conducted at the Indoor Fish Hatchery complex of Federal College of Freshwater Fisheries Technology, Baga, Nigeria ($11^0$51'43" N latitude, $13^0$13'36" E longitudes and an altitude of 312 m above mean sea level). A total of twelve tanks, comprises of 3 white and 3 black each for concrete (5.28 $m^3$) and plastic (2.21 $m^3$) were used for incubation and fry rearing under flow-through system. The water source to the hatchery was groundwater borehole purified using sedimentation before pumping to the overhead tank for hatchery use.

### Broodstock selection and Hypophysation

Four Brooders (2 males and 2 females) of C*larias gariepinus* (1.70±0.57kg) were obtained from the Teaching and Research farm of Federal College of Freshwater Fisheries Technology Baga, Nigeria. The brooders were selected based on the external features and maturity (Oyelese, 2006). The female brood fish were injected intramuscularly with Ovaspec hormone @ 0.4ml $kg^{-1}$ of body weight, while the male brooders received half dose (0.2ml $kg^{-1}$). The injected fish were kept in tanks to complete ovulation @ 27 $^0$C water temperature.

### Stripping and Fertilization

After 10–11 hours of injection, final maturation and ovulation was reached. The eggs were stripped by applying gentle pressure on the abdomen of the female fish. A few minutes prior to the stripping of females, male brooders were sacrificed, and the testes were removed, cleaned from blood stains and placed in a well-dried bowl. Eggs were then stripped from the female into a pre-weighted plastic bowl and fertilized by spreading milt onto the eggs through maceration of testes, following gentle shake for thorough fertilization. Thereafter, the eggs were rinsed with physiological saline solution (0.9% NaCl) to remove used sperm before proceeding for the incubation process.

### Incubation of fertilized eggs and hatching

**Five (**5) grams of weight of fertilized eggs was incubated each in eight (8) incubating tanks, which represents four treatments (WCT – white concrete tanks, BCT – black concrete tanks, WPT – white plastic tanks, BPT – black plastic tanks) in duplicates. Eggs were spread on spawning mats in each of the tanks at $27^0$C °C water temperature under a flow-through system. Dead and unviable eggs that turned whitish were removed after 20 hours of incubation by siphoning out from each of the tanks. The number of eggs in each tank was estimated by putting 1-gram of egg into a plastic tray containing water and

counting them physically. After counting, the 1-gram weight of C*larias gariepinus* eggs gave 742 eggs. Hatchability was evaluated 29 hours after incubation and the post-yolk fry were fed to satiation with decapsulated artemia for 7 days before given commercial feed (0.2 mm) for 4 days.

Thereafter, 500 fry (0.22±0.05g) each were randomly distributed into the treatment tanks and reared for 42 days. Fry were fed ad libitum, under similar hatchery conditions, four times daily (06:00, 10:00, 14:00 and 18:00 h) with 45% crude protein 0.3–0.5mm commercial diet. Fish were sampled weekly for evaluation of growth and survival in each tank.

**Estimation of Hatchability, Survival and Growth**

The hatching (HR) and larval survival rates (SR) of larvae were calculated following Haniffa and Sridhar (2002) formula:

$$Hatching\ Rate = \frac{Total\ number\ of\ hatched\ eggs}{Total\ number\ of\ fertilized\ eggs} \times 100$$

$$SR\ of\ larval\ (4\text{-}day\ old) = \frac{Total\ number\ of\ larvae - Mortality}{Total\ number\ of\ larvae} \times 100$$

**Mean Weight Gain (MWG)**

This was calculated as;

$$MWG\ (g) = Initial\ mean\ weight - final\ mean\ weight$$

**Specific Growth Rate (SGR)**

This was calculated from data on changes of body weight over a given time interval;

$$SGR = \frac{100 \times (\ln FBW - \ln IBW)}{D}$$

Where: FBW = final body weight (g) (weight at the end of the time interval studied)
IBW = initial body weight (g) (weight at the beginning of the time interval studied)
D = number of days

**Survival Rate (SR)**

The fry survival rate was calculated as:

$$SR\ of\ fingerlings = \frac{Total\ \ fish\ number\ harvested}{Total\ \ fish\ number\ stocked} \times 100$$

**Monitoring of Water quality parameters**

Water temperature, pH and dissolved oxygen concentrations in water were monitored daily, while nitrate was measured weekly. Temperature was measured using a mercury in-glass thermometer. pH and dissolved oxygen were measured with a pH meter (BICASA model B.E.104), while nitrate was determined in the laboratory following APHA (1998) procedure.

**Statistical Analysis:** The data generated were subjected to One-way analysis of variance (ANOVA) using Statistical Package for Social Sciences version 20.0 (SPSS Inc., Chicago, IL, USA). Differences between individual means were tested by Fisher's LSD $\alpha_{0.05}$.

**RESULTS**

The weight of female brooders and fertilized eggs used in the experiment are 1.70±0.28 gand 5.00±0.00 g, respectively. The number of fertilized eggs of C*larias gariepinus* for each treatment is 3710.00±0.00 (Table 1). The number of hatched eggs in black concrete tank (BCT) was significantly highest (2887±101.30) compared to other treatment groups ($p<0.05$). Similarly, the percentage hatchability

was markedly higher (77.82±5.91 %) in BCT while least was recorded in WCT (67.93±7.07 %) and BPT (68.13±1.29 %). Meanwhile, the larval in WPT recorded lowest survival rate of (80.14±10.25 %) while larval in BPT was highest (83.86±4.83 %). Statistically, there were no significant differences in survival rates ($p>0.05$) between treatment tanks.

**Table 1:** Hatching and survival performance parameters of *Clarias gariepinus* in White and Black concrete and plastic tanks.

| | Treatments | | | |
|---|---|---|---|---|
| **Parameters** | **WCT** | **BCT** | **WPT** | **BPT** |
| Weight of female breeders (kg) | $1.70\pm0.28_a$ | $1.70\pm0.28_a$ | $1.70\pm0.28_a$ | $1.70\pm0.28_a$ |
| Weight of fertilized eggs (g) | $5.00\pm0.00_a$ | $5.00\pm0.00_a$ | $5.00\pm0.00_a$ | $5.00\pm0.00_a$ |
| Number of fertilized eggs | $3710.00\pm0.00_a$ | $3710.00\pm0.00_a$ | $3710.00\pm0.00_a$ | $3710.00\pm0.00_a$ |
| Number of hatched eggs | $2520.33\pm262.50_c$ | $2887\pm101.30_a$ | $2642\pm66.00_b$ | $2528.00\pm48.00_c$ |
| Hatching rate (%) | $67.93\pm7.07_b$ | $77.82\pm5.91_a$ | $71.21\pm11.20_a$ | $68.13\pm1.29_b$ |
| Survival rate (%) | $80.54\pm0.85_a$ | $81.70\pm2.14_a$ | $80.14\pm10.25_a$ | $83.86\pm4.83_a$ |

**Legend**; WCT: White concrete tank, BPT: Black concrete tank, White plastic tank, BPT: Black plastic tank.

The growth performance and survival rate of *Clarias gariepinus* fry in the experimental tanks are shown in Table 2. The results show that significant highest mean final weight was obtained in BPT (2.88±0.67 g) and WPT (2.77±0.95), while WCT had the least (2.31±0.29 g). There were no significant differences ($p>0.05$) in the mean weight gain and specific growth rate between treatment groups. Fry in BPT had higher weight gain (2.64±0.68 g) and specific growth rate (1.27±0.23 % $day^{-1}$) than fish in other treatment groups. Similarly, shooters were significantly noticed in fish kept in BPT (8.62±1.06 %) and WPT (8.11±0.88 %) ($p<0.05$). Significantly higher survival rate was however, obtained in fry raised in WCT (85.60±5.64 %) and BCT (80.75±4.85 %) compared with those raised in plastic tank groups ($p<0.05$).

**Table 2.** Growth performance and survivability parameters of *Clarias gariepinus* fry in experimental tanks

| | Treatments | | | |
|---|---|---|---|---|
| **Parameters** | **WCT** | **BCT** | **WPT** | **BPT** |
| Mean Initial Weight (g) | $0.24\pm1.06_a$ | $0.23\pm0.51_a$ | $0.22\pm1.02_a$ | $0.22\pm0.50_a$ |
| Mean Final Weight (g) | $2.31\pm0.29_b$ | $2.39\pm1.09_b$ | $2.77\pm0.95_a$ | $2.88\pm0.67_a$ |
| Mean Weight Gain (g) | $2.08\pm0.30_a$ | $2.11\pm0.84_a$ | $2.59\pm0.53_a$ | $2.64\pm0.68_a$ |
| SGR (% $day^{-1}$) | $1.12\pm0.11_a$ | $1.15\pm0.31_a$ | $1.23\pm0.49_a$ | $1.27\pm0.23_a$ |
| Shooter (%) | $5.42\pm1.20_b$ | $5.86\pm0.97_b$ | $8.11\pm0.88_a$ | $8.62\pm1.06_a$ |
| Survival rate (%) | $85.60\pm5.64_a$ | $80.75\pm4.85_a$ | $70.50\pm3.64_b$ | $72.40\pm5.32_b$ |

**Legend**; WCT: White concrete tank, BPT: Black concrete tank, White plastic tank, BPT: Black plastic tank, SGR: Specific growth rate, $^*p<0.05$

Water quality values as obtained in the experimental tanks were as presented in Table 3. Statistical analysis did not reveal any significant differences in terms of water quality parameters between treatment groups ($p>0.05$). White concrete tank had higher dissolved oxygen (5.24±0.82 mg $l^{-1}$) and nitrate

($4.12 \pm 0.01$ mg $l^{-1}$) contents than other treatment groups. However, higher temperature ($27.10 \pm 0.35$ $^{0}$C) and pH ($7.74 \pm 0.34$) were recorded in BPT.

## DISCUSSION

Successful production of C*larias gariepinus* fry/fingerlings in the hatchery depends on the provision of a suitable rearing environment among other factors. Enclosure for hatching and nursing fry/fingerlings in indoor hatchery include fiberglass tank, concrete tank, plastic tank, aquaria glass tank and wooden troughs (Omitoyin, 2007). These enclosures also come with different background colour which constitutes an important factor that affects eggs hatchability, growth and survival rates of fry (Dada, 2007; Alabi and Ocholi, 2018; Okwiri, 2015).

**Table 3:** Water quality parameters obtained from experimental tanks

| Parameters | Treatments | | | |
|---|---|---|---|---|
| | WCT | BCT | WPT | BPT |
| Temperature ($^{0}$C) | $26.80 \pm 0.86^{a}$ | $26.50 \pm 0.64^{a}$ | $26.90 \pm 0.55^{a}$ | $27.10 \pm 0.35^{a}$ |
| pH | $7.52 \pm 0.25^{a}$ | $7.65 \pm 0.50^{a}$ | $7.72 \pm 0.42^{a}$ | $7.74 \pm 0.34^{a}$ |
| Dissolved Oxygen (mg $l^{-1}$) | $5.24 \pm 0.82^{a}$ | $5.20 \pm 0.61^{a}$ | $5.12 \pm 0.73^{a}$ | $5.15 \pm 0.77^{a}$ |
| Nitrate (mg $l^{-1}$) | $4.12 \pm 0.01^{a}$ | $3.82 \pm 0.40^{a}$ | $4.02 \pm 0.11^{a}$ | $4.08 \pm 1.13^{a}$ |

**Legend**; WCT: White concrete tank, BPT: Black concrete tank, White plastic tank, BPT: Black plastic tank.

In the present study, the size of female brood fishes used for induced breeding were within 300 g and 2000 g (Olaleye, 2005). This size is preferable because they usually have substantial quantity of mature eggs and are easy to manipulate. Also, in the current study, no significant disparities were observed in the larval survival rates but hatching rate was best in black concrete tanks and white plastic tanks. It is crystal clear from this result that tank varieties and background colour did affect hatching performance but survivability of larval was not influenced. The hatching success obtained in this work was in consonance with 50 to 80% hatching rates established (De Graaf *et al.*, 1995). in well-managed hatcheries. In disagreement with this finding, slight differences in hatching rate of C. *gariepinus* reared in black and white trough under recirculating system were reported (Alabi and Ocholi, 2018). Likewise working on O*reochromis niloticus*, it was found that there was no significant effect of background colour on hatching and survival rates of yolk sac fry (Okwiri, 2015).

Fish in black plastic tanks had higher weight gain but no marked difference between treatment groups. This indicates that the fry from both white and black culture tanks grew at approximately the same rate. This favourably agreed with the result obtained by other authors, who worked on the effects of tank background colour on growth in various fish species (Alabi and Ocholi, 2018; Krasteva *et al.*, 2020; Ekokotu and Nwachi, 2014). Our observation on weight gain, thus follow the findings[16] in European catfish (*Silurus glanis L.*) fingerlings, African catfish (C. *gariepinus*) fry (Alabi and Ocholi, 2018 and Okwiri, 2015) in Nile tilapia (O. *niloticus*) fry and Ekokotu and Nwachi, (2014) in African catfish (C. *gariepinus*) fry. However, the slight difference in weight gain observed in this study differed from the findings from Okomoda *et al*. (2017) and Dada, (2007) who observed a considerable difference in weight gain for C. *gariepinus* fry/fingerlings reared in different tank colours. These authors in their respective studies found the best weight gain in black tanks compared to the other tank colours.

The mean values obtained for specific growth rate (SGR) fluctuated negligibly in both white and black culture medium. Fish in black plastic tank showed the highest SGR in concurrence with Alabi and Ocholi, (2018), Okomoda *et al*. (2017) and Dada (2007) who reported highest SGR in C. *gariepinus* fry reared in black trough, but no significant difference compared to the other tank colours. It, however,

differs from Oti and Nwani (2007) who found significant difference in the specific growth rate of C. *gariepinus* juveniles reared in cages suspended in concrete tank and earthen pond. The authors reported a significant higher SGR in fish stocked in earthen pond. The results obtained for the number of shooters in the study were comparably less than the values obtained by Alabi and Ocholi, (2018) who reared 14 days old C. *gariepinus* fry for 42 days in white and black troughs. However, the authors found more shooters in black trough than in white trough, but not significant as against our findings in this study.

In addition, fry reared in concrete tanks have shown significant higher survival rates than plastic tanks. Thus, the result clearly indicated the effects of tank colour on survival of C. *gariepinus* fry. This may be attributed to the habit of this fish species with preference for dark environment (Dada, 2007). The present results were almost similar with that of Alabi and Ocholi, (2018). They found higher survival rates in C. *gariepinus* fry raised in white trough. These results, however, contradict the findings obtained by other authors (Dada, 2007; Okomoda *et al*., 2017) which documented no significant variations in survival rates of C. *gariepinus* fry/fingerlings reared in different tank colours. Combined effect and interaction of rearing tanks and background colours have no effect on water parameters as all the parameters investigated in the study show no marked variations between treatment groups. The parameters values were also in accordance with optimum ranges for C. *gariepinus* (Boyd, 1998). The satisfactory water quality in the experimental tanks could be because of constant flow through.

## CONCLUSION

The results from this study show that black concrete tanks are preferred for C. *gariepinus* hatchability and fry growth. However, the interactions in black plastic tank showed more shooters. White concrete tanks should, however, be considered best for fry survival rate. Meanwhile, future studies may look at the combined effect of other tanks (e.g., fibre tanks, aquaria glass tanks, wooden troughs etc.) and background colours (blue, brown, beige, red etc.) for holistic results.

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# CAGE CULTURE EFFECT ON FISHERIES; AN INTRA-SECTOR INTEREST CONFLICT THAT NEEDS ATTENTION

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**ABSTRACT**

*The fisheries sector, comprising capture and cultured fisheries, requires integrated management to ensure sustainability. Despite projections of a 5% increase in capture fisheries production by 2020, actual production declined to 89.8 million metric tonnes, below the 2013 baseline. This suggests inadequate resource management. In contrast, cultured fisheries have grown steadily, accounting for half of global fish production. However, aquaculture development driven by market demand often overlooks ecological conservation. Cage culture, a form of aquaculture, offers benefits like food security and economic growth but poses risks such as environmental degradation, water quality decline, and biodiversity distortion if not properly managed. To mitigate these issues, guidelines for cage culture management include selecting suitable sites, monitoring water quality, and regulating cage arrangement. Effective policies and management techniques are necessary to address concerns like overstocking, overfeeding, and environmental degradation. Implementing and enforcing these measures can help ensure sustainable cage culture and protect aquatic ecosystems. Proper management is crucial to balance economic benefits with environmental conservation and ensure the long-term viability of fisheries resources. By adopting sustainable practices, the sector can thrive while minimizing its ecological footprint.*

**Keywords**: Fisheries, Aquaculture, Cage culture

## INTRODUCTION

The global demand for aquatic foods is on the rise, driven by the need for protein-rich food sources (FAO, 2022). Aquaculture and capture fisheries are the two main sources of aquatic foods, and both play a crucial role in meeting this demand. The great diversity and capacity of the aquatic food system to supply ecosystem services and sustain healthy diets has made it a viable and effective solution that offers greater opportunities to improve global food security and nutrition both now and, in the future, (FAO, 2024). According to the Food and Agriculture Organization (FAO, 2022) aquaculture production is projected to reach 111 million tonnes by 2032, accounting for 54% of total aquatic animal production. Capture fisheries production is also expected to increase, albeit at a slower rate, reaching 94 million tonnes by 2032 (FAO, 2024). However, the decline in wild fish stocks due to overfishing and disruptions of the functional integrity of the aquatic ecosystems caused to climate change and other environmental factors (Gownaris *et al.*, 2015; FAO, 2022). Aquaculture has become the fastest-growing food production sector, contributing 50% of global fish production in 2022 with over 17 species currently in culture, aquaculture is expected to play an increasingly important role in meeting the global demand for aquatic foods. The FAO projects that aquaculture will account for 60% of total aquatic food for human consumption by 2032, estimated at 184 million tonnes or 90% of total production (FAO, 2024). The fishing sector supports millions of livelihoods, particularly in poor and marginalized communities. Aquaculture has significantly contributed to food security and sustainable development as global population is projected to reach 9.7 billion by 2050. Overall, aquaculture has proven to be a key bridge in ensuring food security in terms of animal protein supplied which has made it a vital component of food security, and its sustainability is crucial for ensuring a healthy and food-secure future. Therefore, the importance of sustainable aquaculture practices and responsible fisheries management cannot be

overstated.

**Cage culture**

Cage culture involves raising fish in enclosures within existing water bodies, allowing for waste removal and water exchange (Mensah *et al.*, 2018). Just as most practice of aquaculture, cage culture is said to originate from Southeast Asia particularly in the freshwater lakes and river systems of Kampuchea (Ling, 1977; Pantalu 1979; Gopakumar, 2009). It seems to have developed independently in at least two countries. Pantalu, (1979) discussed how C*larias spp* and other commercial species are been kept in bamboo or rattan cages and baskets in the Great Lake region of Kampuchea until they are ready to transport to market; the fish in captivity fishes were been fed kitchen scraps and were found to grow readily. This traditional method of culturing fish has then been practiced since then which then spread towards the end of the 20$^{th}$ century (Ling, 1977). Cage culture in the marine environment can be traced back to the 1950s where Fish farming research at the Fisheries laboratory of Kinki University in Japan Kinki led to the commercial culture of yellow tail *Seriola quinqueradiata* which then developed into a significant industry as early as 1960 (Gopakumar, 2009). Thailand in 1970, then developed cage culture techniques for two important marine finfish: the *Pagrus major* (sea bream) and *Epinephelus spp*. (Grouper) after which large scale cage farming of groupers were established in Malaysia and Philipinnes in 1980s (Gopakumar, 2009). Korea has also has been involved in cage culture since 1970s but great success was recorded in the culturing of *Paralichthys olivacens* (Olive flounder) and *Sebastes schlegeli* (Black rockfish) in 1980s which later developed into a successful aquaculture industry in the 1990s (Gopakumar, 2009). Currently many fish species have been cultivated in various designs and sizes of cages in Asia, Europe and other parts of the world; Tilapia and carp predominate in freshwater cage culture in Asia, while *Salmonids spp* are commonly farmed in Europe and the Americas (Gopakumar, 2009).

**Benefits of cage culture**

The use of modern land- and water-based technologies on aquaculture farms has increased the resource-efficiency of the system (Naufal, 2022). Cage culture if sustain can predicate the improvement of the economic, environmental, and social sustainability of the production, processing methods, and supply chain of aquaculture products (Jennings *et al.*, 2016).

According to Gopakumar, (2009);

- Cage construction is comparatively easy irrespective of its type, be it artisanal type or modern sophisticated ones.
- It easy observes your stock in cage culture system, therefore feeding and routine management is easy
- Cage reared fish are said to be superior in quality in terms of condition factor, appearance and taste
- Cages culture explores existing water body which can be access by the non-land owner within or outside the people of the community (fishermen) whose income is affected by many reasons in fishing sector. It therefore acts as an alternative income for such groups.
- Feeding, maintaining and harvesting is typically less labour intensive in cages
- Fish are protected from predators and competitors

**An intra-sector conflicts**

The OECD-FAO (2013) projected a 5% increase in capture fisheries production by 2020, from 91 million metric tonnes to 95 million metric tonnes, tied to improved management of fisheries resources. However, the actual production declined to 89.8 million metric tonnes in 2020, below the baseline projection in 2013. This decrease can be attributed to factors such as climate change, overfishing, and

pollution. Fisheries comprise both capture and cultured fisheries, and both must be managed sustainably to prevent negative impacts on each other. While aquaculture production has grown commendably over the years as shown in (table 1), part of its growth can be linked to the growth recorded in the cage culture sector of aquaculture; therefore, monitoring is required to prevent it from becoming a menace that can decline fisheries resources. To achieve sustainable fisheries and aquaculture in line with Sustainable Development Goals (SDGs), it's essential to understand both the negative and positive environmental and social impacts of aquaculture (Mwamburi *et al.*, 2021).

**Table 1:** Global fisheries production from 2011-2022

| Production | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Inland | 10.7 | 11.2 | 11.2 | 11.3 | 11.4 | 11.4 | 11.9 | 12.0 | 11.5 | 11.4 | 11.3 |
| Marine | 81.7 | 78.4 | 79.4 | 79.9 | 81.2 | 78.3 | 81.2 | 84.4 | 78.3 | 80.3 | 79.7 |
| Total | 92.2 | 89.5 | 90.6 | 91.2 | 92.7 | 90.2 | 93.1 | 96.4 | 89.8 | 91.6 | 91.0 |
| | | | | | | | | | | | |
| Inland | 38.6 | 42.0 | 44.8 | 46.9 | 48.6 | 48.0 | 49.6 | 51.3 | 54.5 | 56.4 | 59.1 |
| Marine | 23.2 | 24.4 | 25.4 | 26.8 | 27.5 | 28.5 | 30.0 | 30.8 | 33.2 | 34.7 | 35.3 |
| Total | 61.8 | 66.4 | 70.2 | 73.7 | 76.1 | 76.5 | 79.5 | 82.1 | 177.5 | 91.2 | 94.4 |
| Grand Total | 154.0 | 156.0 | 160.7 | 164.9 | 168.7 | 166.7 | 172.7 | 178.5 | 177.5 | 182.8 | 185.4 |

*Source: FAO 2018-2024*

The environmental impacts of aquaculture activities are one of the most important challenges facing developing countries (Jahani *et al.*, 2012; FAO, 2006). Aquaculture development has been driven by market demand and does not always address ecological conservation, food security, and poverty alleviation (White, 2021). The growing human population's demand for protein puts pressure on aquaculture, both on enclosed land and open water environments. Effective management and monitoring of aquaculture are crucial to prevent negative impacts on fisheries resources and ensure sustainability. This includes addressing issues such as overstocking, overfeeding, and environmental degradation. By adopting sustainable practices and regulations, we can minimize the negative impacts of cage culture and ensure the long-term viability of fisheries resources. Proper policies and management techniques should be implemented to balance the benefits of aquaculture with the need to protect and conserve fisheries resources.

**Some impacts of cage culture on fisheries and aquatic environment**

Cage culture has benefits for food security and economy, but poor management can lead to environmental degradation, conflicts, and economic losses. Increased production can harm the environment, especially in developing countries. Impacts include water pollution, waste accumulation, and effects on nutrients, genetics, disease, and invasive species.

**Socio-economic impact on Fishermen and community**

According to Akyol *et al.*, (2019), both small scale fishermen and recreational fishers has issues like pollution, fish attraction phenomenon to cages, limited fishing space with sea cage farmers in Izmir and Muğla area, Turkey; however, cage culture has also been shown to have positive impacts, such as reducing occupational migration of fishermen in India from 29% to 9% (Pandit *et al.*, 2021). The introduction of cage farming can lead to resource user conflicts due to limited awareness and stakeholder engagement (Mwamburi *et al.*, 2021). In Ghana's Volta Lake, the establishment of fish cages has raised concerns about water pollution, affecting local communities that rely on the water for various purposes (Mensah *et al.*,

2018). Effective management and stakeholder engagement are crucial to mitigate potential conflicts and ensure sustainable aquaculture practices.

**Environmental impact**

Cage farming in Africa has been found to be non-compliant with best practices, with 138 installations located within 200m of the shore (Fletcher, 2020). This is particularly concerning in rivers such as the Volta (Ghana) and the Nile (Uganda), where 61 installations are situated in small water bodies that do not offer the possibility of a buffer zone due to their shape or size (Fletcher, 2020). Stationary cages and pens are mainly mounted in shallow areas, which are 7m or less deep, and this approximates to the littoral region of most lakes and reservoirs where rooted emergent and submerged vegetation occurs (Goldman and Horne, 1984). The impact of this kind of practice cannot be underestimated, as these areas are well known for emergent plants that serve as breeding grounds for some fish species. Such areas are important as spawning grounds for commercially important fish species such as Phytophilous cyprinids and Pike (Braum, 1978), and substrate spawning tilapias like T. zilli, T. rendalli, and O. macrochir (Ruwet, 1962; Philippart and Ruwet, 1982). This can affect recruitment in the water body, and the cage structures can also interrupt vegetation where predators can be avoided. Effluents from cage culture can impact the local environment, depending on the amounts of waste released, the time-scale over which the releases take place, and the assimilation capacity and flushing ability of the recipient water body (Masser and Wood, 2008). Decreased redox potential in sediments near cages can lead to reduced dissolved oxygen availability (Karakassis *et al.*, 2000). Furthermore, poor management of cage fish farming systems can lead to disease and parasite spread in cages due to a rise in stress levels, which reduce the immune system of fish (Ng'Wigulu, 2021) and these outbreaks can find their way into the immediate environment, causing chaos in the aquatic ecosystem.

**Effects on water quality**

Modern fish culture involves intensive nutrient input through feed, but only a small proportion is converted into the target product (White, 2021). A considerable amount of nutrients reaches the seabed as wasted food pellets or faecal excretions (Karakassis *et al.*, 2000). Organic enrichment of the seabed is a widely encountered impact of cage culture (Gowen and Bradbury, 1987). Unutilized nutrients can accumulate in the water column or sediments, leading to local eutrophication, increased turbidity, and loss of biodiversity (Osei *et al.*, 2019). Cage culture contributes to nutrient pollution, organic matter, and turbidity, deteriorating water quality and biota downstream (Pillay, 1992; Phuong, 1998). Increased organic carbon and nitrogen content in sediments near cages can lead to decreased water quality (Karakassis *et al.*, 2000; Ali *et al.*, 2006). Research on Lake Volta in Ghana showed water quality within WHO minimum requirements in 2014 (Mensah et al., 2018), but a later study by Osei *et al.*, (2019) reported decreased water quality due to increased fish farming intensity. Cage culture has been associated with nutrient loss, low dissolved oxygen, increased ammonia concentration, and eutrophication in lakes like Lake Malawi and Lake Victoria (Fletcher, 2020). The impacts of poor managed cage culture on water quality and the environment has increased significantly over the time. To mitigate these effects, it's essential to adopt sustainable practices, such as proper feed management, regular monitoring of water quality, and effective waste management. By reducing waste and nutrient pollution, we can minimize the negative impacts of cage culture on aquatic ecosystems. This requires a collaborative effort from farmers, regulators, and other environmental stakeholders to prioritize sustainable aquaculture practices and minimize the negative impacts on aquatic ecosystems. By adopting responsible practices, we can ensure a healthy and productive environment for both the farmed fish and the surrounding ecosystem.

**Effect on biodiversity of fisheries resources**

Fish can escape from cages due to human error, net damage, or natural disasters (Secretan, 1979). Escaped fish can introduce foreign or exotic species to an environment, potentially causing harm to native species (Rosenthal, 1976; Mills, 1982). In one lake in Poland, 4 tonnes of trout escaped in one year (Penczak, 1982). Escaped fish can interbreed with native fish, adulterating the genetic pool and potentially causing harm to native species (Rosenthal, 1976; Mills, 1982). Non-native strains of tilapia have been discovered in Lake Volta, likely due to escapees from cage culture (Fletcher, 2020). Escapees can cause changes in the genotypes of wild fish populations and biodiversity (White, 2021). Ipinmoroti and Awotundun, (2022) discovered an interaction between native cichlids and cultured red tilapia in Asejire lake, Nigeria as a total sample of 253 contains 147 native cichlids and 106 interacted species. Generating of hybrids in water body can be a threat to the native species as this new species sometimes can have the ability to outcompete the native species which is an additional threat to the ecosystem balancing sheet in term of biodiversity. Unregulated cage culture can devastate biodiversity and dependent fisheries resources (Fletcher, 2020). The macrofaunal community can be affected up to 25m from the edge of cages (Karakassis *et al.*, 2000). Human-induced impacts, including aquaculture activities, can cause changes in species numbers and endemism (Sayer *et al.*, 2018; Sayer *et al.*, 2019). The collection of wild brood stock or wild fry for stocking can reduce recruitment for wild fisheries (White, 2021). The introduction of new fishing practices, such as aquaculture in Lake Victoria has changed the ecology of lakes whereby the increased number of Nile perch and eutrophication contributed to the disappearance of the native *Labeobarbus microbarbis* in the region (Kwilasa, 2021). To mitigate these impacts, it's essential to adopt sustainable aquaculture practices, including proper cage management and monitoring of escapees. By reducing the risks associated with fish escapes and promoting sustainable aquaculture, we can help protect biodiversity and ensure the long-term sustainability of fisheries resources.

**Sustainable cage culture recommendations**

To minimize the impacts of cage culture, the following recommendations are proposed:

- Proper site selection: Choose locations with sufficient water depth and flow.
- Regular monitoring: Monitor water quality and sediment conditions regularly.
- Sustainable feeding practices: Adopt feeding practices that minimize waste.
- Effluent management: Manage effluents effectively to prevent pollution.
- Prevent escapees: Regularly maintain cages and nets to prevent escapees.
- Use native species: Use native species in cage culture.
- Monitor biodiversity: Regularly monitor biodiversity.
- Stakeholder engagement: Engage with stakeholders to prevent conflicts.
- Regulatory framework: Establish a regulatory framework for sustainable cage culture.
- Benefits sharing: Share benefits equitably among stakeholders.
- Capacity building: Provide training and capacity building programs for cage farmers.

## CONCLUSION

Despite the great contribution of aquaculture to the fish production in the world, there is a special call the adverse effect cage culture can have on the fisheries resources that already over stressed due many factors. Cage culture should be were monitored so as not add to the menaces that are responsible to the depletion in wild stock that needs recovery. Proper policies and management techniques that will put cage culture in check should be implemented and well monitored; issues such as overstocking, overfeeding and condensation of the aquatic environments with cages and pens should be technically and strategically addressed on our water bodies.

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# FISH SPECIES COMPOSITION AND DIVERSITY INDEX OF KALGWAI RESERVOIR, JIGAWA STATE, NIGERIA.

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**ABSTRACT**
*Fish yields for most Nigerian inland waters are generally on the decline. This could be attributed to inadequate management of fisheries resources and environmental degradation of the water bodies. A crucial management tool for a sustainable exploitation of these resources is to have a comprehensive understanding of their present status. Study on fish species composition and diversity of Kalgwai reservoir was conducted for twenty-four consecutive months (January 2022-December 2023). Fish and water samples were collected from three landing sites fortnightly for identification and laboratory analysis. Twenty-seven fish species which belong to sixteen (16) families, were identified in the experimental gill net sampling. While 77,866 fish species were recorded from catch assessment survey of fishermen with a combined weight of 591.81gm were also recorded. They belong to eleven different families. The dominant species identified were Oreochromis niloticus (13.6%), Lates niloticus (9.2%) and Bagrus bajad (7.4%) while the least abundant was Parachanna africana (1%). Most of the fish species were caught during the dry season than rain season. Different types of fishing gears were employed by local fishermen in the area including seine nets, gill nets, cast nets with different mesh sizes without appropriate monitoring by the relevant government agencies, while sixty (60) fishing crafts mainly wooden canoes were recorded during the study period. The study was carried out to determine the fish species composition and diversity of Kalgwai reservoir in Auyo LGA Jigawa State.*

**Keywords**; Kalgwai Reservoir, fish species composition, Diversity Index.

## INTRODUCTION

Generally, fisheries and aquaculture play important roles for food supply, food security and income generation. Some 43.5 million people work directly in the sector with great majority in developing countries (FAO, 2006). When you include that work on processing, marketing, distribution and supply industries, the sector supports nearly 200 million livelihoods.

Fish supply in Africa is in crisis. Per capita consumption in sub-Saharan Africa is the lowest in all regions and it is the only part of the world where consumption is declining. The main reason for this decline is the levelling off in capture fish production and the still-growing population. In order to maintain the current level of per capita supply of fish in sub-Saharan Africa, which is 6.6 kg/ha/year, fish production from capture fisheries and aquaculture must increase by 27.7% over the next few years. This assumes an average annual population growth of 1.9% during the period (World Bank 2004). The study was carried out to determine the fish species composition and diversity of Kalgwai reservoir.

## MATERIALS AND METHOD

Kalgwai Reservoir is about 25km away from Hadejia Town, it is located in Auyo Local Government Area of Jigawa state, Nigeria and it lies between 1100°N to 1300°N and 800°E to 35°E. It was impounded on River Hadejia in 1984 by the Federal Government of Nigeria for the purpose of irrigation under the then

Hadejia Valley irrigation project which was coordinated by the Hadejia – Jama'are River Basin Development Authority (H.J.R.B.D.A) which covers an estimated area of 380 $Km^2$ (Mathes, 1990).

Its maximum surface area normally occurs at the end of the rain season in September. Thereafter, the water recedes till the minimum level is reached just before the start of rain season in June. The extent of flooding varies from year to year and is mainly dependent on the amount of rainfall (Solomon et al. 2014). Hence fish

Production also varies depending on the extent of the volume of water during the season. As demand for fish and competition for access to fishing areas increases, lower income groups are likely to become marginalized, replaced by more powerful groups with growing interests in these scarce natural resources (Delgado et al., 2003). The greatest obstacles to increased inland fish production is the haphazard methods of exploitation due to complete absence of established inland fisheries laws and regulations of small reservoirs and dams (Ita, 1993). The possible solution is perhaps to stock and manage our numerous water bodies very well in order to produce more fish to
meet the increasing demand.

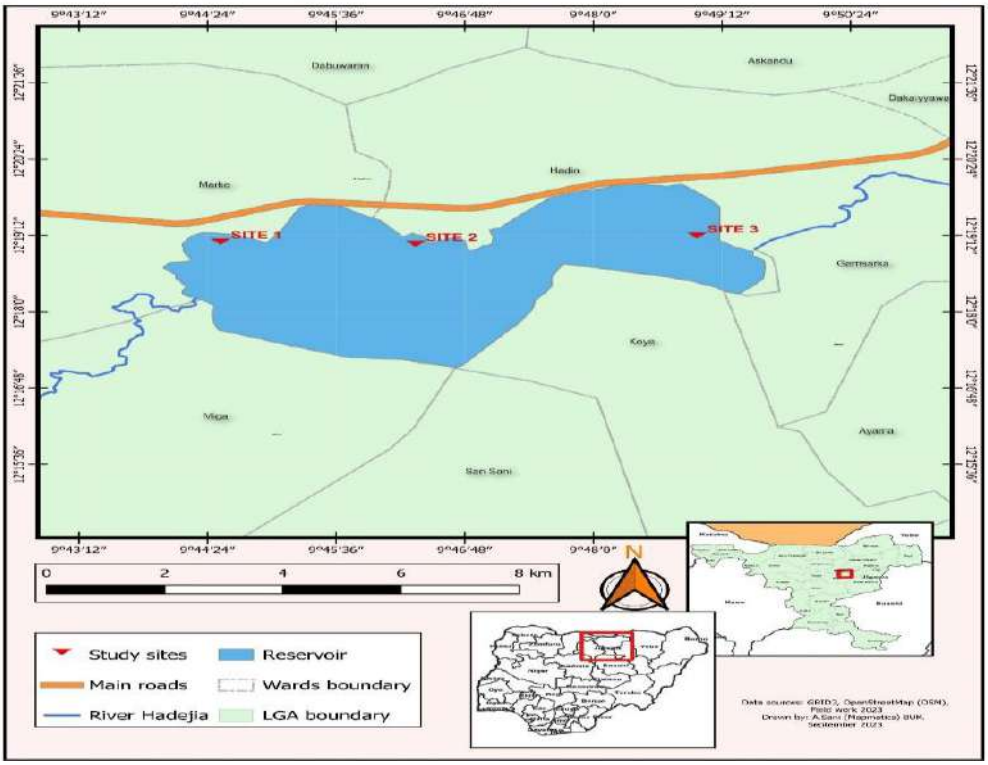



**Figure 1:** Map of Kalgwai reservoir showing three Sampling sites.

**Sample Collection**

Three sampling sites were selected for this study as shown in Figure 1. They are Kalgwai [site 1],Dingare[site 2], and Marke[site 3]

**Survey of Fish Species Composition and Experimental Fish Sampling**

Survey of fish species in Kalgwai reservoir took place at three landing sites by employing both experimental fish sampling and artisanal fishery survey. The period of the survey covered twenty-four (24) consecutive months (January 2022 – December 2023) and data were collected on monthly basis.
A set of seven multifilament gill nets of different sizes were used for the experiment. The nets were

stretched to sample fish species from different water levels. They were set simultaneously to sample the shore, surface and bottom habitats at about 5:00pm in the evening and were checked about 8:00am the next day.
Fish caught in each net were removed and kept into a labelled plastic bowl. They were weighed (in gm) and measured for standard and total lengths (cm).

**Statistical Frame Survey and Catch Assessment Survey**
The statistical frame survey involved total count of fishermen and boats operating on the reservoir water, and recording of the fishing gears and crafts used as described by Jhingran and Pullin [2001]. The Catch assessment survey involves the actual counting and weighing of fishes caught by the local fishermen at the three sites for 24 consecutive months as described by Balongun and Auta (2001).

The total weight of fish caught by each fisherman was obtained by the use of weighing balance (in gm). All fish species were identified using relevant identification guides by Olaosebikan and Raji (1998).

**Determination of biodiversity indices and catch per unit effort (CPUE)**
**Biodiversity indices**
Margalef index (D), Shannon – Weinner index (H) and Shannon's equitability (evenness) (EH) were employed to evaluate species diversity.
Margalef index (D)
$D = \sum (n/N)^2$
While n = the total number of organisms of a particular species
N= number of organisms of all species in the water body
Shannon-Weiner index (H)
$H=\sum (PI) (lnP1)$
Where PI is proportion of the number of the individuals in the population that are specie I.
Shannon's Equitability (evenness) (EH)
$EH = H/lnS$
Where S is the total number of species in the community (richness).
ln is the natural logarithms.

**Survey of fish species composition**
Survey of fish species in Kalgwai reservoir took place at three landing sites, Dingare, Marke and Kalgwai by employing both experimental fish sampling and artisanal fishery survey. The period of the survey covered twenty-four (24) consecutive months (January 2022 – December 2023) and data were collected on monthly basis.

**Experimental Fish Sampling**
A set of seven multifilament gill nets of different sizes were used for the experiment. Mesh sizes of the nets included 38mm, 57mm, 76mm, 101mm, 127mm, 152.4mm and 177. 6mm. The nets were stretched to sample fish species from the shores, surface and bottom habitats of the water body at the three sampling sites. Each of the nets measured about 30m long and 3m deep. They were set simultaneously to sample the shore, surface and bottom habitats at about 5pm in the evening and were checked about 8am the next day.
Fish caught in each net were removed and kept into a labeled plastic bowl. They were weighed (in gm) and measured for standard and total lengths (cm).

**Data Analysis**
Analysis of data was based on monthly data collection. Data obtained from identification, counting and

weighing of fish were used to compute fish composition, distribution and abundance for each stations. Analysis of variance (ANOVA), T-test and Pearson's correlation coefficient (r) were used for the analysis using SPSS version 20.

**Table 1:** Fish Species Composition of Kalgwai Reservoir

| Family/Species | English Name | Local Name | Kalgwai | Dingare | Marke |
|---|---|---|---|---|---|
| **ARAMPAMIDAE** | | | | | |
| *Heterotis niloticus* | African bony tongue | Bargi | ✓ | ✓ | ✓ |
| **Bagridae** | | | | | |
| *Bagrus bajad* | Silver catfish | Musko (Ragon ruwa) | ✓ | ✓ | ✓ |
| *Bagrus longifilis* | Silver catfish | Dinko | ✓ | ✓ | ✓ |
| *Bagrus filamentosus* | Silver catfish | Dinko | ✓ | ✓ | ✓ |
| **Channidae** | | | | | |
| *Parachanna africana* | Snakehead | NA | X | ✓ | ✓ |
| *Channa obscura* | Snakehead | NA | X | ✓ | ✓ |
| **Alestidae** | | | | | |
| *Alestes baremose* | Silver side | Kawara | ✓ | ✓ | ✓ |
| *Hydrocynus forskalii* | Tiger fish | Tsage | X | ✓ | ✓ |
| **Clarotidae** | | | | | |
| *Auchenoglarius occidentalis* | NA | Buro | X | ✓ | ✓ |
| **Cichlidae** | | | | | |
| *Oreochromis niloticus* | Nile Tilapia | Karfasa | ✓ | ✓ | ✓ |
| *Coptodon zilli* | Red belly Tilapia | Karfasa | ✓ | ✓ | ✓ |
| **Citharinidae** | | | | | |
| *Citharinus citharus* | Moon fish | Faliya | X | ✓ | X |
| **Clariidae** | | | | | |
| *Clarias gariepinus* | Mud catfish | Tarwada | ✓ | ✓ | ✓ |
| *Heerobranchus bidorsalis* | Catfish | Ramboshi | ✓ | ✓ | ✓ |
| **Cyprinidae** | | | | | |
| *Labeo senegalensis* | African carp | Farin dumi | ✓ | ✓ | |
| **DISTICHODONTIDAE** | | | | | |

## RESULTS

### Fish Species Composition of Kalgwai Reservoir

The fish species composition of Kalgwai reservoir is presented in table 1. Twenty-seven (27) fish species belonging to sixteen (16) families were identified and recorded in Kalgwai reservoir from January 2022 to December 2023 (24 months). The families identified *were Bagridae, Channidae, Characidae, Arampomidae, Cichlidae, Clarotidae, Citharinidae, Clariidae, Distichodontidae, Latidae, Cyprinidae, Malapteruridae, Mormyridae, Protopteridae, Schilbeidae, and Mochokidae*. All twenty-seven (27) identified fish species were observed at the Dingare landing site, while eight (8) of them were absent at the Kalgwai site (Table 1). Additionally, only one species, *Citharinus citharus*, was not observed at the Marke landing site.

*Note: Sample ticked 'X' indicates absent. NA: Not Applicable*

The diversity indices of species in Kalgwai reservoir from gill net sampling has been presented in table 2. It revealed a high fish species diversity with even distribution in the reservoir. 16 families and 27 species were identified. Shannon-Weinner index (H) was 1.0054, Equitability index (H) was 0.702407 while Marglef index (D) was 3.250131 respectively.

**Table 2:** Diversity indices of fish species composition from gill net sampling in Kalgwai reservoir

| Diversity Index | Kalgwai Reservoir |
|---|---|
| Family richness | 16 |
| Species richness | 27 |
| Abundance (n) | 2980 |
| Shannon-weiner (diversity) index (H) | 1.0054 |
| Equitability index (EH) | 0.702407 |
| Margalef (D) | 3.250131 |

Diversity indices of fish species composition in Kalgwai reservoir from catch assessment is presented in table 3

**Table 3:** Diversity indices of fish species composition from catch assessment survey of Kalgwai reservoir

| Diversity index | Kalgwai reservoir |
|---|---|
| Family richness | 11 |
| Species richness | 27 |
| Abundance (n) | 77,865 |
| Shannon-weiner diversity index (H) | 1.058065 |
| Equitability index (EH) | 0.859901 |
| Margalef (D) | 1.420614 |

The diversity indices indicate high species richness which makes catch per unit effort in the reservoir to be high also. This differs from the findings of Mustpaha (2023) who reported low species richness and low fish diversity in Nguru lake, Yobe State. Catch per unit effort is a measure in terms of weight of fish catches within specified period of time. The study shows that 77,866 fish species were recorded in the catch assessment survey and they belong to 11 families.

## DISCUSSION

A total of 77,866 fish individuals with a combined weight of 591.781 grams were caught in the artisanal catch assessment survey. Seventy-seven thousand eight hundred and sixty-six (77,866) fish species belonging to 11 families were identified and recorded. All of them were also found in the experimental gill net sampling. The percentage of fish species in the artisanal catch assessment survey of Kalgwai Reservoir is presented in Table 2. *Oreochromis niloticus* has the highest percentage (18.7%) of fish species landed by local fishermen in Kalgwai Reservoir, followed by *Clarias gariepinus*, *Coptodon zilli*, *Bagrus bajad*, *Heterotis niloticus*, *Lates niloticus*, *Hydrocynus forskalii*, and *Bagrus filamentosus*, in that order. The least percentage was recorded for *Bagrus longifilis* (0.7%).

### Fish Species Composition from Gill net Sampling in Kalgwai Reservoir

Fish species composition of Kalgwai reservoir as presented in table 4.4 revealed that twenty-seven (27) species belonging to sixteen (16) families were identified and recorded. The identified families were *Bagridae*, *Distichodontidae*, *Latidae*, *Cyprinidae*, *Malapteruridae*, *Mormyridae*, *Protopteridae*, *Schilbeidae and Mochokidae*. *Other Include Channidae*, *Characidae*, *Arampoidae*, *Cirhlidae*,

*Clarotidae, Cithar*inidae *And Clariidae*. This indicates a relatively high species diversity when compared to other studies on some reservoirs in Nigeria, for example Ayanuwale et al., (2013).
The study also further reveals that *Oreochronis niloticus* has the highest percentage abundance (13.6%) followed by *Lates niloticus* (9.2%) and *Bagrus bajad* (7.4%) while *Channa africana* has the least percentage abundance (1%), members of these three families could be said to be the dominant species in the reservoir, however, all the twenty seven species identified were observed at Dingare site, while eight of them were not observed at Kalgwai and only one species *Citharinus citharus* was not observed at Marke site.

**Fish species Composition and abundance from the Artisanal catch Assessment Survey of Kalgwai Reservoir.**
A total of seventy-seven thousand eight hundred and sixty-six (77,866) fish species with a combined weight of 591.781 grams were identified and recorded during this study period. They belong to eleven (11) different families and all of them were also found in the experimental gill net sampling. There was higher fish species abundance in dry season than wet season. This conforms with the findings of Ayoola and Kuton (2009) who reported that more fish were caught in dry season than wet season.

Furthermore, Adeyemi (2011) observed that fish landings in lake Gbedikere and some water bodies in northern Nigeria were highest in December, January and February.

The percentage of fish species in the catchment survey of Kalgwai reservoir as presented in table 4 shows that Oreochromis niloticus has the highest percentage (18.7%) of fish species landed by the local fishermen, followed by *Clarias gariepinus*, *Coptodon zilli*, *Bagrus bajad*, *Heterotis niloticus*, *Hydrocynus forskalii and Bagrus filamentosus*. The least percent was recorded for *Bagrus longifilis* (0.7%).

## CONCLUSION
Twenty-Seven species of fish belonging to sixteen families which are of commercial importance are present in the reservoir. The family *Cichlidae* is the most abundant in both the experimental gill net sampling as well as in the catch assessment survey from the local fishermen landings. There are numerous fish species in the reservoir indicating its richness. Various types of fishing gears are used for fishing in the area without adequate monitoring by the relevant authorities. There were monthly and seasonal variations in fish species composition of Kalgwai reservoir with the family *Cichlidae* dominating in most of the months and also in the two seasons.
The study further revealed that values of length-weight relationship and condition factor for most of the dominant fish species were equal to or greater than 1 thus indicating a positive correlation between length and weight of the fish. Therefore, fish species of Kalgwai reservoir can be said to be in good condition of health

## ACKNOWLEGMENT
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# OPTIMUM LATENCY PERIOD OF *Heterobranchus longifilis* FOR HIGHER YIELD IN THE HATCHERY

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**ABSTRACT**
*Latency period can be defined as the period between the time of hormonal induction and fertilization of eggs, which is influenced by various factors, but most especially by water temperature and real timing. Warmer temperature shortens the latency period, but when the temperature is cooler, that is lower than room temperature will definitely prolong the latency period. This studies reveal the actual time range (latency period) that is more favourable for optimum result in terms of survival which is from 15h to 17h and the survival trend start descending from 19h, meaning that one could arrive at optimum hour by finding the average hours from 15h, 17h, 19h of which the summation is 51h then divide it by 3, the result is 17h. This shows that the best timing to stripe heterobranchus longifilis in the tropics should be between 15-18h which will give ultimate hatchability and survival as recorded in this study.*

**Keywords:** latency, optimum, hatchability, survival

## INTRODUCTION

African catfish C*larias gariepinus* fish has been encouraged in the African continent owing to its ability to withstand adverse pond conditions in addition to it fast growth rate. Legendre (1983) also pointed out the culture potential of *H.longifilis* as a pond fish in Africa.
Heterobranchus and Clarias belong to the same family called clariidae but different genera. The external morphology of clariid catfishes is characterized by an elongated body with long dorsal (always without a spine) and with or without adipose- spine supported by spine (Tueguls 1983).

Adipose fin is present in genus Heterobranchus, the pectoral fin has a strong spine, and four pairs of barbels. In the extremely elongated genera (for example Giymnallubes) the paired fins and anal fins are confluent with the caudal fin. The Asian Clarias and macrocephallus and the African C. gariepnus are the most studied species in this family. These Heterobranchus species has successfully been introduced in aquaculture; under identical conditions its growth rate double that of C. *gariepinus* (Legendre et al., 1992). This genus Heterobranchus has similarity with genus clarias but can be differentiated from the later by the fact that it has rayed dorsal followed by an adipose fin just like clarias they have four pair of barbels on their flattened, strongly depressed head.

Heterobranchus were noted to have well developed gonads between June and September. There are four valid species described by Tuegels (1990). *H.longifilis* has been studied for it reproduction, breeding in brackish and freshwater of Nigeria .Naturally *H.longifilis* shows to have resistance to diseases, adverse condition and fastness in growth. These attributes are noticed from laboratory and field work experience. For this species, there is a problem of seed multiplication and supply with the quantity of eggs and fry produced which lead to constraints on current aqua cultural developments .Improvement in our understanding of the appropriate culture conditions and management procedures for brood fish is essential if we are to programme reproductive development to produce relatively the numbers of eggs and fry required by grow –out farms , it is important to improve our understanding and control of all those process such as latency period for optimum result. Battle (1944) and Carr (1942) stated that life of deposited eggs prior to fertilization is relatively short. This fact must be kept in mind of the fish culturists.

Also, Agbebi et al (2013) stated that any attempt to improve fingerlings production in C*larias gariepinus* must consider the effects of latency period in relation to water temperature. Hence the importance of this study which looks into researching the optimum latency period of *H.longifilis* for higher yield in the hatchery

## MATERIALS AND METHODS

The studies were carried out in the Fish Genetic Improvement Laboratory unit of aquaculture programme of the National Institute for Freshwater Fisheries Research, New Bussa Niger state, Nigeria. Brood stock of *Heterobranchus longifilis* were obtained from the wild, around kanji River basin. Ovaprim hormone was used**,** based on the recommended dosage of 0.5ml /kg, each brood weighed about 800 and 900g respectively, the eggs were striped and fertilized at 15 hr., 17 hr., 19 h. and 21 h respectively from the same female fish. These series of fertilizations were transferred to well-aerated glass aquaria of 60 x 30 x 30 $cm^3$ size tanks in triplicates after fertilization. The water quality parameters were taken into consideration and they were all normal, $DO_2$ 5mg/L, conductivity 100, pH7.4 and temperature 26.1 $^0C$.

### Rearing Indoor

Just after the hatching, one hundred number of hatchlings were picked randomly from each latency stocked in the aquaria with initial and final mean weight gained during indoor rearing recorded. The daily survival in triplicate form were conducted by individual counting on a daily basis for a period of 3 weeks indoors. While indoor for 3 weeks, the fry was fed with freshwater *Moina micrura* zooplankton ad libitum for the period of indoor rearing.

## RESULT AND DISCUSSION

**Table 1:** Summary of Indoor survival of *Heterobranchus longifilis* fry reared for 21 days based on varying latencies

| LT. | D1 | D2 | D3 | D4 | D5 | D6 | D6 | D8 | D9 | D10 | D11 | D12 | D13 | D14 | D15 | D16 | D17 | D18 | D19 | D20 | D21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 100 | 97 | 90 | 85 | 85 | 83 | 83 | 80 | 79 | 75 | 74 | 60 | 60 | 55 | 55 | 55 | 54 | 54 | 54 | 53 | 53 |
| 17 | 100 | 99 | 97 | 95 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 |
| 19 | 100 | 85 | 80 | 80 | 80 | 80 | 80 | 80 | 79 | 79 | 76 | 74 | 74 | 74 | 73 | 70 | 69 | 65 | 60 | 59 | 59 |
| 21 | 100 | 95 | 90 | 85 | 80 | 80 | 79 | 79 | 77 | 77 | 73 | 71 | 71 | 70 | 69 | 69 | 65 | 60 | 55 | 50 | 50 |

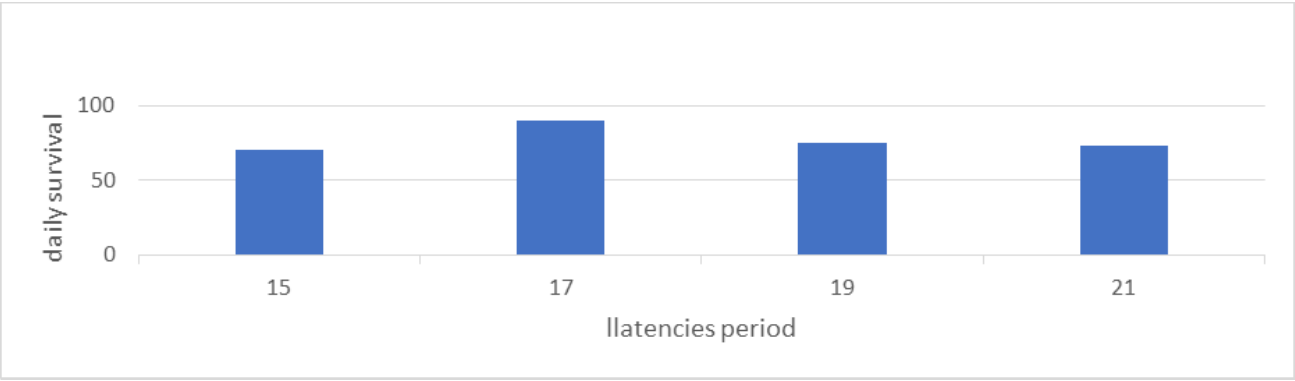



**Figure 1:** Showing daily survival in reference to varying latencies ranges from 15h -21h.

From table 1, fig 1.Immediately after hatching 100 number *of H.longifilis* fry were randomly picked based on their latencies ranging from 15h, 17hr, 19h and 21h and stocked in glass aquaria in triplicates for monitoring for 21 day indoor ,Every each day sampling were conducted by lowering the volume of the water for total counting of the survivor fry, then data of the survival were taken , this was done for the period of twenty one days .Table 2 reflect the effect of varying latencies on the survival of *H. longifilis*

the highest survival was recorded on latency 17hr which is 89% survival of total stocked , followed by 19hr which is also 76% of total stocked ,this result was in agreement with the what Abgebi et al( 2013) says that right latency period and temperature are great factors that influence success in catfish breeding ,likewise Battle( 1944) and Carr( 1942) concluded that fertilization must be done within the proper time because eggs begins to deteriorate after the exact latency period .

## CONCLUSION

Based on the results obtained, it is evident that stripping *H. longifilis* at or before 15 hours does not produce optimal outcomes compared to latency periods beyond 16 hours. The highest survival rate was recorded at 17 hours. However, extending the latency period beyond 17 hours led to a decline in fry survival, suggesting that the eggs had begun to deteriorate before fertilization. This agrees with the findings of Agbebi (2013). Therefore, 17 hours appears to be the optimal time to strip *H. longifilis* during artificial fertilization.

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# EFFECTS OF CROSSING BROODSTOCKS OF *Clarias gariepinus* FROM DIFFERENT FARMS IN MAKURDI ON EARLY GROWTH PERFORMANCE OF OFFSPRINGS

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**ABSTRACT**
*This study evaluated the breeding and growth performance of Clarias gariepinus offspring resulting from crossing brood stock obtained from two fish farms in Makurdi, Benue State, Nigeria. Mature brood stocks were selected using morphological indicators of reproductive readiness and acclimatized before spawning. Fertilization, hatchability, growth, and survival performance of fry were monitored over 14 days under four treatment combinations in a completely randomized design with triplicates. Growth performance indices—mean weight gain and specific growth rate (SGR)—were analysed using one-way ANOVA. Results revealed significant differences in mean weight gain ($p = 0.022$) and SGR ($p = 0.033$) across treatments. Treatment T4 demonstrated superior performance in both growth and survival (75.8 ± 7.36 %), though survival differences were not statistically significant ($p = 0.065$). These results show how important treatment-specific protocols are for the growth and survival of C. gariepinus fry. They also give useful information for choosing brood stock and managing a hatchery.*

**Keywords**: Heterosis; Larval rearing; Genetic diversity; Aquaculture improvement

## INTRODUCTION

Aquaculture plays a vital role in global food security, with *Clarias gariepinus* (African catfish) making a significant contribution to Nigeria's freshwater aquaculture production. Its hardiness, rapid growth rate, and high reproductive potential make it a preferred culture species. However, reliance on genetically homogeneous brood stock often results in inbreeding depression, reduced growth performance, and increased disease susceptibility (Khang *et al*., 2018). Crossing genetically distinct brood stock provides a practical approach to enhancing growth traits through hybrid vigour (heterosis), thereby improving productivity and resilience (Rajab *et al*., 2024). In Makurdi, C. *gariepinus* farming has gained significant traction due to its adaptability to local environmental conditions and economic benefits. However, the genetic diversity within and between fish farms in Makurdi is largely undocumented, posing challenges for the optimization of breeding programmes. The crossbreeding of C. *gariepinus* from different farms could potentially enhance the genetic variability and improve the growth performance of both the brood stock and their offspring. Previous studies have demonstrated that crossbred catfish often exhibit heterosis, or hybrid vigour, leading to improved growth rates and better survival compared to their purebred counterparts (Owodeinde *et al.*, 2012; Ataguba and Abi, 2024). This study aims to evaluate the breeding and growth performance of C. *gariepinus* brood stock and their offspring resulting from crossbreeding individuals from different farms in Makurdi

## MATERIALS AND METHODS

### *Brood stock Collection and Experimental Design*

Brood stock were collected from two farms (Farm A and Farm B) in Makurdi (7°43′55.92″N;

8°32′20.76″E). Mature females were selected based on vent morphology, abdominal distension, and egg extrusion, while males were selected based on urinogenital papilla coloration. Fish were acclimatized in the Teaching and Research Hatchery at Joseph Sarwuan Tarka University, Makurdi, for three days.
Four treatment groups were established:
**T1**: Farm A ♀ × Farm A ♂; **T2**: Farm A ♀ × Farm B ♂; **T3**: Farm B ♀ × Farm B ♂; **T4**: Farm B ♀ × Farm A ♂
Each treatment was replicated three times.

***Hatchability***
Thirty-five grams of eggs were incubated in 40 L plastic tanks with mosquito mesh substrates and aeration. Hatchability was assessed 24 h post-hatch using volumetric sampling and calculated as:

$$\text{Hatching rate} = \frac{\text{Number of hatched eggs}}{\text{Number of incubated eggs}} \times 100$$

Where number of incubated eggs was estimated using the 700 eggs per gram standard of Huisman *et al*. (2012)

***Growth and Survival***
A total of 150 larvae per treatment were stocked in 60 L bowls and fed *Artemia* cysts ad libitum for 7 days, followed by a gradual transition to Coppens micro-feed (200–300 $\mu$m). Growth was monitored every 2 days by bulk weighing. Growth indices were computed as:

$$\text{Mean Weight Gain (g)} = W_1 - W_0$$

$$\text{SGR } (\%\text{day}^{-1}) = \frac{\ln W_1 - \ln W_0}{t} \times 100$$

where:
Initial weight = $W_0$ (g)
Final weight = $W_1$ (g)
Survival was estimated by physical count on day 14.

***Statistical Analysis***
Growth and survival data were analysed by one-way ANOVA, and means were compared using Fisher's LSD at $p < 0.05$.

## RESULTS AND DISCUSSION

***Hatchability and Early Growth Performance***
Hatchability across brood stock pairings (Table 1) ranged from 49.49 ± 3.57% (Farm A♀×Farm A♂) to 84.18 ± 14.8% (Farm B♀×Farm B♂). However, the overall difference was not statistically significant ($p = 0.112$). The markedly higher hatchability in brood stock involving Farm B suggests that genetic or parental-line variation (e.g., brood stock condition, strain, or farm-specific environment) may influence hatching success in C. *gariepinus*, consistent with reported brood stock-combination effects in the species. Egg viability and hatchability in C. *gariepinus* have been shown to depend on brood stock combinations and handling protocols (Ataguba *et al*. 2013; Agbebi *et al*. 2013).

**Table 1:** Early growth performance of fry under four treatments

| Treatment | Hatchability (%) | MIW (g) | MFW (g) | MWG (g) | SGR (%/day) | Survival (%) |
|---|---|---|---|---|---|---|
| Farm A♀×Farm A♂ | 49.49±3.57 | 0.04±0.00 | 0.09±0.00 | 0.04±0.00$^{a}$ | 4.72±0.02$^{a}$ | 53.3±4.40 |
| Farm A♀×Farm B♂ | 64.8±4.59 | 0.06±0.00 | 0.08±0.00 | 0.02±0.00$^{b}$ | 2.12±0.03$^{b}$ | 54.3±0.09 |
| Farm B♀×Farm B♂ | 84.18±14.8 | 0.05±0.01 | 0.09±0.00 | 0.04±0.01$^{ab}$ | 4.04±0.81$^{ab}$ | 55.9±2.91 |
| Farm B♀×Farm A♂ | 81.12±3.57 | 0.04±0.00 | 0.08±0.00 | 0.04±0.00$^{a}$ | 4.50±0.09$^{a}$ | 75.8±7.36 |
| *p*-value | 0.112 | 0.106 | 0.574 | 0.022 | 0.033 | 0.065 |

Means with different superscripts differ significantly at $p < 0.05$. (MIW = Mean Initial Weight, MFW = Mean Final Weight, MWG = Mean Weight Gain, SGR = Specific Growth Rate)

The results clearly demonstrate that crossing brood stock from different farms influenced the growth and survival performance of *Clarias gariepinus* fry during the early rearing phase. Mean weight gain (MWG) and specific growth rate (SGR) differed significantly among the treatment groups ($p = 0.022$ and $p = 0.033$, respectively), indicating treatment-specific effects on growth dynamics. In particular, the cross between Farm B ♀ × Farm A ♂ (T4) exhibited the highest survival (75.8 ± 7.36 %) and competitive growth performance, closely followed by Farm A ♀ × Farm A ♂ (T1) and Farm B ♀ × Farm B ♂ (T3). In contrast, Farm A ♀ × Farm B ♂ (T2) lagged significantly behind, with the lowest MWG (0.02 ± 0.00 g) and SGR (2.12 ± 0.03 %/day), underscoring potential genetic or physiological incompatibilities in this cross (Ataguba *et al.*, 2013).

The superior survival of T4 (75.8%) compared to other treatments (53–56%) suggests that genetic factors may have contributed to increased resilience under the culture conditions used. Similar trends have been reported by Ajani *et al.* (2018) and Salami *et al.* (2019), who observed that crossbreeding C. *gariepinus* strains often results in hybrids with improved growth rates and tolerance to early life stressors. The poor performance of T2, despite having one of the highest initial weights, may indicate that brood stock genetic compatibility plays a crucial role in sustaining growth over time, as early advantages may be negated by suboptimal genetic combinations (Park *et al.*, 2017).

### *Growth Progression*

Figure 1 illustrates the growth trends of fry over 14 days. The growth progression curve further elucidates these patterns. While all groups began with similar mean weights, T2 exhibited an initial growth spurt by Day 3 but subsequently declined mid-culture, ending with the lowest final weight. Conversely, T4 maintained a steady and sustained growth trajectory throughout the 14 days, surpassing all other groups by Day 10 and sustaining its lead until the end of the experiment. This sustained performance likely reflects positive heterosis effects, where complementary genetic traits from the two distinct brood stock populations enhanced growth efficiency and environmental adaptability (Falconer and Mackay, 2016; Ponzoni *et al.*, 2021).

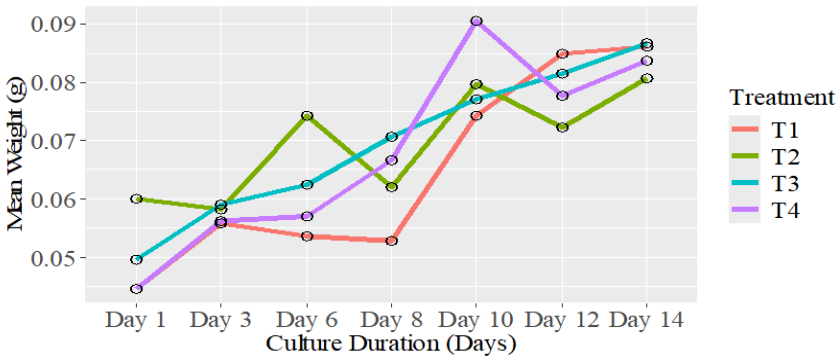



**Figure 1:** Growth progression of fry over two weeks under different treatments.

These findings support the strategic use of crossing between distinct brood stock populations as a practical approach to enhance fry growth and survival performance in catfish aquaculture. Specifically, the Farm B ♀ × Farm A ♂ cross (T4) emerges as a promising combination for hatchery operations in Makurdi, offering both genetic and economic advantages.

## CONCLUSION

Crossbreeding C*larias gariepinus* brood stock from different farms significantly influenced fry growth performance. T4 (Farm B ♀ × Farm A ♂) exhibited superior mean weight gain, SGR, and survival, making it the most effective treatment. T1 and T3 performed moderately, while T2 was the least effective. These results emphasize the benefits of targeted crossbreeding strategies for enhancing early fry development and overall aquaculture productivity in Makurdi.

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# INFLUENCE OF CULTURE WATER VOLUME ON THE WATER QUALITY DYNAMICS IN CULTURE TANKS OF AFRICAN CATFISH (*Clarias gariepinus*)

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**ABSTRACT**
*Aquaculture production is critically influenced by the availability and management of water resources. The efficiency of fish farming, particularly for species like Clarias gariepinus, relies heavily on maintaining optimal water quality, which is significantly affected by water volume. This study explores the impact of varying water volumes on water quality parameters and their subsequent effects on African catfish cultured. Four treatments with varying levels of cultured water (15, 20, 25, and 30 litres) were assessed for their influence on dissolved oxygen (DO), temperature, ammonia-nitrogen, pH, and alkalinity. The findings indicate that all water volumes maintained satisfactory levels for fish health, with no significant differences in the measured parameters across the treatments. The results demonstrate that varying water volumes within the studied range does not adversely impact water quality, thereby supporting the feasibility of using different volumes in catfish culture systems. However, monitoring and managing water quality remains essential for optimal fish growth and system efficiency. These insights contribute to sustainable aquaculture practices by highlighting the robustness of the culture system in maintaining stable water conditions.*

**Keywords:** Aquaculture, Water quality, *Clarias gariepinus*, Water volume, Sustainable management

## INTRODUCTION

Globally, in terms of quantity in the world's aquaculture production, catfishes are ranked 4th according to the top 10 freshwater aquaculture species (FAO, 2020). The African catfish (*Clarias gariepinus*) is one of the most cultivated catfishes in the world, and it is the most cultivated fish in Nigeria (Dauda *et al*., 2018). The progressive dominance of this species is due to its fast growth rate, high resistance to diseases, tolerance to environmental extremes and high consumer preference (Somerville *et al*., 2014 and Fregene *et al*., 2020).

Water quality is one of the most critical factors besides good feed/feeding in fish farming. It is not constant but varies with the time of the day, season of the year, water source, soil type, temperature, stocking density, feeding rate and culture systems (Davies and Ansa, 2007). Water quality determines not only how well fish will grow in an aquaculture operation, but also whether or not they will survive.

Adequate water quality is essential for the health and growth of African catfish, the optimization of culture water volume to maintain optimal water quality parameters remains a subject of investigation (Boyd, 2018). The volume of water in a catfish pond directly influences water quality parameters, impacting fish growth and survival. Sufficient water volume is crucial for maintaining adequate dissolved oxygen levels, preventing the build-up of harmful ammonia and other waste products, and maintaining a stable pH. Inadequate water volume can lead to decreased growth rates, increased susceptibility to diseases, and potentially fish kills.

Dauhan and Efendi (2014) stated that the water quality parameters in the cultivation media must be able to support the growth and wellbeing of the cultured fish. Balancing water quality is a technical skill in aquaculture, and monitoring water quality parameters can be the first step (Xu and Boyd, 2016).

Small water bodies have a smaller buffer capacity, making them more susceptible to rapid changes in water quality parameters. This can lead to more recurrent and severe fluctuations, raising the risk of stress and negative impacts on fish. Several studies have investigated the relationship between water

volume and fish health in aquaculture systems. For example, Adel *et al*. (2016) reported that higher water volumes in recirculating aquaculture systems improved water quality parameters and reduced stress indicators in Nile tilapia (*Oreochromis niloticus*). Similarly, Khatoona *et al*. (2018) found that increasing water volume positively influenced the growth performance and survival rate of Asian sea bass (*Lates calcarifer*). Researches on environmental factors in African catfish culture in controlled receptacles is still very limited, so there is a need to provide information about the dynamics of water quality during the culture of C*larias gariepinus* in different volumes of water. This study therefore aims to evaluate the influence of culture water volume on the dynamics of water quality during the culture of African catfish (C. *gariepinus*).

## MATERIALS AND METHOD

The experiment was carried out at the mini research laboratory of the Department of Fisheries and Aquaculture, Federal University Dutsin-Ma, Katsina State. The fish were reared in rectangular-shaped plastic tanks of 44 cm x 29 cm x 25 cm with capacity of 30L of water (Dauda *et al*., 2023) A complete randomized design (CRD) was used to set up the experiment using four treatments with 15L, 20L, 25L and 30L of water. A measuring tape was used to measure the distance from the tank bottom to the established water level and marked in order to maintain the water level. 120 pieces of African catfish (*Clarias gariepinus*) fingerlings of average weight of 1.5 g were used for the experiment and stocked at 10 fish per tank for the four (4) treatments. The fingerlings were fed twice a day at 5% body weight and weekly weight was taken to adjust the feed supplied. Physicochemical parameters like water temperature (°C) were measured using a mercury-in-glass thermometer, pH, dissolved oxygen (DO, mg/L), alkalinity (mg/L) and total ammonia nitrogen (mg/L) were measured using Fresh Innovative Multitec kits.

The data obtained were presented using (mean±SE), one-way analysis of variance (ANOVA) was used to compare each of the water quality parameters among the different volumes of water, and where there is a significant difference at $P<0.05$, Duncan multiple range test was used as a follow-up test to separate the means. A line graph was used to present the weekly dynamics of the water quality parameters, while Pearson correlation was used to examine the interdependence among the water quality parameters. All the analysis was carried out using Microsoft Excel and IBM SPSS version 27.

## RESULT AND DISCUSSION

As shown in Table 1, the water quality parameters were not significantly different ($P>0.05$) among the treatments. All the water quality parameters measured were within the recommended range for the culture of tropical fish species (Dauda and Akinwole, 2014; Sulem-Yong *et al*., 2023). This reflects that all the experimented stocking volumes were adequate for the growth of stocked fish.

**Table 1:** Water quality parameters (mean±SE) in African catfish culture tanks with different water volumes

| Parameters | T1 (15 litres) | T2 (20 litres) | T3 (25 litres) | T4 (30 litres) |
|---|---|---|---|---|
| Dissolved oxygen (mg/L) | 6.57±0.30 | 6.50±0.37 | 6.71±0.38 | 6.12±O.38 |
| Temperature (°C) | 29.22±O.19 | 29.19±0.13 | 29.30±0.21 | 29.37±0.21 |
| Ammonia-nitrogen (mg/L) | 0.84±0.07 | 0.87±0.08 | 0.84±0.07 | 0.87±0.06 |
| pH | 7.39±0.14 | 7.35±O.14 | 7.33±0.19 | 7.26±0.15 |
| Alkalinity (mg/L) | 25.19±1.72 | 24.44±1.63 | 23.70±1.52 | 24.07±1.53 |

Different letters as superscripts across the row indicate significant differences

The water quality dynamics showed variations across the weeks. The dissolved oxygen (DO) levels across all treatments (Figure 1) ranged from 6.12 mg/L to 6.71 mg/L, with T3 (25 litres) having the highest mean DO and T4 (30 litres) the lowest. Despite these variations, the differences were not statistically significant. Similar findings were reported by Avnimelech and Ritvo (2003), who found that DO levels tend to stabilize in well-managed aquaculture systems, even with varying water volumes. Additionally, Kumar *et al.* (2017) noted that DO levels above 5 mg/L are generally adequate for the optimal growth of African catfish, indicating that all treatments in this study provided sufficient oxygen for the fish. The water temperature (Figure 2) remained relatively consistent across all treatments, with a range of 29.19°C to 29.37°C. This temperature stability is crucial, as noted by Boyd (1998), who emphasized the importance of maintaining optimal temperature ranges (26°C to 30°C) for the growth and metabolic activities of African catfish. Ammonia-nitrogen concentrations (Figure 3) were similar across all treatments, ranging from 0.84 mg/L to 0.87 mg/L. These levels are within the acceptable range for African catfish culture, as excessive ammonia can be toxic. According to Ekubo and Abowei (2011), ammonia concentrations below 1 mg/L are generally safe for catfish, preventing ammonia toxicity. The results of this study are consistent with those of Hargreaves (1998), who found that well-managed aquaculture systems could maintain low ammonia levels, ensuring a healthy environment for fish.

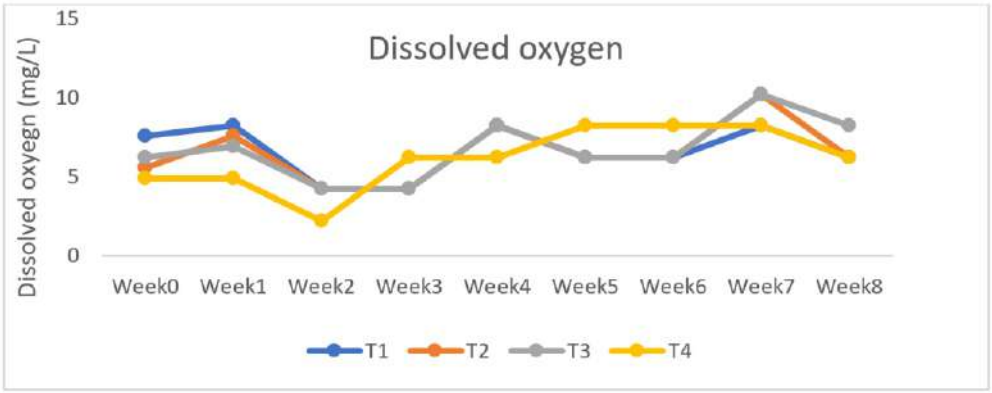



**Figure 1**: Weekly variations in dissolved oxygen in African catfish culture tanks with different water volumes

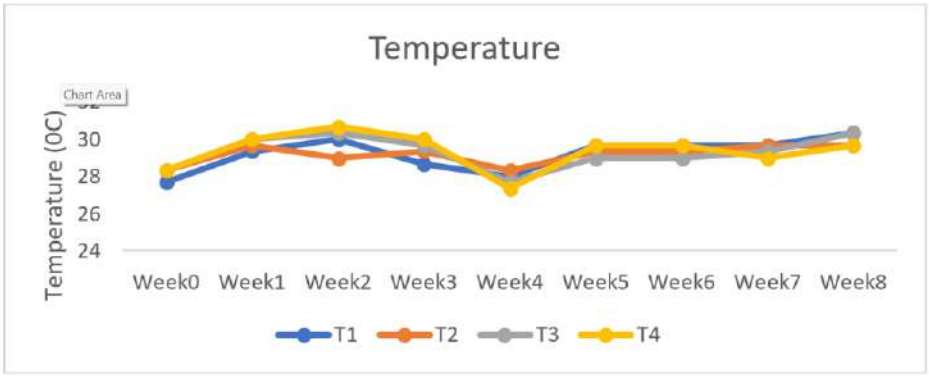



**Figure 2**: Weekly variations in Temperature in African catfish culture tanks with different water volumes

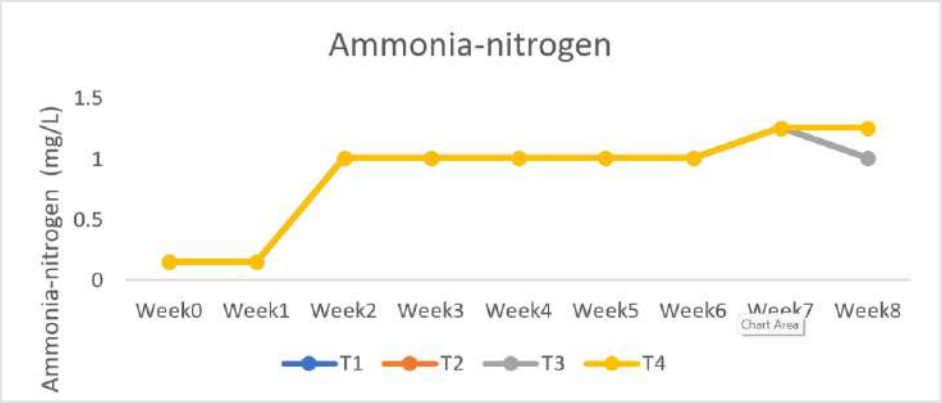



**Figure 3:** Weekly variations in Ammonia-nitrogen in African catfish culture tanks with different water volumes

The pH levels (Figure 4) ranged from 7.26 to 7.39 across all treatments, showing no significant differences. These pH values fall within the optimal range for African catfish culture, which is between 6.5 and 8.5, as noted by Dauda and Akinwole (2014). Maintaining a stable pH is critical for fish health and metabolic functions, and the results of this study align with the findings of Alabaster and Lloyd (2013), who demonstrated that stable pH levels is crucial for the well-being of aquaculture species. Alkalinity levels (Figure 5) varied slightly across the treatments, ranging from 23.70 mg/L to 25.19 mg/L. Although these differences were not significant, the levels observed are indicative of adequate buffering capacity in the water. According to Boyd and Tucker (1992), alkalinity levels between 20 mg/L and 200 mg/L are suitable for aquaculture, providing a stable environment for fish. This study's results are consistent with those of Chatvijitkul *et al.*, (2017), who found that maintaining appropriate alkalinity levels is essential for preventing pH fluctuations and ensuring optimal fish growth.

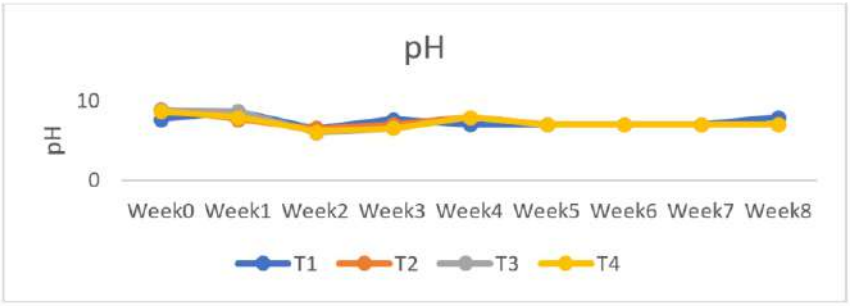



**Figure 4**: Weekly variations in pH in African catfish culture tanks with different water volume.

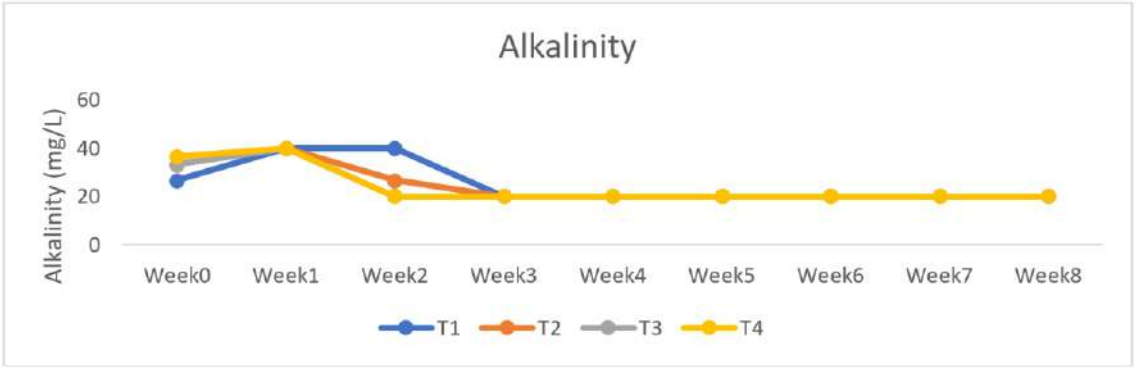



**Figure 5:** Weekly variations in Alkalinity in African catfish culture tanks with different water volumes

In this study, the correlation analysis (Table 2) only revealed a significant negative correlation between temperature and pH. Ammonia had a strong negative correlation with alkalinity. There was also a significant positive correlation between pH and alkalinity. The dissolved oxygen (DO) did not show significant correlations with temperature, ammonia, pH, or alkalinity. This suggests that DO levels in the culture tanks were maintained independently of these other water quality parameters. This finding is consistent with the work of Boyd and Tucker (1992), who noted that DO levels are often influenced more by aeration and water exchange practices than by other water quality parameters in well-managed aquaculture systems. Temperature showed a weak negative correlation with DO (-0.149mg/l) and a weak positive correlation with ammonia (0.186mg/l), though neither was statistically significant. The lack of significant correlation between temperature and DO aligns with previous studies, such as those by Lawson (2013), which highlight that temperature fluctuations within optimal ranges (26°C to 30°C) do not drastically affect DO levels in aquaculture systems. The weak positive correlation with ammonia could be indicative of increased metabolic activity and subsequent ammonia excretion at higher temperatures, as noted by Boyd (1998). Ammonia showed a negative but non-significant correlation with pH (-0.690) and a significant negative correlation with alkalinity (-0.767mg/l).

This significant negative correlation with alkalinity aligns with findings by Hargreaves (1998), who reported that higher alkalinity can buffer the water and reduce ammonia toxicity by converting it to less harmful forms. The negative correlation with pH, although not significant, is consistent with the observations of Ekubo and Abowei (2011), who noted that higher pH levels generally favour the ionized form of ammonia (NH4+), which is less toxic than the un-ionized form ($NH_3$). The study found a significant negative correlation between pH and temperature (-0.414mg/l) and a significant positive correlation with alkalinity (0.482mg/l). The negative correlation with temperature may reflect the tendency for higher temperatures to increase the metabolic rates and $CO_2$ production, which can lower pH levels, as observed by Ezenwa *et al.* (2006). The positive correlation with alkalinity supports the findings of Boyd (1998), who indicated that higher alkalinity levels provide a buffering capacity that stabilizes pH, thereby maintaining it within optimal ranges for fish health. Alkalinity had a significant positive correlation with pH (0.482mg/l) and a significant negative correlation with ammonia (-0.767mg/l). These correlations highlight the critical role of alkalinity in maintaining stable water chemistry. Boyd and Tucker (1992) emphasized that adequate alkalinity levels (20-200 mg/L) are essential for buffering capacity, which helps maintain stable pH levels and reduces the toxicity of ammonia. The interdependence among water quality parameters in African catfish culture tanks with different water volumes reveals critical insights into the complex dynamics within aquaculture systems. The significant correlations between pH, alkalinity, and ammonia emphasize the importance of maintaining balanced water chemistry to ensure the health and productivity of cultured fish. These findings are consistent with previous studies and reinforce the need for integrated water quality management practices in aquaculture (Dauda *et al.*, 2021)

**Table 2:** Interdependence among water quality parameters in African catfish culture tanks with different water volumes

| | D.O | Temperature | Ammonia | pH | Alkalinity |
|---|---|---|---|---|---|
| D.O | 1 | | | | |
| Temperature | -0.149 | 1 | | | |
| Ammonia | 0.109 | 0.186 | 1 | | |
| pH | O.169 | -0.414** | -0.690 | 1 | |
| Alkalinity | -0.093 | 0.052 | -0.767** | 0.482** | 1 |

**. *Correlation is significant at the 0.01 level (2-tailed).*

## CONCLUSION

The study concludes that the experimentally varied water volumes in the African catfish culture tanks have minimal impact on the key water quality parameters, including dissolved oxygen, temperature, ammonia-nitrogen, pH, and alkalinity. All measured parameters remained within acceptable ranges for optimal African catfish growth and health, indicating that the culture system used in this study effectively maintained stable water quality conditions. The significant correlations between certain parameters, such as pH and alkalinity, underscore the importance of integrated water quality management. Overall, the findings support the use of water volumes between 15L and 30L for the growth of African catfish fingerlings stocked up to 5g/L.

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# TECHNOLOGICAL INNOVATIONS IN FISHERIES AND AQUACULTURE – TIFA

# EFFECTS OF RABBIT DROPPINGS IN COMPARISON WITH UREA FERTILIZER ON THE GROWTH AND SURVIVAL OF AFRICAN CATFISH *Clarias gariepinus* JUVENILES

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**ABSTRACT**
*Evaluating the effects of organic and inorganic fertilization in plastic tank waters on the growth performance and survival of African catfish (Clarias gariepinus) juveniles is crucial in fish culture. Four rearing plastic tanks were prepared and filled with water, two plastic tank each were fertilized with rabbit droppings and urea fertilizer respectively and were allowed for two weeks to ensure algae growth. Forty (40) juveniles of C. gariepinus were obtained from a reputable farm in Makurdi and were taken to University of Agriculture Makurdi Research Farm and acclimatized for two weeks before stocking. Water Quality parameters were taken using combine multiparameter water test kit. Fish weight and morphometric parameters were measured by use of sensitive weighing scale and meter rule respectively. Result from this study revealed that fishes grown in plastic tank fertilized with inorganic fertilizer had a mean total length (cm) of 0.08±0.23, mean weight (g) 0.29±0.29, condition factor 0.57±0.07 and those grown in organic fertilizer had mean total length (cm) of 0.79±0.34, mean weight (g) 0.85±0.44 with condition factor of 0.62±0.08 at P-values of 0.10, 0.30 and 0.62 respectively. Water quality parameters of $p^H$, TDS, and Transparency shows significance at a p-value of 0.05, while the temperature was not significant (p>0.05). The study showed Rabbit droppings recorded better fish growth performance and survival than those cultured organic fertilizer (Urea).*

**Keywords**: *Clarias gariepinus*, Rabbit droppings, Urea, pH, and Temperature

## INTRODUCTION

Fertilizer is any material of either natural or synthetic origin that is applied to increase productivity (Bolonduro, 2013). In fisheries, fertilizers are used to increase pond productivity. The two major types of fertilizers in aquaculture are organic and inorganic fertilizers. Organic fertilizers are wastes from plant and animal origin, whereas inorganic fertilizers are synthetic products of agriculture, applying fertilizers in fish ponds stimulates the productivity of organisms that may serve as the first foods for many species of fish and increase fry survival and growth (Ludwig *et al.*, 1998). Urea is one of the most widely used chemical fertilizers in the world. It contains about 42-47% Nitrogen released for productivity of pond water in aquaculture (Bolonduro, 2013). excessive nitrogen fertilization was not recommended as it may lead to waste in resources without improving fish yield (Veverical *et al.*, 2001). Pond/tanks with fertilized water will turn a rich green or reddish color when the plankton becomes abundant as food will be available for fish (Mosha *et al.*, 2016). In aquaculture, fertilizers have been used in various forms and quantities to enhance fish production for greater abundance of fish pond organisms, but excessive use of fertilizers in fish ponds have been shown to have adverse effects on water quality and also cause damage of some tissues in fish (Chapman, 2000).

(Chouhan and Pandey 1987: Palanivelu *et al.* (2005) Urea is the richest source of nitrogen among the common dry fertilizers. According to Jones *et al.* (2012) Rabbit droppings as an organic fertilizer that contains high percentage of nitrogen ($N_2$) contributes highly in boosting zooplankton productivity in fish

pond waters which serve as food to fish. (Richard *et a*l., 2017) report that Rabbit droppings can positively impact the growth performance of C*larias gariepinus* (African catfish) when used as a fertilizer in fish ponds. Zooplankton serves as a natural food source for C*larias* gariepinus, especially during early stage of their development. Tabora *et a*l (2013). Studies have shown that incorporating rabbit manure in fish ponds can lead to improved growth rates and overall performance of Clarias *gariepinus*. On the other hand, urea is a synthetic fertilizer that, when applied to fish pond, productivity of phytoplankton in pond water bodies, which also serves as food to fish. The Clariid catfishes are of great importance as food and vital in the sustainability of the aquaculture (Fagburo *et al.*, 2015). Catfish, especially C*larias gariepinus* aquacultural attributes include: ability to withstand handling stress, disease resistance, high growth rate, yield potential, fecundity and palatability. C. gariepinus is one of the most readily acceptable species of Clarias in Nigeria because they grow to large sizes hence the need to assess their abundance (Fagburo *et al*., 2015). The study determines the growth performance and survival of C*larias gariepinus* juvenile cultured in ponds fertilized with rabbit droppings and urea.

## MATERIALS AND METHODS

### Study Area

The experiment was carried out at the Joseph Sarwua Tarka University Makurdi
Research Fish Farm. The University is geographically located between Latitude 7°73"N – 10°5"N and Longitude 8°"E53 – 13°5"E, which has a catchment area of approximately 32,900 Km2.

### Experimental design

A total of 40 C*larias gariepinus* juveniles (average weight, 17.21±0.12g) were obtained from Joseph Sarwua Tarka University Makurdi Research fish farm were acclimatized for 14 days Ajani *et al*., (2020). After acclimatization, the fish were randomly selected, weighed and distributed into 4 plastic tanks. (45x40x30) $cm^3$following a completely randomized system with 4 per tank.
Pond I; fertilized with Rabbit droppings as Treatment 1 (Tt.1).
Pond II; fertilized with Rabbit droppings as Treatment 1, Replicate 1 (Tt.1Rp.1).
Pond III; fertilized with Urea as Treatment 2 (Tt.2).
Pond IV; fertilized with Urea as Treatment 2, Replicate 1 (Tt.2Rp.1).

### Water quality Analysis

Water parameter such as $P^H$, TDS, Transparency and Temperature. $P^H$ was determined using an API freshwater master test kit. Temperature and TDS were determined using water quality measurement meter. Temperature and $P^H$ were maintained at optimum level of 28.65±0.25°C and 7.13±0.12 respectively. The water parameters were within the ranged recommended by Boyd (1990). To keep the water at this optimal level in term of quality and quantity, continuous aeration was added every day. The plastic tanks were allowed for a period of 15days to boost productivity, after which water sample were collected from each of the treatments and transparency (secchi-disc visibility), pH, temperature and total dissolve solids (TDS) were checked at the Fisheries Department Laboratory, Joseph Sarwua Tarka University Makurdi before stocking the fish. This was done regularly at intervals of 2weeks.

### Juveniles survival and growth

The monitoring of growth of C. *gariepinus* was carried out every three days on five juveniles from each replicate tank' respectively. The biomass of individuals was taken waterless with a scale (sensitivity 0.01 mg). Dead specimens were counted daily in each plastic tank to evaluate larvae survival. Recorded data were used to determine the following zootechnical parameters: Mean weight gain (MWG = (final biomass - initial biomass) / rearing duration); Specific Growth Rate (SGR = [ln (final mean weight)-ln (initial mean weight) / rearing duration)] x 100; Survival Rate (SR = final fish number / initial fish number) x 100 and Production Index (mg/j) (PI = Survival Rate x [final weight – initial weight / rearing

duration)] (Zakaria and Kakati, 2002).

**Statistical Analysis**
Data recorded were analyzed with STATISTICA software (Statsoft inc., Tulsa, OK). Different means were compared by using a one-way analysis of variance (ANOVA). All significant levels were fixed at $p < 0.05$. In case of need, significance of differences among means was tested using the test LSD of Fisher.

## RESULTS AND DISCUSSION

Result from this study shows that fishes (C*larias gariepinus* grown in pond fertilized with inorganic fertilizer had a mean total length (cm) of 0.38±0.23, mean weight (g) 0.29±0.29, condition factor 0.57±0.07 and those grown in organic fertilizer had mean total length (cm) of 0.79±0.34, mean weight (g) 0.85±0.44 with condition factor of 0.62±0.08 at P-values of 0.10, 0.30 and 0.62 respectively. Results on fish (growth and survival) were in the same range as other reported growth for catfish from fertilized ponds with rabbit dropping in China, Bangladesh and India (Quazi and Huque, 1991). This shows that fishes that were raised in plastic tank culture with inorganic fertilizer performed relatively better than those grown in ponds fertilized with inorganic fertilizers, as shown in the numerical values of the result. The C*larias gariepinus* shows average mean weight increased significantly in all treatments, moving from about 0.63±0.83 to 0.66±0.48g in Table 3. The average daily weight gain (DWG g day-$^{1}$) and the specific rate (SGR % day-$^{1}$d) were statistically different between Table 2 and Table 3. C*larias gariepinus* juveniles in T1with rabbit dropping gain 0.39g to 0.45g and 0.21±0.0.40g to 0.31±0.38 and SGR (%day-$^{1}$) of Urea fertilizer 1.30±0.22 to 0.74±0.24. These observations support the findings that none of the four treatments with urea fertilizer in this study have reached a high level of plankton production. Result from Table 1 shows variation in water quality parameters taken in plastic tank fertilized with inorganic fertilizer during the experiment which include mean temperature (°C) 27±0.31, pH 8.84±0.13, TDS (ppm) 89.13±5.11, Transparency (cm) 22.13±1.23 and that of organic fertilizer include Temperature (°C) 26.62±0.37, pH 9.23±0.09, TDS (ppm) 67.69±5.96, Transparency (cm) 15.48±1.23 at P-values of 0.40, 0.03*, 0.01* and <0.01* respectively.

There were significant differences recorded among treatments for all these physico-chemical parameters, this was contrary to the findings of Richard *et al.*, *(*2017) who recorded low mean temperatures (±22°C) and showed a fluctuation from 20.0°C to 25.3°C in rabbit dropping. This result indicates that of all the water quality parameters tested throughout the study, pH, TDS and transparency were statistically significant at P-value of 0.05% while temperature was not statistically significant at 0.05%. This shows that all the water quality parameters tested during the study period were almost fluctuating at the same rate but higher in pond fertilized with inorganic fertilizers which is observe to slow down fish growth while pond fertilized with organic fertilizer has less fluctuations and was observed to trigger fish growth which agrees with the findings of Mmochi *et al.*, 2002, Tepe and Boyd, 2002.

**Table1.** Physico-chemical Parameters of the water

| Parameter | Type of Fertilizer | | df | T-Value | P-Value |
|---|---|---|---|---|---|
| | Inorganic | Organic | | | |
| Temperature (°C) | 27.03±0.31 | 26.62±0.37 | 29 | 0.85 | 0.40 |
| pH | 8.84±0.13 | 9.23±0.09 | 26 | 2.24 | 0.03* |
| Total Dissolved Solids (ppm) | 89.13±5.11 | 67.69±5.96 | 29 | 2.73 | 0.01* |
| Transparency (cm) | 22.13±1.23 | 15.48±0.75 | 24 | 4.60 | <0.01* |

**indicates statistical significance at 0.05%*

**Table 2**: Specific Growth Rate (SGR %.day-1), Daily Weight Gain (DWG g.day-1) and Survival Rate (SR %) of juveniles Clarias gariepinus from rabbit dropping Treatment.

| Treatments | Mean weight | SGR (%.day-1) | DWG (g.day-1) | SR (%) |
|---|---|---|---|---|
| T1 | 4.63 ± 0.83 a | 1.5 ± 0.03 a | 0.39 ± 0.42 a | 1.00 ± 0.00 a |
| T2 | 4.22 ± 0.346b | 0.4 ± 0.05b | 0.47 ± 0.46b | 05.8 ± 7.21 a |
| T3 | 4.00±03.50b | 0.6±0.06 | 0.44±0.44b | 05.8±7.72a |
| T4 | 4.66 ± 06.48b | 0.7 ± 0.03b | 0.43± 0.22c | 05.8 ± 7.22 a |
| LSD (5% level) | 0.3.33** | 0.021* | 0.031** | NS P=0.45 >0.05 |

**Table 3:** Specific Growth Rate (SGR % day-1), Daily Weight Gain (DWG g day-1) and Survival Rate (SR %) of Juvniles Clarias gariepinus from Urea Fertilizer Treatment

| Treatment | Mean weight | SGR (%day-1) | DWG (g dat-1) | SR (%) |
|---|---|---|---|---|
| T1 | 0.27±0.45a | 1.30±0.22 | 0.21±0.40a | 0.40±0.10a |
| T2 | 0.27±0.44b | 0.80±0.29 | 0.34±0.44b | 0.44±0.22a |
| T3 | 0.27±0.39 | 0.75±0.26 | 0.34±0.40 | 0.42±0.20a |
| T4 | 0.20±0.36 | 0.74±0.24 | 0.31±0.38 | 0.40±0.38a |
| LSD (5% Level) | 0.330** | 0.180* | 0.027** | NSP= 0.40 >0.05 |

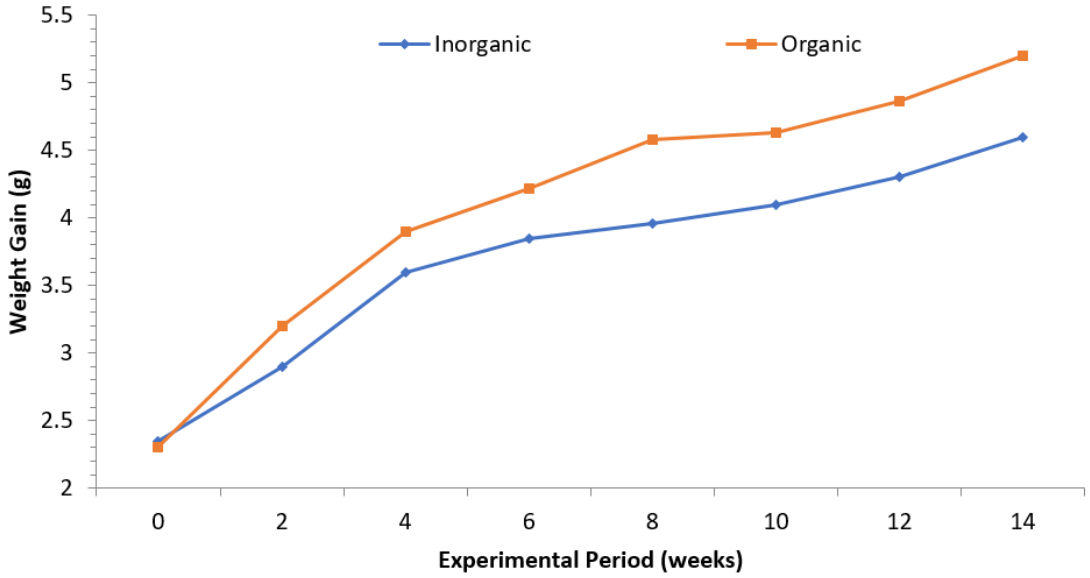



**Figure 5:** Weight Gain for samples from rabbit dropping and Urea Fertilizer

## CONCLUSION

In conclusion, rabbit droppings can be a valuable tool for enhancing Clarias gariepinus juveniles' growth in aquaculture systems by supporting natural food chains and providing essential nutrients. Variation in water quality parameters taken in pond fertilized with inorganic fertilizer during the experiment indicates that, of all the water quality parameters tested throughout the study, pH, TDS and transparency were statistically significant at P-value of 0.05 while temperature was not statistically significant. This shows that all the water quality parameters tested during the study period were almost fluctuating at the same rate but higher in pond fertilized with inorganic fertilizers.

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# THE EFFICACY OF NATURAL GROWTH PROMOTER CARROT (*DAUCUS CAROTA*) ON THE GROWTH AND SURVIVAL OF AFRICAN CATFISH (*Clarias gariepinus*, BURCHELL 1822) IN SAHEL-SAVANNA REGION, NIGERIA

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**ABSTRACT**

*One of the factors leading to poor production of fish in developing countries including Nigeria is inadequate of quality feed that can promote high productivity. Growth promoters of biological origin have been used but their serious effect on public health warranted their banned. Therefore, this study the efficacy of natural growth promoter carrot (Daucus carota) on the growth and survival of African catfish (Clarias gariepinus, Burchell 1822) in Sahel-Savanna region, Nigeria focus on searching alternative growth promoters from natural occurring raw materials. One of such growth promoters that has not been given scientific attention is carrot. Carrot (Daucus carota) is grown in large quantity in Gashua of Yobe State and its environments. Large quantity was obtained and processed into powder form and was incorporated into five (5) dietary treatment (T1, T2, T3, T4 and T5) by 0%, 0.25%, 0.50%, 0.75% and 1.0% respectively. Three hundred (300) fingerlings were randomly selected and divided into five treatments with each treatment having 60 fingerlings, that is, 20 fingerlings per replication and was replicated three times. They were fed three times daily under good management. The fish were fed for the period of 6 weeks (42 days). At the end of the culture period, the following growth indices were estimated and calculated. Final body weight, weight gain, specific growth rate, feed conversion ratio, and mortality rate. The result revealed that the fish fed T4 (0.75% boiled carrot) had the highest body weight, weight gain, lowest feed intake, best FCR while fish fed with 1.0% of the boiled carrot (T5) shows lower values. However, there was no significant difference (P > 0.05) in term of mortality. It can be concluded that boiled carrot as a growth promoter at 0.75% promoted weight gain, improved feed utilization. Therefore, it is recommended as a growth promoter in African catfish (Clarias gariepinus).*

**Key words:** efficacy, Carrot, African catfish, growth promoter, fingerlings.

## INTRODUCTION

Fish and fish products are known worldwide as very important diet to humans because of their high nutrient quality and significance in improving human health (Amao *et al*., 2006). Fish is a high-protein, low-fat food that provides a range of health benefits. Fish is lower in fat than any other source of animal protein and oily, fish are high in omega-3-fatty acids commonly called "the good fats". Since the human body cannot make significant amount of these essential nutrients, fish consumption becomes an important part of the human diet (Uchechukwu *et al*., 2014). However, in Nigeria the production of catfish looks relatively low compared with the growing population. Fish belonging to the family Claridae are the most commonly cultivated fishes (Adewumi and Oluleye, 2011).

The African catfish (*Clarias gariepinus*), also known as the mud catfish (Dauda *et al*., 2018), is a good candidate species for culture to boost fish production for both domestic and global markets, which will improve human nutrition and food security in Africa (Fregene *et al*., 2021). The hardy nature of catfish in

terms of its use of supplementary feeds, high tolerance to water stress, and high market acceptance makes it a suitable candidate for culture promotion in Africa as noted by (Dauda *et al.*, 2018). The rearing of C*larias gariepinus* started in the early 70s in central and western African countries. It received wide acceptance when it was realized to be a very suitable species for aquaculture and of high economic value. It has since been the most widely cultured fish in Nigeria and even in Africa (Adewunmi and Olaleye, 2001).

Carrot *(Daucus carota)* is a biennial plant. In the first year, its rosette of leaves produces large amounts of sugars, which are stored in the taproot to provide energy for the plant to flower in the second year. Soon after germination, carrot seedlings show a distinct demarcation between taproot and stem: the stem is thicker and lacks lateral roots. At the upper end of the stem is the seed leaf. The first true leaf appears about 10–15 days after germination. Subsequent leaves are alternate (with a single leaf attached to a node), spirally arranged, and pinnately compound, with leaf bases sheathing the stem. As the plant grows, the bases of the seed leaves, near the taproot, are pushed apart. The stem, located just above the ground, is compressed and the internodes are not distinct (Wesley, 2012). Taproots are typically long and conical, although cylindrical and nearly-spherical cultivars are available. The root diameter can range from 1 cm (3⁄8 in) to as much as 10 cm (4 in) at the widest part. The root length ranges from 5 to 50 cm (2 to 20 in), although most are between 10 and 25 cm (4 and 10 in) (Rubatsky *et al.*, 1999).

Growth promoters are a kind of feed additives that are principally chemical and/or biological substances added to fish feed with the aim of improving fish growth (Dada, 2012). In intensive and semi-intensive aquaculture systems, growth promoters have become an essential part of fish diet in improving food conversion ratio (FCR), significant reduction in mortality, enhancing digestion of fish etc. The use of such feed additive has been proven to be successful in aquaculture (Ajiboye *et al.*, 2012). It is necessary for fattening fishes and improving the utilization of food to obtain better production and financial results.

According to (Benjamin *et al.*, 1997) the carrot (Daucus carota subsp. sativus) is a root vegetable, typically orange in color, though purple, black, red, white, and yellow cultivars exist, all of which are domesticated forms of the wild carrot, Daucus carota, native to Europe and Southwestern Asia. The plant probably originated in Persia and was originally cultivated for its leaves and seeds. The most commonly eaten part of the plant is the taproot, although the stems and leaves are also eaten. The domestic carrot has been selectively bred for it's enlarged, more palatable, less woody-textured taproot. (Benjamin *et al.* 1997) described the carrot is a biennial plant in the umbelliferon family, Apiaceous. At first, it grows a rosette of leaves while building up the enlarged taproot. Fast-growing cultivars mature within three months (90 days) of sowing the seed, while slower-maturing cultivars need a month longer (120 days). The roots contain high quantities of alpha- and beta-carotene, and are a good source of vitamin A, vitamin K, and vitamin B6. The United Nations Food and Agriculture Organization (FAO) reports that world production of carrots and turnips (these plants are combined by the FAO) for 2020 was 41 million tons, with over 44% of the world total grown in China. Carrots are commonly consumed raw or cooked in various cuisines.

In recent time artificially growth promoter has caused public health challenges and has been banned in many countries of the world (FAO, 2010). However, the challenge of poor growth of fish is daring particularly in developing countries including Nigeria and owning to the high demand of fish and fish products there is a need to search for natural growth promoters which many scientists (Prasad and Mukthiraj, 2011; Cho and Lee, 2012) recommended. One of these natural growth promoters is carrot. Carrot is largely produced in Yobe state and is readily available at all times. Carrots are rich in nutrients and have many health advantages. It has high contents of carotenoids, phenolic compounds, polyacetylenes, and vitamins, and help decrease risk of some illnesses (Zaini *et al.*, 2012). But there is a

paucity of information on the use of boiled carrot as growth promoter. The objectives of this study are the efficacy of using carrot as growth promoter in African catfish C*larias gariepinus*. The optimum inclusion rate of carrot as growth promoter in African catfish C. *gariepinus*. The feed conversion rate of African catfish C. *gariepinus* fed diets containing carrot as growth promoter. The survival rate of fish African catfish C. *gariepinus* fed diets containing carrot as growth promoter. The cost implication of using carrot as growth promoter in African catfish C*larias gariepinus*. Significantly, this study provided a local available and cheap natural growth promoter (boiled carrot) for C. *gariepinus* production.

## MATERIAL AND METHODS

### Study area

This research was conducted at Teaching and Research Farms of the Department of Fisheries and Aquaculture, Faculty of Agriculture, Federal University Gashua, Yobe state Nigeria. It lies on Latitude 12°,52.547/12.8758°N and Longitude 11.0120°/11°00.719E. It is also found within the Sahel Savanna zone of Nigeria with a characteristic of high environmental temperature, low rainfall and low relative humidity (Ovimaps, 2014).

### Collection and Processing of carrot

A required quantity of fresh carrot was purchased in Gashua market of Bade Local Government Area, Yobe State, Nigeria. It was peeled, cut into pieces, heated to a boiling point. Thereafter it was sieved to remove the boiled water and it was then crushed using mortar and pestle. It was allowed to dry in the sun for 3 days. A sample of the crushed boiled carrot was taken to the biological laboratory Yobe State University, Damaturu for proximate analysis. The result of the proximate analysis is shown below in Table 1.

**Table 1:** Proximate composition of boiled carrot

| Parameters | Sample 1 | Sample 2 | Sample 3 | Mean | SD |
|---|---|---|---|---|---|
| Moisture | 4.48 | 4.61 | 4.68 | 4.59 | 0.10 |
| Total Ash | 3.93 | 4.01 | 4.00 | 3.98 | 0.04 |
| Crude Fibre | 4.52 | 4.61 | 4.60 | 4.58 | 0.05 |
| Ether Extract | 16.45 | 16.81 | 17.00 | 16.75 | 0.28 |
| Crude Protein | 26.31 | 26.52 | 26.50 | 26.44 | 0.12 |
| Nitrogen Free Extract | 44.31 | 43.43 | 43.22 | 43.65 | 0.58 |

### Experimental diet

The ingredients used to formulate the experimental diets were fish meal, soybean meal, groundnut cake, yellow maize, palm oil, vitamin-premix, binder (starch), sodium chloride and carrot which were all purchased from Gashua town of Yobe State, Nigeria. The feed ingredients were weighed out following the combinations as shown in Table 2. The diet (T1, T2, T3, T4 and T5) were formulated following the nutrient specification of catfish fingerling. The processed carrot was incorporated into the diet as growth promoter by 0%, 0.25%, 0.5%, 0.75% and 1.0% respectively. The 0% diet served as control. The level of inclusion of carrot as growth promoter was adopted following the level used by Abdel-Hakim (2014). The feed ingredients were weighed out following the combinations in Table 1 and each sample was separately prepared by first mixing the dry feed ingredients together, and then separately mixing the wet ingredients (2g molasses, 5g red palm oil, 1g sodium chloride and 1g micro nutrients premix) before combining and mixing all the ingredients together. After mixing, hot water (5%) weight of the feed was added to the mixture to form dough. The dough was extruded into feed sizes (2mm) using a locally fabricated extruder.

**Proximate Analysis of the formulated feed**

The proximate parameters were analysed using the Official Methods of Analysis of the Association of Analytical Chemists (AOAC, 2005). The carbohydrate content of the samples was obtained as the difference between the total summations of percentage moisture, fat, fibre, protein, ash and 100 % Carbohydrate 100 - (% moisture + % fat + % protein + % fibre + % ash). The result of the proximate composition of experimental diet is indicated in table 3 below.

**Experimental design**

Three hundred (300) *Clarias gariepinus* fingerlings with an average weight and length of 5g and 30mm were used for the experiment. The fish were grouped into five (5) treatments with each treatment having sixty (60) fingerlings. That is 20 fingerlings per replication. The fingerlings were reared for six (6) weeks in 25 litre capacity plastic basin. The fish were fed with the experiment diet according to the percentage carrot incorporation 0%, 0.25%, 0.5%, 0.75% and 1.0% which served as T1, T2, T3, T4 and T5 respectively. At the end of the culture period growth indices such as final weight, weight gain, daily weight gain, specific growth rate, feed conversation ratio, condition factor and survival rate were estimated and calculated. The experiment was conducted under complete randomize design manner (CRD)

**Feeding and Management**

The fish were fed two times daily (8am in the morning and 5pm in the afternoon). Broadcasting method of feeding was used to feed the fish. At every feeding, the fish were fed to satiation and caution was taken not to administer excess feed as this could lead to pollution of the pond which possibly could depletes the dissolved oxygen level of the pond and also wastage of the feed. The pond water was changed every two days or earlier if the pond water became too cloudy. Dirty pond water might lead to suffocation of the fishes and possibly death of the fish. The tempera ture, ph and Dissolved oxygen were determined using thermometer, ph meter and D.O meter respectively.

**Data analysis**

The statistical program used to analyze data generated was SPSS (IBM, version 25, Chicago, USA). The data were subjected to one-way analysis of variance (ANOVA). Where variation was observed in means it was separated using Duncan's multiple range test (DMRT) and significant results were declared at $P<0.05$.**Results**

**Feed consumption**

Table 1 shows the feed consumption rate of fish fed experimental diets. There was a significant difference ($p<0.05$) by treatment. The feed consumption rate fluctuates across the weeks with increased level carrot. It progressively decreased from T1-T4 and increased at T5. Treatment 1 had the highest feed consumption rate while T4 had the lowest. Similarly, the total feed intake and daily feed intake were highest in T1 and lowest in T4.

**Table 2:** Feed consumption rate of fish fed experimental diets

| Parameters | T1 | T2 | T3 | T4 | T5 | ±SEM |
|---|---|---|---|---|---|---|
| Week1 | 22.88 | 21.10 | 19.76 | 18.72 | 19.58 | 1.62 |
| Week2 | 43.92 | 37.10 | 38.48 | 33.74 | 35.57 | 3.87 |
| Week3 | 81.72 | 69.20 | 72.20 | 63.86 | 67.54 | 6.75 |
| Week4 | 138.60 | 117.40 | 96.98 | 108.93 | 115.42 | 15.20 |
| Week5 | 233.28 | 197.70 | 185.39 | 184.11 | 195.34 | 19.98 |
| Week6 | 346.80 | 294.10 | 308.37 | 274.39 | 291.17 | 27.32 |
| Total feed intake | 867.20 | 736.60 | 721.17 | 683.76 | 724.61 | 70.22 |
| Daily feed intake | 20.65 | 17.54 | 17.17 | 16.28 | 17.25 | 1.67 |

**Growth performance**

Table 2 shows the weights of fish fed experimental diets. There was also significant different ($p<0.05$) across the weeks. It also fluctuates with increased level of carrot. Live weight increased from T1-T4 and decreased at T5. Also, the total live weight and daily weight gain were highest in T4 and lowest in T1.

**Table 3:** Weights of fish fed experimental diets

| Parameters | T1 | T2 | T3 | T4 | T5 | ±SEM |
|---|---|---|---|---|---|---|
| Week1 | 8.57 | 8.76 | 10.16 | 12.21 | 8.43 | 1.60 |
| Week2 | 25.26 | 25.70 | 28.42 | 32.51 | 23.80 | 3.44 |
| Week3 | 50.48 | 51.38 | 56.81 | 65.02 | 53.20 | 5.91 |
| Week4 | 88.37 | 89.94 | 99.43 | 113.79 | 86.80 | 11.26 |
| Week5 | 151.48 | 154.17 | 170.44 | 181.08 | 156.80 | 12.56 |
| Week6 | 227.22 | 231.25 | 255.67 | 266.00 | 252.00 | 16.57 |
| Total live weight (g) | 551.38 | 561.20 | 620.93 | 670.60 | 581.03 | 49.01 |
| Daily weight gain (g) | 13.13 | 13.36 | 14.78 | 15.97 | 13.83 | 1.17 |

**Feed conversion ratio**

Table 4.3 shows the feed conversion ratio of fish fed experiment diets. There was also significant different ($p<0.05$) by treatment across the weeks. This result also occurs in a fluctuating pattern. Feed conversion ratio improved from 0% to 0.75% of boiled carrot in the diets. The higher value beyond at 1.0% boiled carrot further depicts the limit of inclusion of boiled carrot at 0.75%. The efficiency of feed utilization improves with increased of carrot in the diets as growth promoter.

**Table 4:** Feed conversion ratio of fish fed experimental diets

| Parameters | T1 | T2 | T3 | T4 | T5 | ±SEM |
|---|---|---|---|---|---|---|
| Week1 | 2.67 | 2.41 | 1.94 | 1.53 | 2.32 | 0.44 |
| Week2 | 1.74 | 1.44 | 1.35 | 1.04 | 1.49 | 0.25 |
| Week3 | 1.62 | 1.35 | 1.27 | 0.98 | 1.27 | 0.23 |
| Week4 | 1.57 | 1.31 | 0.98 | 0.96 | 1.33 | 0.26 |
| Week5 | 1.54 | 1.28 | 1.09 | 1.02 | 1.25 | 0.20 |
| Week6 | 1.53 | 1.27 | 1.21 | 1.03 | 1.16 | 0.18 |
| Daily feed conversion ratio | 0.25 | 0.22 | 0.19 | 0.16 | 0.21 | 0.04 |

**Mortality and survivability rate**

Table 4.4 shows the survivability and mortality rates of fish fed experimental diets. There was no significant different ($p>0.05$) with increased of carrot in the diets. However, the number of fish died in T1 and T5 were the highest followed by those on T2 and T4 while those on T3 had lowest number.

**Table 5:** Mortality rate of fish fed experimental diets

| Parameters | T1 | T2 | T3 | T4 | T5 | ±SEM | LOS |
|---|---|---|---|---|---|---|---|
| Number stocked | 50 | 50 | 50 | 50 | 50 | 0.00 | NS |
| Week1 | 1 | 2 | 1 | 1 | 2 | 0.55 | NS |
| Week2 | 0 | 0 | 0 | 0 | 0 | 0.00 | NS |
| Week3 | 0 | 1 | 0 | 1 | 0 | 0.55 | NS |
| Week4 | 1 | 0 | 0 | 0 | 1 | 0.55 | NS |
| Week5 | 1 | 0 | 0 | 0 | 1 | 0.55 | NS |
| Week6 | 1 | 0 | 0 | 0 | 0 | 0.45 | NS |
| Number survived | 46 | 47 | 49 | 48 | 46 | 1.30 | NS |
| Number died | 4 | 3 | 1 | 2 | 4 | 1.30 | NS |
| % survivability | 92 | 94 | 98 | 96 | 92 | 2.61 | NS |
| % mortality | 8 | 6 | 2 | 4 | 8 | 2.61 | NS |

## DISCUSSION

The significant highest feed intake by the fish fed T1 (0% boiled carrot) and the lowest by those fed T4 indicates that the inclusion of boiled carrot as growth promoter reduced feed consumption at 0.75%. The increased in feed consumption at 1.0% indicates that for economic of feed consumption, boiled carrot be added in fish diet at 0.75%. The introduction of boiled carrot as growth promoter is a good development in the right direction and is collaborated the report of Limbu (2020) that the culture of African catfish (*Clarias gariepinus*) in most developing countries lacks suitable diets for semi-intensive production and sustainability.

The lower feed intake obtained at 0.75% agrees the efficiency of feed utilization improves with increased of carrot in the diets as growth promoter. Growth performance and feed conversion ratio were significantly ($P< 0.05$) improved with natural growth promoter and reported by Abdel-Hakim *et al*. (2014). The significant progressive increased in live body weight in the fish from T1 to T4 and a decreased in T5 shows that inclusion of boiled carrot as growth promoter was effective at from 0.5-0.75%. Indicating that the optimum inclusion is at .75% and beyond 0.75% it will have deleterious effect on growth performance.

The excellent growth performance and the reduced feed consumption of the fish demonstrated that inclusion of boiled carrot at 0.75% influences lower input and higher output. This study confirms the report of Shoko *et al*. (2016) that incorporation of natural growth promoter fosters fast growth in African catfish. Growth performance and feed conversion ratio were significantly ($P< 0.05$) improved which agrees with Abdel-Hakim *et al*. (2014) who reported similar results natural growth promoters' influences growth rate.

The feed conversion ratio observed in this study followed similar trend with the results of feed consumption and growth performance. It improved from 0% -0.75% and declined by 1.0%. The fish fed 0.75% boiled carrot had the best while their counterparts that were fed with 1.0% boiled carrot had the worst feed conversion ratio. The higher value beyond at 1.0% boiled carrot further depicts the limit of inclusion of boiled carrot at 0.75%. The insignificant difference in mortality and survivability rate observed in this study demonstrated that boiled carrot is generally not harmful to fish, but for economic of production it should be included from 0.25% to 0.75%. However, the mortality recorded may not be due to the test ingredients but rather due to environmental or other unknown factors. The survival rate, feed conversion ratio and protein efficiency ratio of fish did not differ among the diets (Limbu, 2020).

## CONCLUSION

The results in this study revealed that using boiled carrot at a dietary level of 0.75 % influenced high

growth performance and better feed utilization. It did not have significant effect on mortality, therefore, it can be concluded that boiled carrot do not have deleterious effect on African catfish.

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# EFFECT OF AQUEOUS CLOVE (*Eugenia aromaticum*) SEED EXTRACT ON SEDATION OF *Clarias gariepinus* (BURCHELL 1822) JUVENILES

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**ABSTRACT**

*The anaesthetic effects of aqueous clove (Eugenia aromaticum) seed extract on Clarias gariepinus juveniles were evaluated at concentrations of 150, 200, 250, 300, and 350 mg/L. A total of 300 juveniles, averaging 8.7–9.3 cm in length and 46.4–57 g in weight, were randomly assigned to five treatment groups, each replicated thrice with 10 fish per replicate. Anaesthesia induction and recovery times were recorded using a digital stopwatch, with induction categorized by three phases: partial loss of equilibrium, cessation of swimming and reflexes, and complete loss of muscle control. The shortest mean induction time (5.6 minutes) was observed at 350 mg/L, while the longest (14 minutes) occurred at 150 mg/L. Induction time decreased significantly as extract concentration increased. Recovery time was shortest at the lowest concentrations (150, 200, and 250 mg/L), occurring within 21 to 38 seconds, whereas longer recovery durations were observed at 300 and 350 mg/L (up to 11.4 minutes). No statistically significant differences ($p > 0.05$) were found in recovery times across treatments. Mortality was absent in fish exposed to 150, 200, and 300 mg/L concentrations, with normal recovery observed. These findings suggest that aqueous clove seed extract is an effective and safe anaesthetic agent for juvenile Clarias gariepinus.*

**Keywords:** Fish, clove seed extract, anaesthesia, induction time, recovery, survival rate

## INTRODUCTION

*Clarias gariepinus* is a freshwater fish species that is easy to cultivate and can be maintained with a high stocking density (Mukhammad *et al*., 2021). *Clariasgariepinus* can be cultivated in marginal areas and is water efficient, rich in nutritional content, the amount of protein reached 20% (Omitogun *et al*., 2012). The advantage of C. *gariepinus* seeds is the high growth performance maintenance from juvenile until harvest can be achieved within 4-5 months (Gunda *et al*., 2004).

*Clarias gariepinus* (Burchell, 1822) belong to the family Clariidae is generally considered to be one of the most important tropical catfish species for aquaculture in West Africa (Nigeria, Ghana, Niger etc). The African catfish *Clarias gariepinus* is widely distributed in African freshwaters, especially in the Niger and Nile River systems, extending to Southern Africa, in the Limpopo, Orange–Vall, Okavango River systems and most of the East African rift lakes (Dadebo, 2009). The African catfish, Clarias gariepinus is an ecologically important and commercially valued fish for the Nigerian fishing industry. These mud fish are frequently and widely cultured in ponds and they also occur freely in Nigeria natural fresh water (Adelakun *et al*., 2017). The fast-growing African catfish C. *gariepinus* is propagated in Africa (mainly South Africa and Nigeria) and in Europe and has been promoted in Netherland, Germany, and Belgium (Rosa *et al*., 2006). The large African catfish species which are of interest for aquaculture belong to the subgenus Clarias. C. *gariepinus* has been the suitable candidate for aquaculture because of the following characteristics viz: high prolificacy and simplicity of culture, the existence of an arborescent air-breathing organ, omnivorous feeding habits, enhanced/rapid growth rate and improved feed conversion rate (Hecht *etal*., 1996)

Clove belongs to the family Papaveraceae, the high-performance liquid chromatography (HPLC) showed that a large number of volatile oils (aromatic compounds) and flavonoids are present in the clove bud extract. (Bin-shan*et al*., 2005). Clove (*Syzygiumaromaticum*) is a natural anaesthetic agent that can be used in the transportation of fish (Mukhammad et al., 2021). Cloves are exported primarily to Indonesia to be used in the production of the local cigarettes known as kretek (Danthu*et al*., 2017). Cloves are classified as essential oil-producing plant of the Myrtaceae family, which are widely used as raw materials for cigarettes and as spices, as a crucial oil-producing plant, cloves are commonly used in pharmacology as a raw material for medicines, cosmetics and perfume industries, food shields and food preservatives (Anna *et al*., 2023).

Clove oil can also serve as an anaesthesia for a variety of fish; however, lengthy exposures can cause mortality and sub-acute morbidity (Rojas et al., 2014). Clove contains a volatile oil; eugenol (up to 95 %), acetyl eugenol, β-caryophyllene, methyl salicylate, pinene, vanillin (Nurdjannah*et al*., 2012). The clove oil was used in Chinook salmon Oncorhynchus tshawytscha, Coho salmon O. kisutch, rainbow trout O. mykiss, and white sturgeon *Acipensertransmontanus* (Taylor *et al*., 1999). Clove is native of Indonesia but it has also been cultured in several parts of the world including Pakistan (Shahid et al., 2017). Madagascar is the world's number one exporter of Clove, Products from the clove tree, along with vanilla, account for the largest (second largest in some years) proportion of Madagascar's agricultural exports (Pascal *et al*., 2014).

Anaesthesia is defined as a reversible state that is produced by an external agent and results in the loss of sensation through depression of the central nervous system (Sneddon, 2012). Anaesthetics may be local or general, depending on their applications, general anaesthesia suppresses central nervous system activity and results in unconsciousness and a total lack of sensation (Martins et al., 2016). Anaesthesia is used in aquaculture as a valuable method to reduce fish stress and avoid physical injury to fish when handling them during routine practices, such as anaesthesia for measuring fish weighing, sorting and marking, vaccine administration, live transport, blood or gonadal biopsy sampling, gametes collection and to cite some of the main applications (Maricchiolo and Genovese, 2011). Anaesthetics are widely used in Fisheries Science and Management to immobilize fish for handling so as to reduce stress and physical damage for example, capture by nets or hook and line, subsequent measuring, fin clipping, collection of scale samples and insertion of identifying tags constitutes a level of handling that stress a fish, the level of stress, a fish undergoes may affect the animals immune response and can make it vulnerable to disease (Sarah *et al*., 2012).

Synthetic anaesthetics MS-222, (quinaldine, and benzocaine) are commonly used as anaesthesia in fish. However, anaesthesia uses to leave some residues in the fish (Muhammad *et al*., 2021). Thus, synthetic anaesthetic uses to have some indirect negative effects on fish health status by leaving some of the residues in their flesh. Secondly, the synthetic anaesthetics are not readily available. Various plant-based natural compounds such as eugenol, menthol, globulol, linalool, guaiol etc. have been reported to have anaesthetic properties (Vishnu *et al*., 2023). Therefore, it is of paramount importance to search for natural compounds as anaesthesia which relatively cheaper. The objective of this study is to investigate the efficacy of clove seed extract as an aesthetic agent on C*larias gariepinus* juvenile.

## MATERIALS AND METHODS

### Study Area

The experiment was conducted at the teaching and research fish hatchery unit, Department of Fisheries, University of Maiduguri, located at latitude 11°15′N and longitude 13°15′E (Haruna *et al*., 2021). The area experiences an average annual rainfall of approximately 550 mm (Shettima, 2018).

**Collection and Extraction of Clove Seed Extract**
One hundred and fifty grams (150 g) of dried clove (*Eugenia aromaticum*) seeds were purchased from a local market in Maiduguri. The seeds were weighed using a sensitive balance (WANT Balance Instrument Co., Ltd, UK), then ground into a fine powder using an electric grinder.

**Experimental Fish**
Three hundred juvenile C*larias gariepinus* (4–5.8 g weight and 8–9 cm length) were obtained from a local fish farm in Maiduguri. The fish were acclimatized in indoor concrete tanks (2.0 m × 1.3 m × 1.0 m) for three days without feeding prior to the experiment.

**Experimental Design**
Five clove seed extract concentrations (150, 200, 250, 300, and 350 mg/L) were prepared and tested using glass aquaria containing 3 L of water. Each treatment group consisted of 10 juveniles, with three replicates per concentration. Fish were immersed in respective concentrations for anaesthetic trials. Following induction, fish were transferred to recovery tanks containing 10 L of fresh water to monitor recovery. Anaesthetic stages recorded included partial loss of equilibrium, cessation of swimming and reflexes, and muscular collapse, as described by Yoshikawa et al. (1988). Induction time, recovery time, and post-sedation survival were recorded using a digital stopwatch. Two concentrations demonstrating the most effective anaesthesia were further tested for extended sedation over six and twenty-four hours to identify the optimum dose. Average fish length was measured by randomly selecting three individuals per replicate, measuring each thrice, and calculating the mean.

**Survival rate**
Survival rate (SR) was calculated using the following formula:

$$SR\ (\%) = \frac{\text{Number of fish at the end of the experiment}}{\text{Number of fish at beggining of the experiment}} \text{x } 100$$

**Water Quality Parameters**
Water temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), and electrical conductivity (EC) were measured for each treatment and recovery tank using appropriate meters.

**Data Analysis**
Data obtained were subjected to one-way analysis of variance (ANOVA). Differences among means were evaluated using Tukey's Honest Significant Difference (HSD) test with the aid of Statistics 8.0 software. Significance was accepted at $p < 0.05$.

**RESULTS**
Table 1. shows the anaesthetic effect of clove seed extract on C*larias gariepinus* juveniles.The anaesthetic effects of aqueous clove seed extract on C*larias gariepinus* juveniles were dose-dependent, with induction and recovery times varying across concentrations (Table 1). At the lowest concentration (150 mg/L), the longest mean induction time to complete loss of equilibrium was 14.6 minutes, while the shortest induction time was 2.55 minutes. Conversely, at the highest concentration (350 mg/L), induction times were significantly shorter, with the shortest time recorded as 51 seconds and the longest 5.6 minutes.

Recovery times followed an inverse trend; shorter recoveries were observed at lower concentrations. Fish exposed to 150, 200, and 250 mg/L clove extract recovered within 21 to 38 seconds. Longer recovery periods occurred at 300 and 350 mg/L, lasting up to 11.4 minutes at 350 mg/L concentration. However,

statistical analysis showed no significant difference ($p > 0.05$) in recovery times among all treatment groups.

Post-recovery mortality was negligible across treatments: 0% mortality at 150, 200, and 300 mg/L, and a minimal 1.0% at 350 mg/L, indicating good tolerance of the anaesthetic.
Fish weight and length varied slightly between groups but showed no significant correlation with induction or recovery parameters.

**Table 1:** Mean anaesthetic effect of clove seed extract on C*larias gariepinus* juveniles

| Parameter | Clove seed extract (mg/L) | | | | |
|---|---|---|---|---|---|
| | **150** | **200** | **250** | **300** | **350** |
| XFish Weight (g) | 46.40$^{b}$ | 57.0$^{a}$ | 46.0$^{b}$ | 51.00$^{ab}$ | 52.00$^{ab}$ |
| Fish Length (cm) | 8.70$^{b}$ | 9.30$^{a}$ | 8.70$^{b}$ | 9.30$^{a}$ | 9.10$^{ab}$ |
| Response Induction (min) | 2:33$^{b}$ | 1:03$^{b}$ | 1:00$^{b}$ | 1:00$^{b}$ | 0:51$^{a}$ |
| Final Induction (min) | 14:36$^{a}$ | 14:24$^{a}$ | 9:31$^{bc}$ | 10:12$^{b}$ | 5:36$^{c}$ |
| Recovery Response (min) | 0:21 | 0:38 | 0:37 | 2:00 | 1:50 |
| Final Recovery (min) | 3:00$^{b}$ | 4:00$^{b}$ | 4:03$^{b}$ | 5:00$^{b}$ | 11:40$^{a}$ |
| Post-recovery Mortality (%) | 0.00$^{b}$ | 0.00$^{b}$ | 0.30$^{ab}$ | 0.00$^{b}$ | 1.00$^{a}$ |

Means with the same superscripts within rows are not significantly different ($p > 0.05$).

**Water Quality Parameters**
Water quality during anaesthetic exposure remained within optimal ranges for C*larias gariepinus* culture, and parameter variations among treatments were not statistically significant ($p > 0.05$) (Table 2). Recorded temperatures ranged from 26.8°C to 29.1°C, dissolved oxygen (DO) from 5.2 to 6.3 mg/L, and pH values between 7.3 and 7.8. Total dissolved solids (TDS) and electrical conductivity (EC) values were also consistent with aquaculture standards. These stable conditions suggest that water quality did not confound the anaesthetic effects observed.

**Table 2:** Mean water quality parameters in sedation tanks during anaesthetic trials

| Parameter | Clove seed extract (mg/L) | | | | |
|---|---|---|---|---|---|
| | **150 mg/L** | **200 mg/L** | **250 mg/L** | **300 mg/L** | **350 mg/L** |
| Temperature (°C) | 29.1 (a) | 28.5 (a) | 28.9 (a) | 28.8 (a) | 26.8 (b) |
| DO (mg/L) | 5.2 (a) | 6.3 (a) | 5.4 (a) | 5.2 (a) | 6.3 (a) |
| pH | 7.3 (b) | 7.4 (b) | 7.3 (b) | 7.7 (a) | 7.8 (a) |
| TDS (µS/cm) | 330 (a) | 168 (b) | 325 (a) | 334 (a) | 336 (a) |
| EC (µS/cm) | 159 (c) | 92 (d) | 162 (bc) | 167 (ab) | 169 (a) |

Means with the same superscripts within rows are not significantly different ($P>0.05$).
Key: DO = Dissolved Oxygen, EC = Electrical Conductivity, TDS = Total Dissolved Solids.

## DISCUSSION

**Anaesthesia and Recovery**
This study confirms that aqueous clove seed extract is an effective anaesthetic agent for C*larias gariepinus* juveniles. During induction, fish remained calm and exhibited no erratic swimming, indicating good welfare. Induction time decreased significantly with increasing clove seed extract concentration, showing that juveniles immersed in 350 mg/L responded fastest within 51 seconds compared to slower

induction at 150 mg/L (up to 14 minutes). These findings align with previous reports of clove oil's anaesthetic properties (Monday and Wilson, 1997; Peake, 1998).

Recovery time showed an inverse relationship; fish exposed to lower concentrations (150–250 mg/L) recovered quickly (21–38 seconds), while higher concentrations (300 and 350 mg/L) resulted in prolonged recovery up to 11.4 minutes. The longer recovery at higher doses may be due to clove oil's high lipid solubility, which slows its elimination and prolongs respiratory depression (Keene et al., 2007). However, no statistically significant differences ($p > 0.05$) in induction or recovery times were observed within treatments.

No mortality occurred at 150, 200, and 300 mg/L concentrations, whereas minor mortality (up to 1%) was noted at 250 and 350 mg/L, potentially linked to observed minor ulcerations. These mortality findings differ from Yildiz *et al.* (2012), who reported no fish deaths after clove oil anaesthesia. Overall, the anaesthetic effect was dose-dependent and consistent with known pharmacodynamics of clove oil.

**Water Quality Parameters**

All the water quality parameters observed during this study were within recommended levels for C*larias gariepinus* culture (El-Shafei, 2016). These results concur with findings by Akinrotimi *et al.* (2018) in similar studies on C*larias gariepinus*.

## CONCLUSION

The clove seed extract demonstrated effective sedation with minimal mortality at 200 - 300 mg/L, supporting its potential as a safe anaesthesia for fish handling and transportation. Clove seed extract therefore represents a viable alternative to synthetic anaesthetics, reducing stress and associated mortalities during routine aquaculture procedures.

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# AQUAPONICS AS A SUSTAINABLE SYSTEM FOR FOOD AND NUTRITION SECURITY IN NIGERIA: A REVIEW

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**ABSTRACT**
*Aquaponics system holds phenomenal potentials in transforming aquaculture and crop production that could improve food and nutrition security in the face of climate change and limited resources. The system could significantly reduce the environmental impacts from agricultural wastes through utilization of spent inputs and organic manure in crop production. Aquaponics system has the potentialities of improving the environment, social, economic and livelihood of the farmers in a country like Nigeria. Aquaponics system could help the populace in improving their source of income, and be food and nutritionally secured, provide employment opportunities to women and youths, and generate revenue to the government if well adopted in Nigeria. Therefore, there is review highlighted major components of aquaponics, categories of aquaponics systems, suitable fish species for aquaponics system in Nigeria, categories of crops cultivated in aquaponics system, status of aquaponics system in Nigeria, potentials of aquaponics system in Nigeria, and challenges of aquaponics system in Nigeria.*

**Keywords:** Aquaculture, Aquaponics, Food and Nutrition, Sustainable system

## INTRODUCTION

The aquaponics refers to an integrated and symbiotic farming concept systems (aquaculture and crop production) which ensures proper recirculation of nutrient efficiently in the system. It involves breaking down of the excretory products of the fish by microorganisms and the by-products are then inputted into the hydroponic system for the support and growth of plants (Bosma *et al.*, 2017; Salele. *et al.*, 2022). According to Tyson *et al.* (2011), aquaponics is a sustainable agriculture system that minimizes the use of non-renewable resources, maximizes the use of natural biological cycles to supply nitrogen, and combines the crop production and the aquaculture production of fish. As an integrated system because it could help solve food security, resource use efficiency, and environmental sustainability challenges (Mudashiru *et al.*, 2025).

The concept of aquaponics accentuates its merits as sustainable, space-wise, and water conserving system; a climate smart system of food production (Ibrahim *et al.*, 2023). It is a sustainable food production system that uses a biomimetic natural system to curtail inputs and waste, a mechanism that incorporates sustainable growth of intensive food production (Joly *et al.*, 2015; Obirikorang *et al.*, 2021). As a hybrid technology, it reutilizes nutrients and wastewater to improve food and nutrition security, it could also mitigate some of the effects of climate change on food production, and results in a significant water re-use efficiency particularly for Sub-Saharan regions of Africa (Dalsgaard *et al.*, 2013; Junge *et al.*, 2017; Goddek and Körner, 2019). Fish waste contains ammonia that is toxic to fish but through microbial communities such as nitrifying bacteria, it gets converted into nitrate that plants can absorb as nutrients (Mudashiru *et al.*, 2025).

According to Oladimeji *et al.* (2020) Aquaponics provides an enabling environment for the growth of crops without or less use of chemicals such as synthetic fertilizers and as well production of fish under minimum cost of water maintenance and can be regarded more as a sustainable system which make use of both hydroponics (plants) and aquaculture (animals) systems. The key feature of this system comprises

utilization of waste such that the waste of one system becomes the input of the other system (Salele *et al.*, 2022). Recycling, being one of the approaches in minimizing waste, offers three benefits: (i) reduce the demand for new resources; (ii) cut down on transport and production energy costs and (iii) utilizes waste which would otherwise channels to rivers and streams as contaminants (Oladimeji *et al.*, 2020).

The practice Aquaponics began from the Aztec Indians one of the first groups before becoming a great empire in Central America (Dauda *et al.*, 2019). The Aztecs were a nomadic people living near the shores of Lake Tenochtitlan. One of the ways they found for raised plants was by building floating rafts called chinampas on the surface of the lake and plant their vegetables on it. Some remnants of chinampas can still be found today in Central Mexico. The Chinese also have used a system of integrated aquaculture in which fish, ducks and plants coexisted in a symbiotic relationship centuries ago (Jim, 2014). However, the concept of Aquaponics has not been well practiced in developing countries especially Africa, even though the system holds great potentialities in terms of economic, environment, livelihood and social sustainability if well harnessed as a sustainable food production system. The major challenges to Aquaponics and other soilless culture systems in Nigeria include: high cost of investment, lack of power supply, require high technical know-how, and government policies on land use and pollution (Ajibade and Oyeniyi, 2018). The review aimed at highlighting major components of aquaponics, categories of aquaponics systems design, fish species suitable for aquaponics system in Nigeria, categories of crops cultivated in aquaponics system, status of aquaponics system in Nigeria, potentials of aquaponics system in Nigeria, and challenges of aquaponics system in Nigeria.

**Major Components of Aquaponics System**

According to Salele *et al.* (2022) the main components of aquaponics system are;

- **Fish culture tank**; it's a component or unit used for rearing fish.
- **Settling sink**; is a unit which is meant for collection of uneaten food, fish wastewater, and detached biofilms for settling out fine particulates.
- **Biofilter**; is a component where the nitrifying bacteria grow and convert ammonia into nitrates which are usable by the plants.
- **Hydroponics**: a sub-system where crops are cultivated by absorbing excess nutrients from the fish wastewater.
- **Sump**; the lowest point in the system where the water flows to after nutrients are reused by crops and from which it's pumped back to the rearing tanks using pumping machine.

**Categories of Aquaponics Systems Design**

Salele *et al.* (2022) classify the system of aquaponics into the following:

a) **Wicky-bed system:** in this system grow containers for crop cultivation are used and water from the fish tank is fed once or twice a week through a slotted pipe which allows the water to flow down and slowly wick its way up by capillary action and feed the plants roots from the bottom up.
b) **Media-based system:** involves the use of rocks as biological and solid filters. It is aimed at using grow containers packed with rock medium of expanded clay or clay-loam, which are permeable to absorb water and air, and plant seedlings are directly grown. Fish wastewater is circulated through the containers to allow the plants to absorb/access nutrients before the water collected into a sump and then pumped back to the fish rearing tank(s).
c) **Deep-Water Culture (DWC) system:** allows crops to float on water surface thereby allowing the roots to hang down into the water. The system consists of long water channels and a deep of 30-40cm with boards that floats on top of the water. The board comprises of slums on which the plants are fitted into.
d) **Nutrient film technique (NFT):** is a thin film of water and nutrients which are flown through a

horizontal pipe or gutter and the crops are suspended above the water. The roots touch the thin film of water and nutrients, thereby taking their nutritional requirement.

e) **Vertical system:** water is flown directly from fish tank to a column where the crops are grown and as the fish wastewater passes through the column, the roots of the crops absorb their nutrient from the water which then is subsequently pass back to the fish tank. The system involves little or no wastage of water. Crops that are mostly cultivated include lettuce and other leafy vegetables.

**Fishes Suitable for Aquaponics System**

A number of fish species are suitable in Aquaponics system globally includes: Tilapia, Catfish, Carp, Salmon, Barramundi, Bass, Jade Perch, Golden Perch, Silver Perch, and Trout. In Nigeria, Tilapia and Catfish are the most commonly cultured fishes in aquaponics system due to the fact that they grow fast and (i.e.) and can tolerate poor water quality (FAO, 2014).

**Categories of Vegetable Crops for Aquaponics System**

A vast array of plants such as tomatoes, cucumbers, lettuce, cabbage, pumpkin, hot and sweet peppers, onion, okra, watermelon, eggplants, and green leafy vegetables (amaranths), high priced herbs (basils and celeries) and other root crops such carrot and beetroot (Quagrainie *et al.*, 2028). In Nigeria, lettuce, amaranths, cabbage, cucumber, tomatoes, onion, watermelon and peppers are the most suitable vegetable crops for aquaponics system.

**Status of Aquaponics System in Nigeria**

Nigeria has been confronted with different challenges such as climate change, low agricultural productivity which affects food availability, lack technical know-how in advanced modern farming techniques, inadequate finance or capital to finance projects, inconsistency in government policies. Therefore, there is the need to develop an intensive food production system such as aquaponics which could at the same time address the challenges of water and inputs scarcity in aquaculture and again provide an addition source of food from plant materials cultured through hydroponics which is the bases of modern aquaculture system of farming termed AQUAPONICS.

According to Ajibade and Oyeniyi (2018), climate change, high cost of investment, technical know-how, government policies are the major constraints to the development of aquaponics in Nigeria. Hence, farmers have increasingly made efforts to adapt to climate change through shifting planting dates and draught-resistant crop varieties but the recent trends in yield improvements will not match the estimated global food demand by 2050, signifying that new technologies such as aquaponics. The system of aquaponics is efficient enough to support plants growth and waste management as described by Dauda *et al.* (2019) and Oladimeji *et al*. (2020). Aquaponics as an integrated system (fish and crops) has been considered more economical than the unitary fish farming in Nigeria (Daba *et al*., 2017).

Oladimeji *et al.* (2020) gave substantial evidence to support the claim that the aquaponics system is more efficient in the production of African catfish and pumpkin compared to other production systems in terms of input cost for optimum performance. Growing fish and pumpkin in the aquaponics system is much cheaper than conventional means of growing them separately in Nigeria. Agricultural produce (foods) from aquaponics are easily marketed because they are healthier than most other foods including those from field crops hence, there is need to develop a model of intervention to simplify the production of aquaponic system to benefit more famers in the rural communities in Nigeria (Mcuhunu *et al.*, 2017). Based on the assumption of Ajibade and Oyeniyi, (2018) aquaponics in Nigeria and other sub-saharan states is poorly developed with sparse of knowledge added to it. There is information on the commercial scale aquaponics production in Nigeria at the moment. Ibrahim *et al.* (2023) observed that agripreneurs have in addition to growing fish and crops using aquaponics, added the production and sales of fingerlings

and seedlings for more revenue generation.

**Potentials of Aquaponics System in Nigeria**

Thomaier *et al*. (2015) discussed the potential of aquaponics in modern farming, highlighting its role in sustainability and contribution to rural and urban resilience by reducing food miles, enhancing local food production systems, making efficient use of space, reducing labor costs, use and recycling of water sources, energy consumption and production, recycling of organic waste, new landscape opportunities (Chunjie *et al.*, 2018), and enhancing productivity through automation and smart systems . Aquaponics is a symbiotic amalgamation which was developed to provide a new technique which will be more efficient as an integrated modern farming system. The system has the potentiality to improve cost effectiveness, environmental impacts, economy and social benefit including fish and crop health management (Daba *et al.*, 2017 a). Aquaponics takes on and address multiple challenges such as scarcity of water, land constraints, degradation of the environment and hunger through a holistic approach towards farming while upholding sustainability, creativity and community empowerment. Love *et al.* (2015) surveyed aquaponics users and found that sustainability, water conservation, and organic food production were among the main drivers for adopting aquaponics. More recently, researchers have focused on technological advancements in aquaponics with the target on improving system efficiency in Nigeria.

**Economic Benefit**

Aquaponics as an integrated system has been considered more economical than the unitary fish farming (Daba *et al*., 2017 and Mcuhunu *et al.*, 2017). The system even though does not support all crops, Benjamin *et al*. (2020) reported a higher profit margin and Return on investment (ROI) in pumpkin and amaranths than the main fish products, this may be due to little or no fertilizer usage in the process of growing the plants which reduce the total cost of production of the plants.

**Environmental and Ecological Benefit**

According to Mcuhunu *et al.* (2017), farmers can achieve food security, environmental and ecological sustainability from aquaponics system by reducing the level of fertilizer usage. Further afield, the system can intensively produce larger volume of fish using the conventional RAS which include species of fish and crops that are of high value and at the same time reduce environmental and ecological pressure from the aquaculture system (Dauda, 2020). There has been a rising issues of great concern on source of pollution since 1990, from the systems of agriculture, which involve pollution due to nitrates (which are possibly from fertilizer run-off), pesticides, insecticides, herbicides, erosion, greenhouse gas emission and biodiversity loses (Mchunu *et al.*, 2017). Aquaponics therefore, has the potential especially in urban areas to check the problem of water and other pollution sources especially those from the aquaculture system. The aquaponics system can therefore significantly reduce the environmental impacts from agriculture through crop production and fish farming (Junge *et al.*, 2017). The environmental and ecological benefits of aquaponics may include; reducing food miles and transport emission, use and recycling of water sources, energy consumption and production, recycling of organic waste, new landscape opportunities among others (Chunjie *et al.*, 2018).

**Social Benefit**

The establishment of aquaponics could serve as vocational training centers for skill acquisition and could used extensively as a field of study thought in primary, secondary and tertiary level in the educational sector in Nigeria (Junge *et al.*, 2014; Graber *et al*., 2014). Mchunu *et al.* (2017) stated that Aquaponics can still be implemented to train many among the teaming population of unemployed youths in Nigeria to reduce the rate of unemployment and as well to provide a social investment for the future, food security can be achieved via food production in aquaponics, but still there is need to implement and develop a skill development for the system. Even though there is still less comprehensive assessment on sustainability of

aquaponics in the urban environment (Junge *et al.*, 2017). Chunjie *et al.* (2018) opined that the social potentials of aquaponics include: food security, educational facilities, serve as a design inspiration, source of relatively cheap protein, affordable to low individual income, and better working condition

**Challenges of Aquaponics System in Nigeria**

Aquaponics system is currently faced with major challenges which include; economic viability, technical complexity, and scalability in Nigeria. Its design and application is considered as an extremely multidisciplinary approach sketch from environmental, mechanical and civil engineering design concepts as well as aquatic and plant related biology, biochemistry and biotechnology. Aquaponics also require knowledge of subjects related to the field of computer science for automatic control systems due to system specific measurements and control technologies involved. This high level of complexity necessarily demands in-depth knowledge and expertise of all involved fields (Goddek *et al.*, 2015)

## CONCLUSION

Aquaponics represents a promising approach to sustainable food production, offering significant benefits in terms of resource efficiency, environmental sustainability, and urban farming. Although, it is not well embraced in developing countries like Nigeria which could be due to poor power supply and high cost of initial investment, land use policies and law enforcement agencies also focus less on the influence of waste products from the agricultural sector to the environment in both rural and urban communities due to negligence of the government in law enforcement. Aquaponics system could help farmers in improving their source of income, and be food and nutritionally secured in Nigeria.

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# CLIMATE-SMART AQUACULTURE IN NIGERIA: INTEGRATING INNOVATIONS FOR RESILIENT FOOD SYSTEMS

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**ABSTRACT**
*Aquaculture plays a vital role in ensuring food and nutritional security in Nigeria, contributing significantly to livelihoods and the national economy. However, the sector faces growing threats from climate change, including rising temperatures, erratic rainfall, flooding, sea level rise, and water quality degradation. These climate-induced stressors directly impact fish health, growth, and productivity, while also undermining infrastructure and ecosystem stability. In response to these challenges, climate-smart aquaculture (CSA) provides a comprehensive framework that integrates productivity, adaptation, and mitigation strategies to enhance resilience and sustainability. This paper explores the implications of climate change on aquaculture in Nigeria and highlights innovative technologies and practices that promote climate resilience. Key interventions discussed include the adoption of renewable energy sources, the use of climate-resilient fish species, development of flood-proof infrastructure, early warning systems, and the integration of advanced technologies such as recirculating aquaculture systems, aquaponics, and Internet of Things (IoT) applications. These approaches not only minimize environmental impact and resource use but also support year-round production and economic viability. Drawing from both local realities and global best practices, the paper emphasizes the need for coordinated policy support, investment in innovation, and capacity building to mainstream CSA across Nigeria's aquaculture landscape. Implementing these strategies is essential for transforming the sector into a climate-resilient and sustainable component of the nation's food system.*

**Keywords**: Climate Change, Fish Production, Innovative Aquaculture Technologies

## INTRODUCTION

Aquaculture has emerged as one of the fastest-growing food production sectors globally, playing a vital role in meeting the protein and nutritional needs of an expanding population (Rakkannan and Agarwal, 2025). In Nigeria, aquaculture contributes significantly to food security, employment, and rural livelihoods, particularly within coastal and inland communities (Saidu, 2025). However, the sector is increasingly threatened by the multifaceted impacts of climate change, including rising temperatures, altered precipitation patterns, extreme weather events, sea level rise, and changes in water quality and availability (Eriegha *et al.*, 2019; Yadav *et al.*, 2024).

Climate change refers to long-term shifts in temperature, precipitation patterns, sea levels, and other atmospheric conditions on Earth. While climate variations have naturally occurred throughout history, the current trend is primarily driven by human activities, especially the burning of fossil fuels, deforestation, and industrial emissions. These activities release greenhouse gases such as carbon dioxide, methane, and nitrous oxide, which trap heat in the Earth's atmosphere, leading to global warming (Gao *et al.*, 2017). These climate-related stressors have direct and indirect effects on aquaculture systems, influencing fish health, growth rates, species distribution, and overall productivity (Yadav *et al.*, 2024). If not addressed, these challenges could undermine Nigeria's progress toward achieving sustainable food systems and eradicating hunger. It is therefore imperative to adopt approaches that not only enhance aquaculture productivity but also build resilience to climate variability and shocks.

The concept of climate-smart aquaculture (CSA) offers a transformative framework for addressing these challenges. The climate-smart agriculture concept was first brought to light by the Food and Agriculture Organization (FAO) of the United Nations (FAO, 2013) in 2009 to improve agricultural production in the face of climate change. CSA is based on three pillars, productivity, adaptation, and mitigation, and requires practices that address synergies and trade-offs among the three pillars (Collins-Sowah, 2018). CSA promotes the integration of innovation and sustainability through practices that enhance productivity, support adaptation to climate change, and reduce environmental footprints. With the right investments, technologies, and policy support, CSA can serve as a powerful tool in strengthening Nigeria's aquaculture sector while contributing to broader food system resilience. This paper explores the application of innovative strategies within climate-smart aquaculture, drawing from global best practices and local opportunities. It highlights practical approaches for integrating innovation into Nigeria's aquaculture landscape, with the aim of informing policy, research, and development pathways that support sustainable and climate-resilient food systems.

**Climate Change and Its Impacts on Aquaculture**

Climate change poses a complex range of threats to aquaculture development in Nigeria, primarily through its influence on environmental variables that determine water quality, fish health, and ecosystem productivity. Although aquaculture is often perceived as more manageable than capture fisheries, many culture systems rely on natural water sources such as rivers, lakes, and floodplains. As a result, changes in climate and hydrological patterns indirectly and directly impact aquaculture operations, making climate adaptation an urgent priority (Gwari, 2013). Climate change has increasingly manifested through prolonged dry seasons, irregular rainfall patterns, rising water temperatures, and more frequent flooding (Shiru et al., 2020). These changes disrupt the thermal and oxygen regimes of aquaculture ponds, promote disease outbreaks, and increase stress in cultured fish. In brackish and coastal environments, sea level rise and saltwater intrusion threaten the ecological balance and freshwater availability, further compromising aquaculture productivity.

Flooding which is one of the most visible and destructive consequences of climate change, has significant implications for aquaculture (Reid *et al*., 2019). In low lying regions such as the Nigeria's Niger Delta, flood events often breach pond embankments, wash away fish stocks, damage infrastructure, and introduce pollutants and debris into aquaculture systems (Afia and Iwatt, 2023). Escaped cultured fish may invade nearby natural ecosystems, disrupting biodiversity and food webs. Furthermore, floodwaters frequently carry excessive nutrients from agricultural and urban runoff into ponds and rivers, triggering algal blooms and dense aquatic vegetation. These conditions reduce dissolved oxygen, which can cause fish stress, poor growth, or mortality. On the other hand, prolonged droughts can reduce pond volumes and concentrate pollutants, thereby impairing water quality and fish health. This alternating cycle of flood and drought increases environmental volatility and threatens the sustainability of aquaculture livelihoods.

Rising temperatures also affect fish physiology and water quality. As cold-blooded organisms, fish depend on surrounding water temperature for metabolic processes. When water becomes excessively warm, fish may experience stress, reduced growth, increased disease susceptibility, and, in severe cases, mortality. In deeper lakes and reservoirs, warmer conditions often lead to thermal layering (Agarwal *et al*., 2024). This limits the circulation of oxygen between surface and bottom layers and can result in oxygen deficiency in deeper zones. Strong winds or storms may disrupt this stability, releasing toxic gases such as hydrogen sulfide into surface waters, which can lead to sudden fish deaths, as observed in Lake Kainji. A further consequence of elevated temperature is the reduction in dissolved oxygen levels. Warm water holds less oxygen, and this condition is especially dangerous in intensive aquaculture operations where oxygen demand is high. Additionally, pollutants such as pesticides and heavy metals become more toxic in warm

water. As a result, fish in such environments face a higher risk of bioaccumulating harmful substances, which may pose serious health concerns for human consumers (Gwari, 2013).

Climate change also disrupts hydrological regimes. Reduced rainfall and increased evaporation may lead to shrinking of aquatic habitats and diminished water supply for fish farms. The long term drying of Lake Chad is an example of how changing weather patterns affect water availability in West Africa. With less water available, pond conditions may deteriorate quickly, leading to poor growth and survival rates (Ovie and Belal, 2019). Another impact is the potential reduction in aquatic primary productivity. Changes in rainfall and surface runoff may limit the nutrients entering natural and artificial water bodies (Pesce *et al.*, 2018). This affects the growth of plankton and other base organisms in the aquatic food web, ultimately reducing the feed available to cultured fish and lowering aquaculture yield.

**Innovative Technologies and Practices for Climate Resilience**

To effectively address the growing challenges posed by climate change, aquaculture systems must adopt adaptive technologies and sustainable practices that improve their resilience. Climate-smart aquaculture promotes innovations that reduce vulnerability to environmental stress, conserve natural resources, and ensure consistent productivity despite climatic fluctuations. These technologies not only enhance operational efficiency but also support environmental sustainability and long-term food security. The following are key innovations and practices that contribute significantly to climate-resilient aquaculture:

***i. Use of Renewable Energy***

Transitioning to renewable energy sources such as solar power helps reduce the carbon footprint of aquaculture operations (Zhang *et al.*, 2024). Solar-powered aerators, water pumps, and lighting systems are particularly valuable in off-grid or rural areas with limited electricity access. In addition to reducing greenhouse gas emissions, renewable energy technologies lower operational costs and improve environmental sustainability.

***ii. Selection of Climate Resilient Species***

Choosing species that can tolerate fluctuations in temperature, salinity, and oxygen levels enhances the adaptive capacity of aquaculture systems (Ahmed *et al.*, 2019). Common examples include tilapia and catfish, which are hardy, fast-growing, and disease-resistant. Genetic improvement through selective breeding can further develop fish strains with enhanced tolerance to climate variability, contributing to stable production in stressful environments.

***iii. Development of Climate Resilient Infrastructure***.

Infrastructure that can withstand climate extremes is crucial to sustaining production (Argyroudis *et al.*, 2022). This includes flood-resistant ponds, elevated embankments, and reinforced drainage systems. In areas vulnerable to sea level rise or coastal erosion, lined or raised culture units are effective in preventing contamination and physical damage. These structural adaptations help protect investments and ensure system continuity during climate-related disturbances.

***iv. Early Warning Systems and Forecasting Tools***

Access to accurate climate information empowers farmers to make timely decisions. Mobile alerts, local weather stations, and forecasting tools help predict floods, heatwaves, and cold spells (Eddamiri *et al.*, 2025). These systems enable farmers to take preventive actions such as adjusting feeding schedules, relocating stock, or harvesting early, thus reducing losses and improving resilience.

***v. Recirculating Aquaculture Systems (RAS)***

Recirculating Aquaculture Systems (RAS) represent a cutting-edge innovation that aligns directly with

climate-smart principles. RAS operates by continuously filtering and reusing water within a closed-loop system. This minimizes freshwater demand, limits nutrient discharge into surrounding ecosystems, and enables fish culture in areas with poor water quality or limited space. RAS allows for precise control of environmental conditions such as temperature, pH, and dissolved oxygen, thus decoupling production from climate variability (Gupta *et al*., 2024). The system's efficiency and compact footprint make it especially suitable for urban aquaculture, desert regions, or areas with high water stress.

***vi. Aquaponics***

Aquaponics is an integrated system that combines fish farming with crop cultivation in a mutually beneficial setup. Fish waste provides nutrients for plants, and the plants in turn purify the water, which is recycled back to the fish tanks. This system conserves water, eliminates the need for synthetic fertilizers, and produces both fish and vegetables (Baganz *et al*., 2022). Its closed-loop nature makes it suitable for use in greenhouses, rooftops, or small-scale urban farms, making it a practical and sustainable food production method for climate-vulnerable regions.

***vii. Bio-floc Technology (BFT)***

Bio-floc Technology significantly helps to reduce water quality issues in aquaculture systems in beneficial and manageable ways. Some of the benefits include

(a) Control of ammonia through promoting the growth of heterotrophic bacteria that convert toxic ammonia ($NH_3/NH_4^+$) into microbial biomass, which serve as food for fish.
(b) Improve water stability of critical water quality parameters such as pH and dissolved Oxygen (DO), through the maintenance of a balanced microbial community.
(c) Reduction of organic load and wastes like uneaten feed and fecal matter in water. These are converted into microbial aggregates (Bio-floc) that serve as food for fish and shrimps.
(d) Bio-floc serves naturally as supplementary feed, by supplying protein-rich food sources. Hence improving feed efficiency and reduction of feed cost.
(e) It helps reduce the rate of water pollution and frequency of changing water in aquaculture systems in built up areas and urban settlements where water supply and discharge are issues.

***vii. Application of IoT and Smart Sensor Technologies***

The integration of Internet of Things (IoT) technologies and smart sensors allows for continuous, real-time monitoring of key water quality parameters such as temperature, pH, dissolved oxygen, and ammonia (Prapti *et al*., 2022). These systems help detect and address water quality issues before they escalate (Argyroudis *et al*., 2022). Automated feeding technologies, powered by artificial intelligence, use sensor feedback to optimize feeding schedules, reduce waste, and improve growth performance. Remote surveillance tools like underwater cameras and mobile monitoring platforms enable better farm management and reduce the need for constant physical presence. These technologies greatly enhance operational efficiency, resilience, and sustainability.

## CONCLUSION AND RECOMMENDATIONS

Climate change presents a multifaceted threat to the sustainability of aquaculture in Nigeria, manifesting through rising temperatures, erratic rainfall, flooding, drought, and salinity intrusion. These stressors affect water quality, fish physiology, infrastructure, and production efficiency, thereby threatening food security, livelihoods, and ecosystem health. As aquaculture systems become increasingly exposed to climate variability, the adoption of climate-smart strategies is no longer optional but essential. This paper has demonstrated that climate-smart aquaculture offers a practical and forward-looking framework for enhancing resilience, productivity, and environmental sustainability. By integrating renewable energy, resilient infrastructure, early warning systems, innovative production systems like RAS and aquaponics, and smart technologies such as IoT and automated monitoring tools, aquaculture can adapt to climate

shocks while ensuring economic and nutritional stability.

To achieve widespread adoption, it is recommended that government agencies, research institutions, and private stakeholders invest in targeted capacity building, farmer sensitization, and technology transfer. Policies should be aligned to support sustainable practices, incentivize innovation, and promote access to climate finance. Public-private partnerships should also be encouraged to drive technological development, data-sharing platforms, and extension services. Furthermore, local knowledge must be integrated with global best practices to develop context-specific solutions that suit Nigeria's ecological and socio-economic realities. Implementing these recommendations will not only safeguard aquaculture livelihoods against the impacts of climate change but also position the sector as a key driver of resilient and sustainable food systems in Nigeria and beyond.

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# PERFORMANCE EVALUATION OF A DIGITAL SYSTEM FOR MONITORING PARAMETERS IN THE FISH DRYING PROCESS

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**ABSTRACT**

*Fish drying is a common preservation method that involves exposing fish to heat and airflow to remove moisture. Traditional fish drying technologies, however, are associated with several limitations, including high energy consumption, post-harvest losses, and the introduction of bypass fluids during inspections. This study presents the development and implementation of a digital monitoring system for tracking internal drying parameters during the fish drying process. The system was installed on a medium-sized electric convection dryer to continuously monitor key parameters: temperature, humidity, and smoke, while simultaneously recording data for validation against standard measurement equipment. Twenty-five kilograms (25 kg) of fish (Clarias gariepinus) with an initial moisture content of 80% (wet basis) were dried to a final moisture content of 28.57% within 7 hours and 35 minutes. The collected data were analysed statistically using Microsoft Excel. Results indicated that the rate of fish dehydration decreased as the drying chamber temperature increased from 29.87 °C to 60.10 °C, with an average drying rate of 0.09 kg/hr. The developed digital monitoring system proved effective in accurately tracking the drying parameters, providing a reliable tool for optimising the fish drying process.*

**Keywords:** Dryer, Humidity, Smoke, Temperature, Traditional, Techniques

## INTRODUCTION

Fish drying is a crucial preservation technique that significantly extends shelf life by reducing the moisture content of fish, thereby inhibiting microbial growth and spoilage (Wankhade et al., 2013). Despite its importance in ensuring year-round fish availability and minimizing post-harvest losses, traditional drying techniques commonly used in many developing regions such as open air sun drying and smoking present numerous challenges. These conventional methods lack precise control over key process parameters like temperature, humidity, and airflow. Consequently, they often result in inconsistent product quality, nutrient degradation, and exposure to contaminants such as dust, insects, and Polycyclic Aromatic Hydrocarbons (PAHs) (Anyakora & Coker, 2007; Davies & Davies, 2009). Moreover, these methods are typically labour-intensive, time-consuming, and energy-inefficient, leading to significant post-harvest losses and reduced market value (Okouzi et al., 2020).

In response to these limitations, recent advancements in digital technologies particularly the Internet of Things (IoT), Artificial Intelligence (AI), and sensor-based monitoring systems have created opportunities for optimising fish drying operations (Neil, 2022). These emerging systems provide real-time monitoring and control of environmental parameters, enhancing process accuracy and ensuring uniform product quality. They also support energy efficiency, traceability, and contamination prevention, aligning with global efforts toward sustainable and technology-driven food processing systems.

However, despite their potential, the practical application and performance evaluation of digital monitoring systems in fish drying remain limited, especially in terms of their accuracy, reliability, and cost-effectiveness under local operating conditions. There is a need to assess how these systems perform in real drying environments and determine their impact on product quality and safety.

Therefore, this study was carried out to evaluate the performance of a digital monitoring system designed to track critical parameters such as temperature, humidity, and PAH levels during fish drying. The objectives are to assess the accuracy and reliability of the monitoring system, analyses its influence on the quality of dried fish, and determine its overall feasibility for improving fish drying operations. The findings from this research are expected to contribute to the development of efficient, hygienic, and sustainable drying technologies that can reduce post-harvest losses, ensure food safety, and enhance productivity within the fisheries sector.

## MATERIALS AND METHODS

### Study Area

The study was conducted at the National Institute for Freshwater Fisheries New Bussa located within **Borgu Local Government, Niger State, Nigeria.** The area lies within the **Guinea Savannah ecological zone,** characterised by a **tropical climate** with two distinct seasons: the **wet season (April–October)** and the **dry season (November–March).** Average annual temperature ranges from **24°C to 35°C**, with relative humidity between **50–80%.** These climatic conditions make the area suitable for both aquaculture and fish processing activities, including drying operations.

### Materials, Equipment, and Tools

The following equipment and tools were used in the study:

- **Digital Monitoring System:** Comprising a microcontroller (Arduino Uno), DHT22 sensors (for temperature and humidity), MQ2 gas sensor (for PAH and air quality detection), clock module, micro SD card module and a Liquid Crystal Display (LCD) unit for real-time data output. The design and implementation details are available at (Aliyu *et al.*, 2025).
- **Drying Chamber:** Constructed from galvanised steel sheets with air inlets and a ventilation outlet for controlled airflow.
- **Data Logger:** For recording temperature, humidity, and gas concentration readings at 5-minute intervals.
- **Analytical Instruments:** Thermometer and hygrometer for calibration and validation of sensor readings.
- **Fish Samples:** Fresh catfish (*Clarias gariepinus*) was obtained from local aquaculture farms in the study area.

### a. Experimental Procedure

- **System Design and Setup:** The digital monitoring system was designed and assembled to continuously track environmental parameters during drying. Sensors were interfaced with the Arduino microcontroller, and data were displayed on the LCD and stored in a memory module for later analysis (Aliyu *et al.* 2025).
- **Calibration and Testing:** The sensors were calibrated using standard reference instruments to ensure accuracy. The system's response time and sensitivity were tested under controlled temperature and humidity conditions.
- **Drying Experiment:** Freshly gutted and cleaned catfish (*Clarias gariepinus*,) samples were obtained from the study area and drying was carried out over a period of 8 hours, with periodic monitoring and data collection. However, performance evaluation was conducted by installing the digital system on a small-medium size dryer while processing the fish sample, with ambient conditions also recorded.

Standard instruments (HCT-2 data logger, and laboratory thermometer) were used to measure the same parameters (temperature and humidity) for validation as shown on plate (2a)-(2d).

- **Data Collection and Analysis:** Data on temperature, humidity, and PAH concentration were recorded and analysed using Microsoft Excel software. Product quality was assessed based on **moisture content**.
- **Evaluation:** The system's performance was evaluated based on **accuracy, stability, energy efficiency**, and **impact on product quality**. Results were compared between traditional and digitally monitored drying methods.



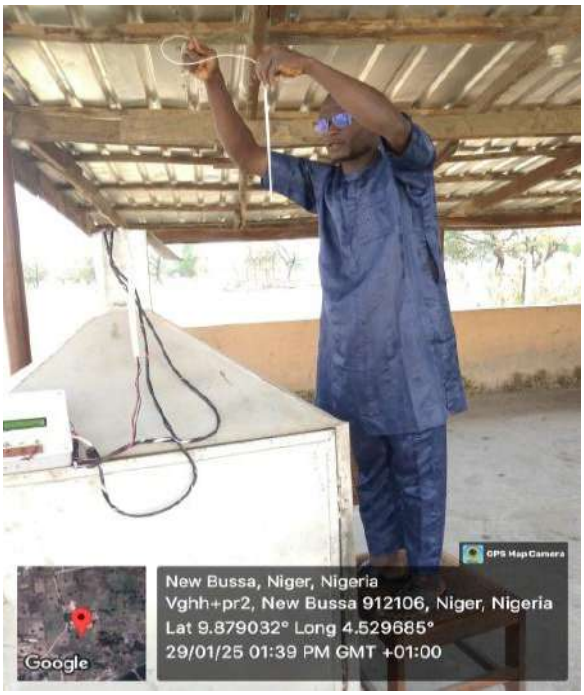

Plate 2(a). The digital system installed on the dryer




Plate 2(b). Displaying reading of drying parameters




Plate 2(c). Using other standard devices to measure drying parameters




Pate 2(d). Reading temperature value from a laboratory thermometer

### b. Drying Rate (α) and Moisture Content ($M_C$) Determination

The rate of moisture removal (drying rate) can be calculated from the data recorded during the drying process. The drying rate is calculated according to Ichsani and Dyah (2002).

$$\alpha = \left(\frac{dM}{dt}\right) = \frac{m_i - m_f}{t} \quad (1)$$

where; α is the drying rate in kg/hr, $dM$ is the change in mass (kg), $dt$ is the change in time (hr) and t is the total time (hr), $m_i$ and $m_f$ are the initial and final mass of fish samples respectively in kilogram. The moisture content ($M_c$) expressed in percentage (%) is determined using Equation 2;

$$M_C\,(\%) = \left(\frac{W_f - W_d}{W_f}\right) \times 100 \quad (2)$$

Where $M_C$ is the moisture content of the fish, $W_f$ is the weight of fresh fish and $W_d$ is the weight of dried fish?

## RESULTS AND DISCUSSIONS

### Temperature – Humidity profile of the drying process

Figure 1 illustrates the temperature and relative humidity variations within the drying chamber as measured by both the designed digital monitoring system and standard instruments. The average chamber temperature during the process was 38.87°C, initially starting at 29.87°C and gradually increasing to a peak of 60.1°C at 90 minutes, due to heat from the electrical heater. The temperature then fluctuated, dropping to 30.20°C at 130 minutes, rising again to 55.30°C at 170 minutes, and finally stabilising around 39.05°C by the end of the drying period.

The mean relative humidity recorded was 13.35%, beginning at 23% and decreasing to 3% as temperature rose. Fluctuations in humidity (increasing to 22% at 130-170 minutes and 15% at 210 minutes) were attributed to moisture release from the fish flesh before finally stabilising at 12%.

A total of 25 kg of fish with an initial moisture content of 80% (wet basis) was dried to 28.57% within 7 hours and 35 minutes. This performance surpasses that of Omodara et al. (2016), who achieved a final moisture content of 6.90% after 12 hours using an electrical fish kiln. The shorter drying time and lower energy use in the present study are attributed to the digital monitoring system, which optimised temperature and humidity control, enhancing efficiency without disrupting the drying process.

### Interpretation of Temperature and Humidity Trends (Figure 1)

The graphical representation in Figure 1 shows an inverse relationship between temperature and relative humidity within the drying chamber throughout the process. As the temperature increased from 29.87°C to a peak of 64°C within the first 90 minutes, the relative humidity decreased sharply from 23% to 3%, indicating effective moisture removal from the fish surface. The intermittent rise in humidity observed between 130 and 210 minutes corresponded with temporary temperature drops, suggesting the release of internal moisture from the fish tissues into the chamber air. This pattern aligns with the characteristic *falling-rate period* of the drying curve, where moisture diffusion from inner layers dominates the drying process.

The final stabilization of temperature (around 39°C) and humidity (approximately 12%) indicates the attainment of equilibrium moisture content, marking the end of active drying. This observed inverse

temperature–humidity trend agrees with the findings of Wankhade *et al.* (2013) and Okouzi *et al.* (2020), who reported similar behavior in controlled drying environments. Minor fluctuations noted in both parameters can be attributed to variations in heater intensity and the dynamic release of bound moisture within the fish matrix.

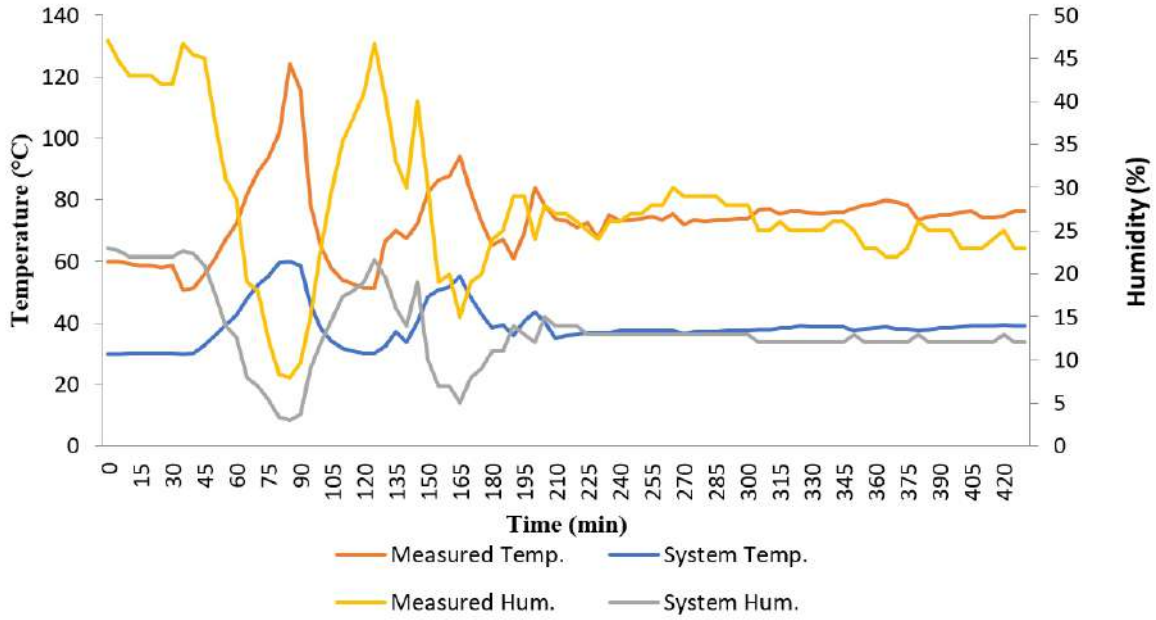



**Figure 1:** Comparison of Temperature and -Humidity profile of the designed digital system and the standard devices.

**Smoke concentration profile of the drying process**

As demonstrated in Figure 2, the smoke concentration of the drying process exhibits a time-dependent variation. At the inception of the process (0 to 195 minutes), the smoke concentration is negligible due to the absence of water molecules migrating from the flesh to the surface of the fish and the lack of melting fat due to the low temperature. Subsequently, the smoke concentration increases to a maximum value of 1.2ppm. This increase is attributed to the combustion of melted fat from the fish, which, is due to the high temperature within the drying chamber, contributing to rapid drops of melted fats onto the hot damper plate of the dryer. Upon complete combustion process, the smoke component is carbon dioxide; this exerts no effect on the products, as illustrated in the general equation for complete combustion of fat.

$$(C_{16}H_{32}O_2 + 23O_2 \rightarrow 16CO_2 + 16H_2O + \text{Energy}) \quad (3)$$

Conversely, if the combustion process is incomplete as presented also in the general equation for incomplete combustion of fat

$$(C_{16}H_{32}O_2 + 12O_2 \rightarrow 8CO + 8C + 16H_2O + \text{Energy}) \quad (4)$$

The smoke component is carbon monoxide and carbon, which may appear as soot or particulate matter. This component is also carcinogenic and exerts an effect on the end products, as reported in the work of Ramatou *et al.* (2023). The concentration value undergoes a further decline to approximately 345 minutes and subsequently rises to 0.61ppm at 350 minutes. Subsequently, it continues to decrease to a final value of 0.15ppm at 435 minutes, at which point the process is halted.

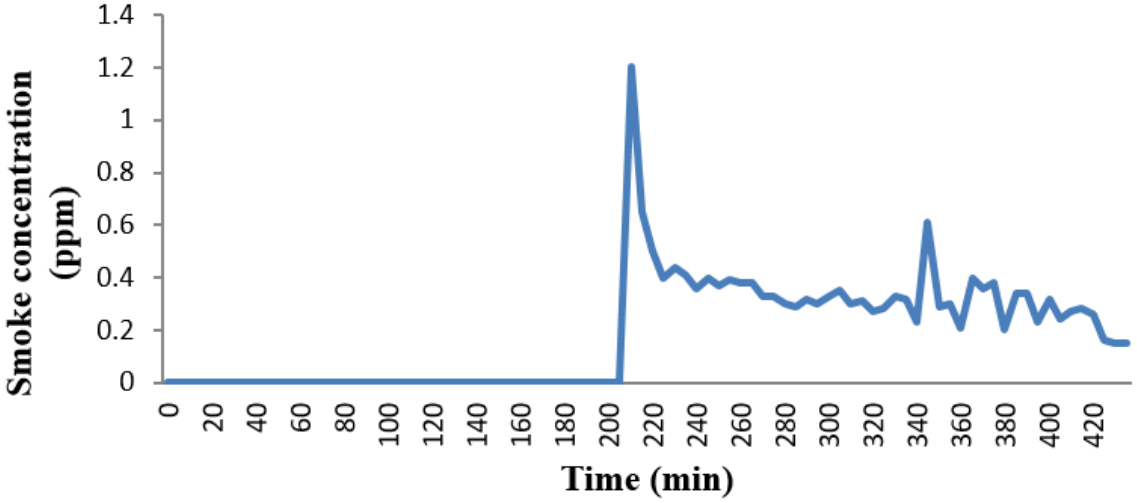



**Figure 2:** Smoke concentration profile of the drying process

**Drying Rate curve for the drying process**

As demonstrated in Figure 3, the rate of water activity decline in the fish during the drying process exhibits a marked decrease over time. Initially, the drying rate is rapid, reaching 0.3 kg/hr during the first hour of the drying process. However, this rate subsequently declines due to change in the temperature of the chamber. Ultimately, the drying rate approaches zero by the end of the process, approximately eight hours later. The constant drying rate occurs at the first stage of the drying process (0 to 1 hour), while the falling rate occurs from the first to the seventh hours of the drying process. These results align with those reported in the literature (Omodara *et al.*, 2016; Wankhade *et al.*, 2013). The impact of air relative humidity on the drying rate and drying time is such that decreasing relative humidity intensifies the drying rate change over time. That is to say, at low relative humidity, there is a high rate of heat and mass transfer, resulting in significant water loss. However, the temperature exerts the greatest influence on the drying rate of a product.

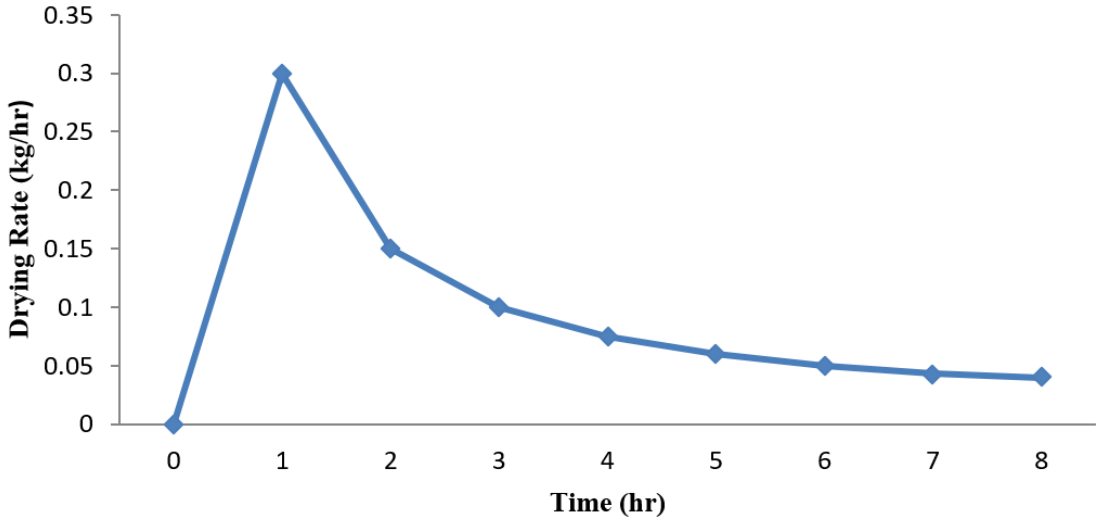



**Figure 3:** Drying Rate curve for the drying process

## CONCLUSION

This study investigated the performance of a digital monitoring system designed to optimise fish drying by controlling critical parameters such as temperature, humidity, and smoke concentration. The study

concludes that the integration of digital technologies into fish drying systems offers a viable, efficient, and sustainable alternative to traditional methods. It has the potential to transform fish processing practices by reducing losses, conserving energy, and ensuring product safety. Future work should focus on scaling the system for commercial application, incorporating artificial intelligence for predictive control, and conducting economic feasibility studies to promote wider adoption among small and medium-scale fish processors. The proposed system has the potential to enhance food security, product quality, and overall acceptability.

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# THE EFFECT OF STORING MILT AND EGGS OF *Clarias gariepinus* IN SALINE FOR 24 HOURS ON HATCHABILITY AND SURVIVAL OF THE FRY OF *Clarias gariepinus*

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**ABSTRACT**

*A study on the effect of storing milt and eggs of Clarias gariepinus in saline for 24 hours was carried out at NIOMR Sapele out station. The results show that there was 90% hatchability for treatment 1 (0 hour). Treatment 2 also recorded 60% hatchability. Both the eggs and milt were stored in ice with temperature of -4$^0$C throughout the duration of the study. The pH ranged from 6.9 to 7.2 in all the treatments. The DO was 5m/l at the point of incubation for all treatments, At 18 hours of incubation. DO for treatment 1 was 4m/l, 3.5m/l for treatment 2. For treatment 3, 4 and 5 (12, 18 and 24 hours respectively), the eggs were still green up to the 20$^{th}$ hour before turning white. Zero hatchability was recorded. The water temperature was 29$^0$C at the time of the first incubation, reduced to 25$^0$C at the 6$^{th}$ and 12$^{th}$ hour and increased to 29$^0$C at 18$^{th}$ to 24$^{th}$ hours.*

**Keywords**: milt, Eggs, Saline, Hatchability and Survival

## INTRODUCTION

The growing population and demand for fish and catfishes of the family *Clariidae* are high and *Clarias gariepinus* is the most commonly cultivated fish in Nigeria and Africa at large. The production of seed which is the most important in the value chain has contributed to the problems faced by Aquaculture in the country today. The quest for quality seed for stocking is also high, but has sometimes been challenged by poor brood stock. As a result, there is an urgent need to carry out research to reduce the problem of poor stocking seeds by improving the quality of egg and milt. The collection of fish milt and eggs for storage is a good technique that may perhaps also improve the aquaculture sector. Spermatozoa motility is very important for successful fertilization of the eggs (Jezierska and Witeska, 1999). According to Sarnowski *et al* (1997), storage of milt for 5hours in the refrigerator of about 0$^0$C did not adversely affect fertilization rate. Babiak and Glogowski (1996) reported longer milt motility time at low temperature. This study is aimed at improve milt and eggs quality by providing a technology which will encourage the easy transportation for both the milt and the egg from one location to another.

## MATERIALS AND METHODES

The study was conducted at the Nigerian Institute for Oceanography and Marine Research Sapele out Station Sapele Local Government Area of Delta State, Nigeria
(N50 54´.5´´E005°39´56.4´´). Brood fish (male and female) were purchased from a reputable farm in Sapele, Delta State. The male and female were purchased from different locations.



**Figure 1:** Selection of brood fish for purchase

The females were induced with the time of inducement recorded, the water temperature at inducement recorded. The females were observed between 8 to 10 hours from the time of inducement, depending on the temperature.



**Figure 2:** Stripping of the eggs



**Figure 3:** The milt collected from the male

At the completion of the latency period, the female were stripped of their eggs, the milt from the male was collected. 0.2g of the egg will be measured out using a digital scale (superior mini digital platform scale, I-2000) in triplicates for five treatments (6 hours interval). These treatments were stored in 1m saline; the mixture were put in 20m test tube and stored in the refrigerator between 0 to 24hours. The treatment was labeled 1 – 5. Fertilization of the egg was done every 6 hours.



**Figure 4:** drawing of 1m of milt in saline



**Figure 5:** Measuring of eggs using digital scale

The water parameters were taken every 6 hours using pen type water quality meter (Temperature and pH), and pen type intelligent dissolved oxygen analyzer (DO9100, Oxygen). The data collected was recorded. The hatching time was also recorded for all the treatments. Percentage hatchability and survival rate is also recorded.



**Figure 6:** Experimental setup

## RESULTS AND DISCUSSIONS

**Table 1:** Hatchability cum water quality parameters result.

| TREATMENT | 1(0HR) | 2(6HR) | 3(12HR) | 4(18HR) | 5(24HR) |
|---|---|---|---|---|---|
| HATCHABILITY (%) | 95 | 60 | 25 | 0 | 0 |
| $P^H$ | 6.9 | 6.7 | 6.7 | 6.7 | 7.2 |
| D O (mg/L) | 5.0 | 4.0 | 3.5 | 3.0 | 3.5 |
| TEMP ($^0$C) | 29 | 25 | 25 | 25 | 29 |

Table 1 shows that there was 90% hatchability for treatment 1 (0 hour). Treatment 2 (6 hours) also recorded 60% hatchability. Both the eggs and milt were stored in ice with temperature of -4$^0$C throughout the duration of the study. The pH ranged from 6.9 to 7.2 in all the treatments. The DO was 5m/l at the point of incubation for all treatments, At 18 hours of incubation. DO for treatment 1 was 4m/l, 3.5m/l for treatment 2. For treatment 3, 4 and 5. (12, 18 and 24 hours respectively), the eggs were still green up to the 20$^{th}$ hour before turning white. Zero hatchability was recorded. The water temperature was 29$^0$C at the time of the first incubation, reduced to 25$^0$C at the 6$^{th}$ and 12$^{th}$ hour and increased to 30$^0$C at 18$^{th}$ to 24$^{th}$ hours. : Babiak and Glojowski (1996) and Makzewski (1988) reported the possibility of milt storage at 00C. according to them, sperm stored at that temperature was able to fertilized eggs, but at lower tempereture temperature, time of sperm motility is longer. This could have been the cause of both low hatchability and zero hatchability recorded in this study. Jezierska and Witeska (1999), reported success in C*larias gariepinus* fertilization up to 48hrs of storage. This may suggest that spermatozoa of C*larias gariepinus* may be motile for up to or more than 48hrs.

## CONCLUSION

This study is ongoing. Other methods of storage at varying temperature will be adopted. This work at conclusion will establish a protocol for storing eggs and milt of C. *gariepinus*.

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# NANOBUBBLE TECHNOLOGY AS A GAME-CHANGER IN AQUACULTURE: A REVIEW

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**ABSTRACT**
*Aquaculture, as the fastest-growing food production sector, faces persistent challenges related to water quality management, oxygen depletion, and disease outbreaks. Traditional aeration systems often fail to sustain optimal dissolved oxygen levels in intensive culture environments, leading to reduced fish growth, increased stress, and higher mortality. Nanobubble technology, a recent breakthrough in water treatment offers a transformative solution. Unlike conventional bubbles, nanobubbles (<200 nm in diameter) remains stable in water for extended periods, deliver oxygen with exceptional efficiency, and generate reactive oxygen species that suppress harmful pathogens. In addition to reviewing their applications, this paper also discusses the different technologies available for nanobubble production, providing insights into how generation methods influence efficiency and field deployment. By integrating this technology, fish farmers can achieve higher yields, healthier stocks, and greater resilience against climate-driven stressors. Hence, this paper highlights the potentials of nanobubbles technology to improve sustainable yield in aquaculture. Although further research is required to overcome potential limitations and refine application techniques, nanobubbles represent a promising innovation for enhancing sustainable aquaculture and contributing to global food security.*

**Keywords**: Aquatic production, Aeration technology, Micro-oxidation

## INTRODUCTION

Aquaculture has emerged as the fastest-growing food production sector, contributing significantly to global food security, nutrition, and livelihoods. With the world's population projected to surpass 9 billion by 2050, demand for fish and aquatic products is expected to rise sharply (FAO, 2022). However, the industry faces persistent challenges, including water quality deterioration, limited dissolved oxygen availability, frequent disease outbreaks, and the need to intensify production without compromising sustainability. Traditional aeration and water treatment methods often fall short in addressing these concerns, particularly under intensive aquaculture systems where oxygen demand and waste accumulation are high. In recent years, nanobubble technology has gained global attention as a novel and disruptive innovation capable of addressing these challenges (Tari and Ramasre, 2024). Nanobubble, also known as ultrafine bubbles, are gas-filled cavities with diameters typically below 200 nanometers smaller than the wavelength of visible light and nearly invisible to the naked eye (Yaparatne *et al*, 2024). Unlike conventional bubbles, which rise rapidly to the surface and burst within seconds, nanobubbles possess unique physical and chemical properties that allow them to remain suspended in water for weeks or even months. This extraordinary stability arises from their high internal pressure, surface charge (zeta potential), and ability to generate hydroxyl radicals and reactive oxygen species (ROS) during collapse (Ahmad *et al*, 2024). One of the most remarkable features of nanobubbles is their oxygen transfer efficiency. While traditional aeration systems lose a significant portion of oxygen to the atmosphere, nanobubbles dissolve oxygen directly into the water column with minimal loss. This property makes them highly effective for maintaining optimal dissolved oxygen levels in aquaculture systems, especially under intensive culture conditions (M. Jia *et al.*2023). Furthermore, nanobubbles improve water circulation, enhance nutrient mixing, and can aid in the removal of organic matter and toxic compounds such as ammonia. These multifunctional properties make nanobubbles not just a tool for aeration but a

versatile technology with potential to revolutionize aquaculture management. By simultaneously enhancing water quality, fish health, and system efficiency, nanobubbles offer a scientific and technological foundation for sustainable intensification of global aquaculture.

**Applications of Nanobubble Technology in Aquaculture**

Nanobubble technology has emerged as a transformative innovation with multiple applications in aquaculture and fisheries. Its multifunctional properties extend far beyond oxygen delivery, offering solutions to some of the most pressing challenges in fish farming as stated below:

**a. Enhanced Oxygen Delivery**

Oxygen is the lifeline of aquaculture, yet maintaining optimal dissolved oxygen (DO) levels is a major challenge, especially in intensive and high-density systems. Traditional aeration systems are inefficient, as most bubbles escape to the atmosphere before dissolving. Nanobubbles, however, have an exceptionally high oxygen transfer rate, ensuring that more oxygen is dissolved and evenly distributed throughout the water column. This reduces fish stress, enhances survival rates, and supports higher stocking densities without compromising animal welfare. Study by Liu et al. (2020) applying nanobubbles in tilapia tanks revealed increased level of DO from 5.0 mg/L to 7.5 mg/L within 30 minutes and remained stable for several hours without continuous aeration. So, also industry application of nanobubble systems integrated into hatcheries increased DO by up to 40% compared to diffused aeration (Moleaer Inc. 2021).

**b. Disease Control and Pathogen Suppression**

When nanobubbles collapse, they generate reactive oxygen species (ROS) such as hydroxyl radicals, which possess strong antimicrobial properties. These ROS can inactivate bacteria, viruses, fungi, and biofilms, thereby reducing the prevalence of diseases like bacterial gill disease and columnaris. Importantly, this mechanism provides a chemical-free alternative to antibiotics, addressing the growing global concern over antimicrobial resistance (AMR) in aquaculture. This is seen in a range of case studies for example Ozone nanobubble treatments was seen to improve survivability of Nile tilapia (Oreochromis niloticus) challenged with a pathogenic multi-drug-resistant *Aeromonas hydrophila* (Dien *et al*, 2021). In another study, ozone nanobubbles were used alongside biofloc to control pathogens (bacteria and viruses), demonstrating improved survival in shrimp larvae.

**c. Improved Feed Conversion and Growth Performance**

Adequate oxygen availability optimizes aerobic respiration, leading to higher ATP yield per unit of feed consumed. Fish under hypoxic conditions switch to anaerobic metabolism, which is less efficient and produces lactic acid, reducing growth. By, improving dissolved oxygen availability, nanobubbles enhance metabolic efficiency and feed utilization in fish and shrimp (Rachmawati, et al, 2020; Mahasri et al., 2018). Studies have shown that fish cultured in nanobubble-treated systems exhibit higher feed conversion ratios (FCR), faster growth rates, and lower mortality (Rachmawati, et al, 2020). This not only boosts productivity but also reduces feed waste, leading to cost savings and minimized environmental pollution.

**d. Water Quality Enhancement**

Water quality deterioration is a common cause of mortality in aquaculture systems. Nanobubbles improve water quality by enhancing gas exchange, reducing ammonia and nitrite levels, and increasing oxidation-reduction potential (ORP) (Atkinson *et al*, 2019). The micro-mixing effect of nanobubbles promotes uniform distribution of nutrients and prevents stratification in ponds and tanks. Furthermore, by suppressing harmful algal blooms and breaking down organic matter, nanobubbles create a healthier and more stable aquatic environment for cultured species. The unique micro-mixing effect of

nanobubbles also promotes uniform distribution of dissolved gases and nutrients throughout the water column, preventing stratification in ponds and tanks and ensuring stable conditions for cultured species (Justin *et al*, 2024). In addition, nanobubbles can suppress harmful algal blooms by disrupting algal physiology and limiting nutrient availability, while also accelerating the breakdown of organic matter and reducing black-odor conditions in eutrophic waters (Zhu *et al*, 2024; Moleaer, 2023)

**Technologies for Producing Nanobubbles**

The generation of nanobubbles relies on several engineering approaches that differ in principle, efficiency, and applicability to aquaculture systems. Understanding these technologies is critical for evaluating their suitability across different production scales.

**a. Hydrodynamic Cavitation**

The technique involves passing water at high velocity through a venturi or nozzle, where sudden pressure drops encourage the formation of bubbles that subsequently collapse into nanoscale sizes. In practical terms, this means that farmers can achieve a higher concentration of dissolved oxygen with relatively modest energy input. For instance, its integration into recirculating aquaculture systems (RAS) has been shown to improve fish survival rates and reduce the need for supplementary aeration. However, one limitation is that the efficiency of cavitation strongly depends on system design and water flow dynamics, which may present challenges in low-resource settings (Kurokawa et al., 2019).

**b. Mechanical Agitation (Shear Methods)**

Mechanical agitation employs high-speed impellers, stirrers, or rotary devices to introduce gas into water. The strong shear forces break down larger bubbles into progressively smaller ones until nanobubbles are formed. While this method is relatively simple and low-cost, it often produces a mixture of micro- and nanobubbles, with less precise size control compared to more advanced methods (Liu *et al.*, 2020).

**c. Membrane Diffusion Systems**

Membrane-based nanobubble generators utilize nano porous or hydrophobic membranes to diffuse gas into water at controlled rates. The extremely fine pores allow for precise regulation of bubble size, producing stable and uniform nanobubbles. Membrane systems are particularly useful in hatcheries and recirculating aquaculture, where consistent oxygenation and water quality management are essential

**d. Electrochemical Methods (Electrolysis)**

Electrolysis-based systems produce nanobubbles by splitting water molecules into hydrogen and oxygen at the electrode surfaces. The gases generated from stable nanobubbles, often with very high purity. This method is effective for producing oxygen or hydrogen nanobubbles but can be energy-intensive and subject to electrode degradation over time

**e. Ultrasonic or Acoustic Cavitation**

Ultrasonic methods use high-frequency sound waves to create alternating pressure zones in water. These zones lead to bubble nucleation, and the resulting microbubbles collapse into nanobubbles under cavitation forces. Ultrasonic generation is highly effective for disinfection and water treatment applications but is relatively costly and energy-demanding for large-scale aquaculture operations

**f. Hybrid and Advanced Systems**

Recent innovations combine two or more nanobubble generation methods to optimize efficiency and bubble stability. Hybrid systems, such as hydrodynamic cavitation coupled with membrane diffusion, allow for higher gas transfer rates and more consistent nanobubble production. Portable, solar-powered hybrid generators are also emerging as promising technologies for smallholder aquaculture in developing

regions (Zhang et al., 2022).

Collectively, these technologies provide flexible options for integrating nanobubbles into aquaculture. While hydrodynamic cavitation and mechanical methods are more suited to large-scale or cost-sensitive operations, membrane diffusion, electrolysis, and ultrasonic systems offer higher precision for specialized applications such as hatcheries, recirculating systems, and disease control.

## CONCLUSION

Nanobubble technology has emerged as a promising innovation for transforming aquaculture practices by improving water quality, enhancing oxygen transfer, and supporting effective disease control. Its ability to maintain high dissolved oxygen levels, promote healthier microbial environments, and minimize chemical dependency makes it a valuable tool for modern fish farming. The technology also contributes to better feed utilization, faster growth, and greater environmental stability, thereby improving overall production efficiency. Nonetheless, further investigations are required to refine bubble generation systems, lower energy costs, and assess long-term environmental implications. With continuous research and adaptation, nanobubble technology could play a pivotal role in achieving more sustainable and resilient aquaculture systems worldwide.

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# DIGITAL TRANSFORMATION AND AQUACULTURE GROWTH IN DELTA CENTRAL AGRICULTURAL DEVELOPMENT ZONE, DELTA STATE, NIGERIA

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**ABSTRACT**

*Digital transformation has the potential to significantly boost aquaculture growth in the Delta Central Agricultural Zone, Nigeria. By leveraging technology, fish farmers can improve efficiency, increase productivity, and access new markets, leading to greater profitability and food security. The study assessed the digital transformation and aquaculture growth in the Delta Agricultural Development Central Zone. Primary data were collected from 187 respondents using a purposive sampling technique. Results revealed that digital transformation boosts production activities. Before the effect of digital transformation by fish farmers, an average of 733.12kg of fingerlings were stocked, which increased to 952.83 kg after the effect of digital transformation. Also, the effect of digital transformation increases fish farm output significantly from 742.28kg to 1,052.82kg. Likewise, fish farmers' revenue increased from 540.905 Naira to 780,444.98 Naira. Therefore, digital transformation has a positive effect on fish farmers, which significantly increases farm output and income by 42.57% to 44.29%. Digital transformation in aquaculture involves integrating technologies to enhance efficiency, sustainability, and profitability. Based on this, the study advocates that fish farmers should be more involved in digital transformation programmes to create a more efficient, resilient, and environmentally friendly aquaculture industry.*

**Keywords:** Digital, Transformation, Aquaculture Growth,

## INTRODUCTION

Aquaculture has emerged as one of the fastest-growing food production sectors globally, with an average annual growth rate of 5.8% since 2001 (FAO, 2020). In Nigeria, fish farming is increasingly being promoted as a strategy for enhancing domestic food and nutrition security and raising incomes for smallholder farmers (Ume et al., 2016). Fish production is a crucial component of global food security and effective aquatic ecosystem management. Fish farming, on the other hand, is considered a key agricultural sector for food production globally. It is viewed as a crucial agricultural activity that can reduce nutritional deficiencies on a global scale and therefore reduce poverty effectively Kaleem and Sabi, 2021. Interestingly, aquaculture, or fish cultivation, offers a significant source of animal protein and contributes substantially to household diets, livelihoods, and economic development in many countries and regions of the world (FAO, 2020).

Nigeria is not left out. In the agricultural sector of the Nigerian economy, aquaculture has been recorded as having the fastest growth rate. Delta state, located in the oil-rich Niger Delta region of Nigeria, has enormous potential for aquaculture growth and productivity, given its extensive river systems, floodplains, and swampy terrains (Obiam and Amadi, 2022). Smallholder catfish farming has particularly thrived as a profitable enterprise and source of livelihood for rural households across the State (Inoni et al., 2017).

Digitalization involves using digital technologies, innovations, and data to transform business models and practices digitalization and across the value chain, address bottlenecks, and increase incomes for

smallholder farmers. According to Zainudin et al. (2023), digital transformation is defined as the application of modern digital technologies (e.g., social/collaborative, cloud, mobile, and analytics). Digital transformation in aquaculture includes integrating technologies to boost efficiency, sustainability, and profitability. This involves tools such as Internet of Things (IoT) sensors, AI-powered analytics, and automation to optimize processes, manage resources more effectively, and support data-driven decision-making. Digital transformation is essential for increasing global competitiveness and helping access new markets more effectively (Qur'ani and Anshar, 2023). Competitive advantage refers to providing added value to consumers, enabling companies and stakeholders to achieve higher profits (Yanti & Astuti, 2023). Digitalization is a major force transforming economies across various sectors, benefiting not only MSMEs but also consumers in multiple ways (Utami and Prasetyo, 2023). Its goal is to improve food and nutrition security, build climate resilience, promote the inclusion of youth and women, and create a more efficient, resilient, and environmentally friendly aquaculture industry. The key aspects of digital transformation in aquaculture include precision farming, automation and robotics, data management and analysis, smart aquaculture systems, traceability, transparency, and sustainability.

Numerous studies have been conducted in the area of digitalization, for instance, Falola et al. (2024); Ali and Dwi (2025); Adebayo et al. (2025), which have shown that digital transformation improves the income and access to information of aquaculture farmers. Despite the popularity of digitalization, aquaculture does not appear to be better off. The majority of aquaculture farms still rely on manual data collection by human operators over prolonged periods. Thus, the operator's experience informs management and decision-making, which may be adversely impacted by human subjectivity (Biazi and Marques 2023). Therefore, this study aims to describe the socio-economic characteristics of fish farmers in the study area, examine the contribution of digital transformation on aquaculture growth in the study area, and investigate the effect of digital transformation before and after on output and income of fish farmers in the study area.

## MATERIALS AND METHODS

### The Study Area, Sample Procedure, and Sample Size

The study area was conducted in the Delta Central Agricultural Zone of Delta State, Nigeria. The state is in the Niger Delta Area of Nigeria. Out of 15 local government areas in the state, the Central Agricultural Zone has 9 local government areas. The vegetation covers freshwater, mangrove, and rainforest ecosystems, contributing to its suitability for various agricultural activities. However, agriculture is the primary livelihood, with a focus on both food and cash crops. Farming practices include crop production (such as yams, cassava, maize, and palm oil) are common. Fisheries (fish farming is a significant activity) and Livestock farming, which involves poultry, piggery, goats, sheep, and even fewer common animals like cane rats, snails, and bees, are reared. The zone is home to many urban and rural settlements, with agriculture serving as a major source of income and employment for the population. The climate is conducive to a wide range of food and cash crops.

### Sampling Techniques

The fish farmers under the Delta Central Agricultural Development Zone were used for the study. There were 205 registered fish farmers in the ADP zone, but only 187 were available for the analysis.

### Data collection

Data was collected from a well-structured digital questionnaire, a Computer-Assisted Personal Interview (CAPI), and an application installed on an Android phone.

### Data Analysis

In analysing the data, descriptive statistics such as means, percentages, and frequencies, and a T-test were

used to compare the aquaculture growth of fish farmers before and after digitalization transformation on input and output.

## RESULTS AND DISCUSSION

### Socio-Economic characteristics of fish farmers

This section mainly describes the personal characteristics of respondents involved in digital transformation for aquaculture growth. The statistical summary of the fish farmers' socio-economic characteristics is presented in Table 1. The results showed that most fish farmers (80. 7%) were males, while only 19. 3% were females. This suggests that fish farming is a male-dominated activity, likely due to the labour-intensive work involved. A larger proportion of the fish farmers (43. 3%) in the study area were between 35 and 44 years old, with a mean age of 38. 50 years, indicating an age group that is economically active and capable of utilizing digital transformation to improve their fishing activities. Younger farmers recognize the benefits of innovation in their farming and tend to have higher levels of technology use compared to older farmers (Nechar et al., 2021; Foguesatto and Machado, 2022). The household size distribution revealed that fish farmers have an average household of six members, reflecting the large size typical of rural farming households in Nigeria, which often rely on polygamous and extended family structures. This setup provides access to inexpensive family labour for farming operations (Chiemela et al., 2022; Falola et al., 2022c). The majority (53. 3%) were married, followed by singles (21. 39%), widows (11. 76%), divorced (5. 35%), and separated (8. 02%). Most respondents (98. 93%) were educated. This high level of education enhances their decision-making and ability to adopt new technology, as they are aware of its benefits (Akanbi et al., 2024; Boyaci, 2022; Gbigbi and Ndubuokwu, 2022; Mukaila et al., 2022). Additionally, using Information and Communication Technologies requires a certain level of education- at least enough to read information and operate the technology (Nectar et al., 2021). Most respondents (29. 9%) had an average of 8 years of fishing experience, indicating that they are experienced fish farmers with substantial knowledge of fish farming. Farming experience can positively influence their adoption of ICT-related innovations (Mansour, 2022). The respondents had an average monthly income of 140,855.12 Naira, suggesting that those engaged in digital transformation are likely to increase their income.

### Level of Contribution of digital transformation to aquaculture growth

The level of digital transformation to the growth of aquaculture, as perceived by the respondents, is shown in Table 2. The majority (74.9%) and (72.2%) of the respondents' contributions were high with increased income generation and enhanced efficiency, profitability, and sustainability, respectively. Furthermore, above half, (66.8%), (64.2%) (64.2%), (63.1%), and (63.1%) of the respondents had high contributions on enhanced access to information and knowledge, improved market linkages and access to finance, training and capacity building, record keeping and data collection, and improved traceability and transparency, respectively. Table 2 further illustrates that for improved farm management, better disease management, and enhanced biosecurity, digital transformation had a high contribution to aquaculture growth, with 53.5%, 53.0%, and 51.9% contributions, respectively. This implies that digital transformation contributes to aquaculture growth, and all the means are higher than the cut-off point mean of 1.00 according to the mean ranking.

**Table 1:** Distribution of the respondents according to their socioeconomic characteristics.

| Characteristics | Frequency | Percentages | Mean |
|---|---|---|---|
| Sex | | | |
| Female | 36 | 19.3 | |
| Male | 151 | 80.7 | |
| Total | 187 | 100 | |
| Age | | | |
| 25—34 | 67 | 35.8 | |
| 35-44 | 81 | 43.3 | 38.50 |
| 45-54 | 39 | 20.0 | |
| Total | 187 | 100 | |
| Household Size | | | |
| <4 | 40 | 21.4 | |
| 4-7 | 114 | 61 | 5.6 |
| >7 | 33 | 17.6 | |
| Total | 187 | 100 | |
| Marital Status | | | |
| Married | 100 | 53.33 | |
| Single | 40 | 21.39 | |
| Widowed | 22 | 11.76 | |
| Divorced | 10 | 5.35 | |
| Separated | 15 | 8.02 | |
| Total | 187 | 100 | |
| Level of Education | | | |
| No formal | 2 | 1.07 | |
| Primary | 14 | 7.49 | |
| Secondary | 61 | 32.62 | |
| Tertiary | 110 | 58.82 | |
| Total | 187 | 100 | |
| Year of Fishing Experience | | | |
| <4 | 43 | 23 | |
| 4-7 | 47 | 25.1 | 8.3 |
| 8-11 | 56 | 29.9 | |
| 12-15 | 20 | 10.7 | |
| >15 | 21 | 11.2 | |
| Total | 187 | 100 | |
| Major Occupation | | | |
| Fish farming | 138 | 73.8 | |
| Trading | 28 | 15 | |
| Civil servant | 6 | 3.2 | |
| Artisan | 15 | 8 | |
| Total | 30 | 100 | |
| Monthly Income | | | |
| <50,000 | 18 | 9.6 | |
| 50,001-100,000 | 48 | 25.7 | 140,855.12 |
| 100,001-150,000 | 70 | 37.4 | |
| >150,000 | 51 | 27.3 | |
| Total | 100 | 100 | |

***Source:*** *Field Survey, 2025*

**Table 2:** Distribution of respondents according to the level of contribution of digital transformation to aquaculture growth

| | Level of digital transformation for aquaculture growth. | | | | |
|---|---|---|---|---|---|
| **Contributions** | **High Contribution (2)** | **Contribution (1)** | **No Contribution(0)** | **Mean** | **Rank** |
| Increased income generation. | 140 (74.9) | 40 (21.4) | 7 (3.7) | 1.71 | 1 |
| Enhanced efficiency, profitability, and sustainability. | 135 (72.2) | 40 (21.4) | 12 (6.4) | 1.65 | 2 |
| Record keeping and data collection. | 118 (63.1) | 65 (34.8) | 4 (2.1) | 1.61 | 3 |
| Improved traceability and transparency. | 118 (63.1) | 65 (34.8) | 4 (2.1) | 1.61 | 4 |
| Improved market linkage and access to finance. | 120 (64.2) | 57 (30.5) | 10 (5.3) | 1.58 | 5 |
| Training and capacity building. | 120 (64.2) | 57 (30.5) | 10 (5.3) | 1.58 | 6 |
| Enhanced access to information and knowledge. | 125 (66.8) | 45 (24.1) | 17 (42.5) | 1.57 | 7 |
| Improved farm management. | 100 (53.5) | 78 (41.7) | 9 (4.8) | 1.48 | 8 |
| Better disease management. | 99 (53.0) | 70 (37.4) | 18 (9.6) | 1.43 | 9 |
| Improved Biosecurity. | 97 (51.0) | 72 (32.5) | 18 (9.6) | 1.42 | 10 |

***Source**: Field Survey, 2025. Figures in parentheses are percentages*

The distribution of the effect of digital transformation on aquaculture growth among respondents is shown in Table 3. The t-test analysis shows that the number of ponds (4) is higher after the effect of digital transformation, compared to before the effect of digital transformation, which was 3. Thus, there is a significant difference of 1 pond at 1% statistical level, resulting in a 59.90% increase in respondents' ponds. This implies that the effect of digital transformation has a positive effect on fish farmers in the study area. This is in agreement with Falola *et al*. (2025). Table 3 reveals that the pond size after the effects of digital transformation was 924.87$m^{3,}$ and before the effects of digital transformation was 797.60$m^3$. The difference in pond size of the fish farmers before and after the effect of digital transformation was 127.27 $m^3$, which is significant at the 1% statistical level. This resulted in a 15.94% increase in fish farmers' pond size, leading to higher production levels as there would be more pond space for an increase in the number of fingerlings stocked. Table 3 further depicts that the effect of digital transformation before and after on aquaculture growth was 733.12 fingerlings and 952.12 fingerlings. The number of fingerlings stocked after the effect of digital transformation increased by 219.7 fingerlings. This resulted in a 29.97% increase in the number of fingerlings stocked in the study area. It can be deduced that there is a significant difference in the number of fingerlings stocked by fish farmers before and after the effect of digital transformation at 1% level of significance. This implies that fish farmers were able to stock an additional 219.7 fingerlings on average in their ponds after the effect of digital transformation, which means that fish farmers would have access to farm inputs (fingerlings) due to the effect of digital transformation on farmers in the study area. Table 3 clearly shows that before the digital transformation, the yield was 742.25kg per production cycle. Following the impact of digital transformation, the yield per cycle was 1,059.81 kg per production cycle. The yield per production cycle increased by 315.53kg, which resulted in a 42.51% increase in fish yield. Thus, there is a significant

difference in the yield of fish farmers before and after the effect of digital transformation at 1% level of significance.

This emphasizes that the effect of digital transformation is necessary to boost fish farmers' production. This will consequently increase food and nutrition security. This corroborates the arguments of previous studies (Arouna et al., 2020; Quandt et al., 2020; Kudama et al., 2021) that digital technology increases production. The distribution of respondents for the effects of digital transformation on respondents shows that before the effect of digital transformation, respondents had 540, 905:11 Naira from their fish farms. Immediately after the digital transformation affected their fish farms, they had an average income of 780,444:98 Naira. The income generated before and after the digital transformation increased by 239,539:87 Naira per production cycle. This indicates that the effect of digital transformation resulted in a 44.29% increase in farmers' income. Thus, there is a significant difference in the income of farmers after the effect of digital transformation at 1% statistical level of significance. In other words, farmers in the study area experienced an increase of 239,539:87 Naira after the effect of digital transformation. This result implies that digital transformation in agriculture is a crucial aspect for enhancing farmers' output and income, which will consequently reduce the poverty of farming households due to its contribution to farm output. These findings support previous reports, as in Adebote et al., (2024), El-Bilali and Allahyari (2018), and Falola et al., (2021).

**Table 3:** Distribution of respondents based on the effect of digital transformation on aquaculture growth before and after on output and income.

| | Before Adoption | After Adoption | Mean Difference | t-value | Percentage Increase |
|---|---|---|---|---|---|
| Variables | | | | | |
| Number of ponds | 3.02 | 4.22 | 1.21*** | 18.305 | 59.90 |
| Pond size | 798.4 | 925.67 | 127.27*** | 12.8522 | 15.94 |
| Number of fingerlings | 733.12 | 952.83 | 219.71*** | 8.515 | 29. 97 |
| Yield per production cycle (Kg per harvest) | 742.28 | 1,057.81 | 315.53*** | 7.1594 | 42.51 |
| Income | 540,905:11 | 780,444:98 | 237.539:87*** | 6.8538 | 44,29 |

***Source:*** *Field Survey, 2025.*
****shows the mean difference is significant at 1% statistical level*

## CONCLUSION AND RECOMMENDATION

The study concluded that fish farmers in the study area were predominantly males, in their active age, educated, and had high incomes generated from their fish farming activities. The level of digital transformation had a positive contribution to aquaculture growth. The effect of digital transformation on fish farmers' output and income also increases, leading to poverty reduction, improved livelihood status, and farm inputs for aquaculture growth. Based on the study findings, fish farmers should be encouraged to know and learn more about digital transformation for aquaculture growth. The study further recommends that stakeholders include fisheries experts, fisheries extension agents, non-governmental organizations, government ministries and agencies, and institutions to come into play to create more awareness on digital tools that can be used to transform the aquaculture sector to make food

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# QUANTIFYING DNA AND RNA IN *Clarias gariepinus* EXPOSED TO DIFFERENT LIGHT-EMITTING DIODE COLOUR OF VARYING INTENSITY AND DURATION

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**ABSTRACT**
*Light characteristics such as colour, intensity, and duration is significant in the growth and development of fish in captivity. Light-Emitting Diode is adopted in recirculatory and aquapoincs fish systems. This study investigated the effects of Green 528 nm Red 628 nm, and Orange 590 nm LED with two different intensity levels of 60 ± 2 lux and 30 ± 2 lux each and four exposure durations of 4, 6, 8, and 10 hours on the genetic parameters of African catfish. The experiment was setup with solar powered LED exposed to catfish for a period of 8-weeks. At the end of the rearing trial, the DNA and RNA levels were determined after extracting 1g tissue samples using spectrophotometric method. The results showed that LED light treatments influence nucleic acid content in Clarias gariepinus. Under the green light, the lowest DNA content (2.82 μg/mg) was recorded at 60 lux for 10 hours, while the highest (2.88 μg/mg) was observed at 30 lux for 8 hours. Red light exposure at 60 lux for 6 hours yielded the highest overall DNA concentration (3.90 μg/mg). Conversely, the lowest DNA level among all treatments (2.80 μg/mg) was observed under orange light at 30 lux for 8 hours. The values of RNA although generally lower, its trend was well compared to DNA. These findings suggest that LED light parameters significantly modulate cellular activity in C. gariepinus, with red light showing the most pronounced physiological effect and it can be recommended for a moderate period of 6 hours.*

**Keywords**: C*larias gariepinus*, LED light, DNA, RNA

## INTRODUCTION

Aquaculture has emerged as one of the fastest-growing food-producing sectors globally, with an increasing demand for sustainable and efficient methods to enhance fish growth and health (FAO, 2022). Among various aquaculture species, C*larias gariepinus* holds significant economic importance in many developing countries due to its rapid growth, high feed conversion efficiency, and adaptability to diverse environmental conditions (Yakubu *et al*., 2020). Optimizing environmental factors, particularly light, has become a subject of growing interest in improving aquaculture productivity. Light plays a crucial role in regulating fish physiology, behaviour, and metabolism. It affects feeding activity, growth rate, immune function, and even reproductive performance (El-Sayed and El-Ghobashy, 2011). Artificial lighting, particularly using energy-efficient LED (Light Emitting Diode) technology, offers a promising tool for manipulating light characteristics such as colour (wavelength), intensity, and duration to create optimal conditions for aquaculture systems (Yeh *et al*., 2014). Previous studies have demonstrated that different light colours can elicit distinct physiological responses in fish species. For instance, red and blue wavelengths have been associated with enhanced growth and reduced stress in various cultured species (Noureldin *et al*., 2021; El-Sayed and Mansour, 2021). However, the influence of specific light regimes, especially combinations of colour, intensity, and photoperiod, on the growth performance and biochemical composition of C*larias gariepinus* remains underexplored. Furthermore, light-induced stress responses can influence metabolic processes, including the synthesis of proteins, lipids, and carbohydrates, thereby affecting the overall biochemical profile of fish (El-Sayed, 2005). Hence, this

study investigated the effects of Green, Red, and Orange LED with two different intensity levels and four exposure durations on the DNA and RNA levels in catfish.

## MATERIALS AND METHODS

### Experimental Setup

The experimental was conducted at Biofuel Research Laboratory at the Ibrahim Shehu Shema Center for Renewable Energy and Research (ISSCeRER), Umaru Musa Yar'adua University, Katsina State, from May to July 2024. Two hundred and sixty fingerlings fish with initial average weight of ±1.55g of mixed sex of catfish were collected from Bio resources Development Centre Katsina and were transported in the laboratory. After 2 weeks acclimatization, the fish were distributed in twenty-five (25) plastic fish tanks, each with a capacity of 30liters. The fishes were subjected to visible light spectrum at different LED wavelengths of Green 528 nm (G), Red 628 nm (R), or Orange 590 nm (O) with two different intensity levels of 60±2 lux (1) and 30±2 lux (2) each in duplicates. The light was generated by solar powered light emitting diode for varying durations of 4 hours, 6 hours, 8 hours, and 10 hours per day for a duration of 8 weeks. The control group was maintained without exposure to any visible light.

### Rearing and feeding

During the exposure period, the fish were fed a commercial feed equivalent to 5% of their body weight per day, divided into two feedings. All uneaten feeds were removed after 10 minutes post-feeding. The water in the rearing containers was renewed every two days for all the experimental setup.

### DNA and RNA quantification

At the end of the 8-week trial period, the DNA/RNA ratio was determined following Cestari and Stuart (2013) after extraction of DNA and RNA from 1g tissue samples and read its absorbance in UV radiation at 260 nm using spectrophotometer. The absorbance was measured, and the concentration is calculated against pure DNA sample.

### Statistical analysis

The collected data were analysed using two-way analysis of variance (ANOVA) between LED colour and wavelengths. The means differences were significance at $p<0.05$. Analysis were performed using SPSS statistical package version 23.

## RESULTS AND DISCUSSION

The nucleic acid content of C*larias gariepinus* showed significant variation across different LED light treatments and the control group, indicating differential biochemical and cellular activity under varying light intensities and durations (Table 1). In the green light, the lowest DNA content (2.82 $\mu$g/mg) was observed in catfish exposed to 60lux for 10hours. While the highest DNA concentration was recorded in catfish exposed 30 lux, 8hours with a value of (3.26 $\mu$g/mg) with significant difference ($p > 0.05$) among them. In the red light, the highest DNA content (3.90 $\mu$g/mg ) was observed in catfish exposed to 60lux for 6hours and this was the highest value among the three LED colours used. However, lowest DNA concentrations among the treatment was recorded in catfish exposed orange LED colour of 30lux for 8hours with a value of (2.80 $\mu$g/mg) (Table 1).

**Table 1:** DNA Level in Catfish Muscle under Green LED Light Conditions

| | Treatment | DNA level (μg/mg) | | |
|---|---|---|---|---|
| | | Green | Red | Orange |
| | Control | 2.83 ± 0.15[a] | 2.84 ± 0.10[a] | 2.84 ± 0.20[a] |
| 528 nm | 4hours | 2.85 ± 0.10[a] | 2.85 ± 0.15[a] | 2.83 ± 0.18[a] |
| 60±2 lux | 6hours | 2.97 ± 0.16[b] | 3.90 ± 0.10[c] | 2. 83 ± 0.15[a] |
| | 8hours | 2.95 ± 0.10[b] | 3.04 ± 0.15[b] | 2.88 ± 0.17[a] |
| | 10 hours | 2.82 ± 0.10[a] | 2.87 ± 0.18[a] | 2.87± 0.10[a] |
| 528 nm | 4hours | 2.85 ± 0.11[a] | 2.83 ± 0.11[a] | 2.83 ± 0.11[a] |
| 30±2 lux | 6hours | 2.85 ± 0.15[a] | 2.82 ± 0.10[a] | 2.89 ± 0.20[a] |
| | 8hours | 3.26 ± 0.10[a] | 2.88 ± 0.10[b] | 2.80 ± 0.10[a] |
| | 10 hours | 2.83 ± 0.13[c] | 2.85 ± 0.05[b] | 2. 83 ± 0.50[a] |

Values with similar superscripts across the column imply there is no significant difference at P>0.05.

**Table 2:** RNA Level in Catfish Muscle under Red LED Light Conditions

| | Ponds | RNA | | |
|---|---|---|---|---|
| | | Green | Red | Orange |
| | Control | 1.59± 0.20[b] | 1.53± 0.11[b] | 1. 57 ± 0.15[b] |
| 528 nm | 4hours | 1.51 ± 0.31[a] | 1.53 ± 0.25[b] | 1.48± 0.22[a] |
| 60±2 lux | 6hours | 1.51 ± 0.18[a] | 1.60 ± 0.11[c] | 1. 48 ± 0.10[a] |
| | 8hours | 1.52 ± 0.20[a] | 1.65 ± 0.20[c] | 1. 56 ± 0.20[b] |
| | 10 hours | 1.54 ± 0.23[b] | 1.47± 0.22[a] | 1.57± 0.15[b] |
| 528 nm | 4hours | 1.53± 0.12[b] | 1.46 ± 0.11[a] | 1..57 ± 0.20[b] |
| 30±2 lux | 6hours | 1.61 ± 0. 15[c] | 1.59 ± 0.30[b] | 1.59 ± 0.17[b] |
| | 8hours | 1.86 ± 0.20[c] | 1.54 ± 0.24[b] | 1.59± 0.20[b] |
| | 10 hours | 1.56 ± 0.21[b] | 1.56 ± 0.13[c] | 1.55± 0.20[b] |

Values with similar superscripts across the column imply there is no significant difference at P>0.05.

The RNA also showed significant difference between light colours and their intensities. In the green light, the highest RNA content (1.86 μg/mg) was observed in catfish exposed to 30lux for 8hours, this was also the highest RNA level observed among all the treatments. While the lowest RNA concentrations were recorded in catfish exposed 30 lux, 8 and 6 hours with a value of (1.52 μg/mg) (Table 2). The values of RNA were generally lower than DNA in all the treatments in this experiment.

The present study investigated the effects of different LED light exposure treatments on the DNA/RNA levels of C*larias gariepinus*. The findings reveal significant variations in these parameters as physiological indicators of the various light treatments, suggesting that light exposure exerts an influence on the health and development of catfish. The DNA and RNA absorbance levels reflect cellular activity and protein synthesis (Cestari and Stuart, 2013). Red light exposure led to significantly higher DNA and RNA absorbance levels compared to the other light treatments. This suggests that red light may stimulate cellular proliferation and protein synthesis, both of which are crucial for growth and development (Caraglia *et al*., 2000). Increased RNA content, in particular, is often linked to enhanced protein synthesis (Noller, 2012) which supports the higher growth observed in the red-light treatments. This result is consistent with Chen *et al*. (2022), who found that red light exposure enhances RNA synthesis in trout, potentially contributing to improved growth and metabolic function.

## CONCLUSION

This study demonstrates that LED light colour, intensity, and duration significantly influence the physiological and biochemical responses of *Clarias gariepinus*. Red LED light, particularly at 60±2 lux for 6 hours, was most effective in enhancing DNA and RNA synthesis, suggesting improved cellular activity. While orange light appeared less favourable for growth and nucleic acid synthesis. Future research should explore long-term effects of LED exposure on reproductive performance, immune response, and stress indicators to further refine lighting protocols for commercial aquaculture.

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# INFORMATION AND COMMUNICATION TECHNOLOGIES USAGE BY YOUTHS IN FISH FARMING IN EBONYI STATE NORTH AGRICULTURAL ZONE

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**ABSTRACT**
*The study assessed the usage of information and communication technologies among youths in fish farming in Ebonyi State North Agricultural Zone, to enable leveraging and dynamics of agricultural practices for sustainable development. A multistage sampling procedure was used to select 116 respondents. Data for the study was collected using interview schedule and analysed with descriptive statistics. Factor analysis was used to analyse the constraints. Result shows that Mobile phone had high level (100%) of use, followed by internet (64.96%) and Facebook (34.48%). The youth fish farmers' preference in use of ICTs showed that mobile phone (96.28%) was preferred followed by Internet (85.84%) and WhatsApp (67.28%). The constraints the youths faced in the use of ICTs include; high cost of device, low income of farmers, erratic power supply and low scale fish production among others. It was recommended that adequate training be given to the youth fish farmers by the extension officers in the use of multiple ICTs to increase their production and income. Supply of power and network services should be improved by the various bodies responsible for the services and a good government policy that will favour youths in farming be put in place.*

**Keywords**: ICTs usage, fish farmers, Ebonyi State North Agricultural Zone

## INTRODUCTION

Fish farmers need rapid access to emerging technologies as they are faced with many constraints and more in spite of job opportunities. In addition to being profitable, they need to meet environmental standards and regulations, as well as deal with direct and indirect consumer and lobby group pressures. Fish farmers may also be flooded with information from government and industry that make choosing appropriate technologies difficult, these innovations which transform economy and sustain livelihood make farmers change their production and management practices in response to agricultural policies that include environmental conditions (Sulaiman, et al. 2022).

Information and communication technologies (ICTs) play inevitable roles in every aspect of human activities today, including agriculture. The key players in agriculture are the farmers, and their ability to use improved technologies defines the role of ICT in agriculture generally (Nwagwu and Opeyemi, 2015). The use of ICTs seems to be on the increase now globally as it increases access to and exchanging of information, ICT offers the potential to increase efficiency, productivity, competitiveness and growth in various aspects of agricultural sector. Those that engage in agriculture in small scale utilize various forms of ICT such as mobile phones, computers, the internet, and so forth (Yekinni *et al.* 2019). ICTs have been a great companion in sustainable development issues in remote areas as it enhances production capacity of the rural dwellers. Similarly, they can be used to breakdown both national and international barriers and have turned the world into a universal village, making information available to everyone, everywhere and at the needed time (Ogbonna and Agwu, 2013). The rapid growth in the demand for fish and fish products in Nigeria call for provision of efficient flow of information and knowledge to the fish farmers, without gender prejudice, for better decision making. Fish farming has become a common practice to

increase income of practitioners and in the process reduce the wage bill expended on fish importation (FAO, 2022). Fish farmers thus need information to optimize production (Zeinab *et al.* 2014). Chhiato (2018) asserted that information dissemination is the activity of conveying and spreading one's ideas and knowledge through the exchange of thoughts, messages, as by symbols, signs, speeches, visuals, signals, writing, or behavior; and also, it is the meaningful exchange of information between two or among a group of people. Bello and Aghadiuno (2019) summarized information dissemination as the channel through which facts are linked to the rightful individual seekers and organizations. All these may not be achieved without the necessary information and communication technology (ICT) in place.

Information technology in Nigeria has gone a long way, but despite its existence, there seems to be limited access and utilization of these technologies. Consequently, there is the need to examine the utilization of ICTs by fish farmers in Ebonyi State North agricultural zone. Zango (2019) stressed that without constant power supply, the ICT facilities and equipment cannot be fully used for global purposes. There is dearth of information and data in this important area of agriculture in the study area.
Objective of the study: The major objective of the study was to assess the level of use of ICTs among youth fish farmers in Ebonyi State North Agricultural zones of Ebonyi State.

## MATERIALS AND METHOD

This study was carried out in Ebonyi North agricultural zones of Ebonyi State, comprising of Abakaliki, Ebonyi, Izzi and Ishelu Local Government Areas. A multistage sampling technique was used in the study. Four communities from each of Local Government Areas were purposely selected because of their fish farming activities. Twenty percent of fish farmers were selected through random sampling procedure from each of the twelve communities to give a total of 116 respondents.

Data were collected with the use of interview schedule from the selected respondents. The interview schedules were personally administered by the researcher.

Descriptive statistics was used to show the frequency, percentages and means. Factor analysis was used to determine the constraints of the fish farmers in the use of ICTs.

**Table 1:** Sample size selection

| Ebonyi North Agricultural zone | LGA | Communities | Sample frame | Sample size |
|---|---|---|---|---|
| | Abakaliki | Abakpa | 45 | 9 |
| | | Amachi | 36 | 7 |
| | | Amagu | 48 | 10 |
| | | Azuiyiokwu | 41 | 8 |
| | Ishielu | Ezillo | 51 | 10 |
| | | Obeagu | 49 | 10 |
| | | Agba | 66 | 13 |
| | | Ntezi | 50 | 10 |
| | Izzi | Abaja | 44 | 9 |
| | | Igbeagu | 58 | 12 |
| | | Mgbala Ukwu | 45 | 9 |
| | | Ndieze | 46 | 9 |
| | | Total | 579 | 116 |

*Source; Adapted from Ebonyi State Ministry of Agriculture Fisheries Sector 2023.*

## RESULTS AND DISCUSSION

Table 2 below shows that new technological applications are being used across the fisheries value chains (inland and aquaculture). Mobile phones as well as traditional media such as the radio are used in promotion of agricultural development. ICTs are known to enhance or expand human networks (Yun *et al*. 2016). Mobile technology has a particularly positive impact in this area, fosters networks of farmers and agribusiness, so that they can support each other. Specialized applications are developed to further extend this impact, mobile phones for trading and emergencies, radio programming targeted at and in many cases compiled by fishing communities and Web-based serves fisheries specific information and networking resources (Ejiogu-Okeke, *et al.*, 2016). Nwobodo and Nwabugwu (2016) reported a high usage of ICTs by farmers in Anambra State, Nigeria. Wole-Alo and Oluwagbemi (2020) reported a high level of usage of ICTs by farmers in Ondo State, Nigeria.

**Table 2:** Level of ICTs usage in the study area

| ICT | High F (%) | Low F (%) | Moderate F(%) | Not used F (5) | Mean |
|---|---|---|---|---|---|
| Mobile phone | 116(100 %) | - | - | - | 4 |
| WhatsApp | 8(6.90) | 5(4.31) | 103(88.79) | - | 2.98 |
| Radio | 9(7.76) | 7(6.03) | 99(85.34) | 1(0.86) | 2.95 |
| Video CD | - | 70(60.34) | 7(6.03) | 39(33.62) | 1.67 |
| E-mail | 19(16.38) | 44(37.93) | 38(32.76) | 15(12.93) | 2.46 |
| Facebook | 40(34.48) | 44(37093) | 15(12.93) | 17(14.66) | 2.59 |
| Internet | 56(64.96) | 20(17.24) | 20(17.24) | 20(17.24) | 3.10 |
| Satelite Television | 5(5.93) | 132(52.17) | 25(9.88) | 81(32.02) | 2.3 |
| Home video | 6(5.17) | 29(25) | 81(69.83) | - | 2.75 |

*Source; Field survey 2023*
*Figures outside the parenthesis are frequencies and those inside parenthesis are percentages*

The video CDs are used by the fish farmers in watching documentaries on fish farming and programmes, Satellite television helps deliver signals in areas where customers may not be served by cable television or "terrestrial" broadcasting. The fish farmers use the television in watching the State broadcast on agricultural programmes example fish productions in the State. This result agrees with the assertion that among modern ICTs, mobile phones serve as a means for effective transfer of knowledge and information about agricultural market and technology to farmers that enable them to apply the knowledge directly to improve their farming output and make easy access to market (Chhachhar *et al.*, 2014). Digital and electronic technologies are transforming our economies, societies and lives. Technology has had a profound impact on the information and communication technologies.

### Preferred ICTs by the Respondents

Table 3 revealed the preferred ICT among the farmers. A good number the youths (96.28%) preferred Mobile phones. Mobile phones are used in various ways; used for making calls, sending short messages. Those with Android mobile phones could check their e-mails, browse the internet and send messages through Facebook, WhatsApp, telegram and Instagram. They could listen to radio programmes and use it as television. It shows that the fish farmers are literate and can make use of electronic media. The result indicates that use of mobile phones are reliable for adoption. New information and communication technologies are used across the fisheries value chains (maritime, inland and aquaculture). In addition, motivating farmers in adoption of new agricultural technologies remained a focal point of the agricultural extension (Muddassir *et al.*, 2016). Several studies have been conducted and prove that fish farmers

prefer mobile phone with different purposes and goals. It has been observed by different experiences that modern fish farmers require accurate and reliable information. Mobile phones are good source of communication to connect with customers' relatives and friends on market prices and availability of technologies. This aid adoption of improved fish production technologies.

Use of this technology improves fish farmers' basic livelihoods in indirect ways. In this case it has been observed that mobile phones empowered the life of the fish farmers for trading and exchanging the information about weather, danger and location among each other. By using mobile communication technologies their lives improved. Furthermore, mobile phones provides opportunities to fish farmers and merchants to communicate with each other by calls, short message services (SMS) even farmers could sell their product while still harvesting (Zango, 2019). This study showed that mobile phone, Internet, Facebook, WhatsApp, e-mail and radio were the most commonly preferred ICTs.

**Table 3:** Preferred ICTs by the Respondents

| ICT | Percentage |
|---|---|
| Mobile Phone | 96.28 |
| Internet | 85.84 |
| WhatsApp | 67.28 |
| Facebook | 48.72 |
| E-mail | 46.4 |
| Radio | 45.24 |
| Statelite television | 31.32 |

*Source; Field survey 2023*

**Constraints Faced by the Fish Farmers in Accessing ICT Facilities in Ebonyi State North Agricultural Zone.**

Table 4 shows that there were three major categories of constraints faced by the youth fish farmers in accessing information in Ebonyi North Agricultural Zone, namely; Socio-economic constraints (Factor1), Administrative constraints (Factor 2) and Environmental constraints (Factor 3). This is in line with the works of Yekinni *et al*. (2019) who indicated that fish farmers are facing many problems and hindrances in ICT usage.

These three major categories of constraints have several implications as far as use of ICTs is concerned. Firstly, socio-economic constraints can adversely affect fish farmer's access to ICTs facilities and this in turn, can affect its use. Take for instance, high cost of devices, low income of fish farmers can mar fish farmers' accessibility to ICT facilities.

Secondly, administrative constraints such as erratic electricity power supply, fluctuation of services, lack of maintenance can adversely affect accessibility of fish farmers to ICTs and this in turn, can slow down the rate of use.

Thirdly, Environmental constraints such as poor access to ICTs can affect both accessibility of fish farmers to ICTs. Take for instance, poor connectivity to internet due to remoteness of some rural areas to urban centers where ICT facilities are found may hinder fish farmers from having access to ICTs.

Besides, some ICT facilities are too complex for rural fish farmers to comprehend or understand and put into use. This result agrees with the works of Aphunu and Atoma (2011) who found that lack of government enabling policy is one of the main pressing constraints to effective usage of ICTs in Nigeria. Maintenance problems, low scale of fish production and rural poverty were also identified as serious

constraints to ICTs use by youth fish farmers. Suleiman *et al.,* (2022) stated that government's low level of assistance to ICTs infrastructural provision and absence of any policy to encourage farmers gain ICT education pose as threats to agricultural development. Ejiogu-Okeke *et al*. (2016) in their work in Rivers State found that; high cost of device, low income of farmers, low level of education, poor access to ICT device and erratic power supply are major constraints in the use of ICTs by the fish farmers.

**Table 4:** Factor Analysis of Constraints to Accessing Information by Fish Farmers

| | Variable | Factor 1 | Factor 2 | Factor 3 |
|---|---|---|---|---|
| 1 | High cost of devises (HCD) | 0.5496* | -0.353 | 0.1474 |
| 2 | Low Income (LI) | 0.6209* | -0.1213 | 0.0451 |
| 3 | Poor Access to ICTs (PAI) | -0.2258 | 0.2317 | 0.6888*** |
| 4 | Erratic Power Supply (ESP) | -0.4453 | 0.6964** | 0.2103 |
| 5 | Poor connectivity (PC) | -0.3626 | 0.3214 | 0.0616 |
| 6 | Inadequate policy framework (IPF) | -0.0929 | 0.5378** | 0.2562 |
| 7 | Low scale of fish production (LSFP) | -0.2868 | 0.554** | 0.2356 |
| 8 | Low skills (LS) | 0.3669 | 0.3261 | 0.1387 |
| 9 | Low awareness/knowledge (LAK) | 0.4265* | 0.3020 | -0.0024 |
| 10 | Language Barrier (LB) | 0.3616* | 0.4149 | -0.1599 |
| 11 | Lack of interest (LI) | 0.6796* | 0.1601 | -0.2567 |
| 12 | High Call Tariff (HCT) | -0.1126 | 0.5548** | 0.1598 |
| 13 | Poor Maintenance of tools (PMT) | -0.5015 | 0.4644** | 0.1846 |
| 14 | Complexity of ICTS (CI) | 0.1419 | 0.0603 | -0.1180 |

*Source; Field survey 2023*
*Method: Varimax with Kaisar normalization*
** - Socio-economic cum cultural constraints (Factor 1)*
*** - Administrative constraints (Factor 2)*
**** - Environmental constraints (Factor 3)*

## CONCLUSION

ICT plays important roles in fish farming. ICT devices such as mobile phones are highly used, also Facebook, email, radio, WhatsApp and home video are used at a certain high level in the study area. The results showed various other levels of use of the ICTs. The fish farmers preferred mobile phones in their fish farming activities followed by Facebook and radio. This implied that ICT increases production and accessibility of fish among the farmers and customers. Adequate training should be given to the youth fish farmers by the extension officers in the use of multiple ICTs to increase their productivity and income. Supply of power and network services should be improved by the various bodies responsible for the services and a good government policy that will favour youths in farming be put in place.

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# DEVELOPMENT OF LOCALLY SOURCED PROBIOTICS FOR AQUACULTURE: A STUDY ON LACTIC ACID BACTERIA

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**ABSTRACT**
*The applications of Lactic acid bacteria (LAB) in Aquaculture are profound, thus necessitating the development of cost effective ways of producing these LABs locally. This study was designed to produce probiotics using different materials sourced locally. Ten treatments, divided into 3 fermentation groups, were conducted as follows: fermentation of raw and boiled milk (treatments 1-2); fermentation of aquatic plants (treatments 3-6) and fermentation of cereals (treatments 7-10). Products from the different treatments were isolated and identified using biochemical tests, microscopic and macroscopic examinations. The treatments that yielded Lactic acid bacteria (LAB) were further tested for their antimicrobial activity against Aeromonas hydrophila, Bacillus spp and Proteus mirabilis using the disc diffusion method.Antibiotic sensitivity tests were also conducted using the disc diffusion method. The results revealed that Treatment1 (T1), Treatment 8 (T8), Treatment 9 (T9) and Treatment 10 (T10) yielded Lactobacillus species, (LABs). These results indicate that fermenting raw cow milk with rice-wash water (T1) and fermenting millet (T8) and maize (T9) gave substantial amount of LABs. Fermentation of aquatic plants (water hyacinth and duckweed) proved not to be good materials for producing LABs as most of them did not yield any LABs growth. Fermentation of rice-rinse water and milk; fermentation of millet and the fermentation of maize are practical ways of producing probiotics and are thus recommended. These materials can be used by local farmers to produce these beneficial microorganisms and harness their benefits thereof.*

**Keywords:** Probiotics, milk, pap, fish

## INTRODUCTION

Probiotics are live microorganisms which, when added to the fish's diet, confer several health benefits (Heggland, 2024). They can be used as growth promoters and for therapeutic purposes (Ramakrishnan *et al*., 2008). Probiotics may be a single species of microorganisms or a mixture of species. Probiotics can have antimicrobial effect thru editing the intestinal microbial stability, secreting antibacterial substances (bacteriocins and organic acids), formation of bio-film to protect the intestinal mucosal membrane, competing with pathogens to prevent their adhesion to the intestine, competing for nutrients vital for pathogen survival, and producing antitoxin effect (Heggland, 2024 and Wang *et al.*, 2020). Probiotics are also capable of modulating the immune system, regulating the allergic response of the body, and lowering the proliferation of cancer in mammals (Wang *et al*., 2008). They can also improve the water quality of the aquaculture systems (Wang *et al.*, 2020) Lactic acid bacteria (LAB) are one of such groups of micro-organisms known for their probiotic properties. In general, LAB are described as Gram-positive rod or cocci shaped bacteria that are acid tolerant, devoid of cytochromes and porphyrins and therefore are catalase- and oxidase-negative. LABs are anaerobic, but aero-tolerant, non-spore-forming, and are mostly non-motile bacteria (Stiles and Holzapfel, 1997; Jay *et al*. 2005; Holzapfel *et al*. 2014). LABs are well known to ferment carbohydrates to produce lactic acid as a major end product, hence, they are widely used in the fermentation of foods (Bintsis, 2018).

Some LAB species (Lactobacillus, Streptococcus, Enterococcus and Pediococcus) have been reported as active candidates for probiotic use in humans and animals by several researchers (Fuller, 1991). Selection of lactobacilli as potential health-promoting probiotic in food and pharmaceutical preparations entails in vitro screening for certain criteria, which include antibiotic tolerance, bile tolerance, inhibiting the growth of other microorganisms and gastric juice (acid) tolerance which allows them to be established in

the intestinal tract (Vantsawa *et al.*, 2017). In Aquaculture, LABs have been reportedly used to boost fish growth, (Jackson *et al*. 2022; Opiyo *et al*. 2019; Merrifield *et al.* 2010); Improve fish health (Al- Dohail *et al*. 2009) and Improve the water quality of the aquaculture systems (Aly *et al.* 2008).

It is therefore imperative that cost effective ways of producing these LAB locally be developed in order to help the local farmers harness the benefits of these probiotics. Therefore this research was tailored to investigate different materials for producing probiotics locally and its implications for Aquaculture.

## MATERIALS AND METHODS

### Local Production of Probiotics

Three groups of fermentation were carried out viz: fermentation of milk (treatments 1-2); fermentation of aquatic plants (treatments 3-6) and fermentation of cereals (treatments 7-10). Various materials were used to produce probiotics as follows:

Treatment 1 and 2 were prepared using raw cow milk and boiled cow milk respectively, according to the method described by Ikeda *et al.* (2013). Unpolished rice weighing 250 grams was measured and washed with sterile water of 500ml for about 5 minutes. After washing, the rice was sieved and the water was collected and stored for 3 days in a tightly closed container. The fermented rice water was then added to one litre of raw milk/ boiled and cooled milk at a ratio of 1:10 before being stored for another 5 days in a container covered with muslin cloth. The mixture was kept in a dark room during this process. On the 5th day, the solid layer was removed and probiotics (liquid part) was collected into sterile bottle and used for bacteriological analysis.

Treatment 3 and 5 were prepared using water hyacinth and duckweed respectively. According to the method of Wafula *et al. (*2023), each aquatic plant (Water hyacinth/ duckweed) collected from Jabi Lake, Abuja, was thoroughly washed and chopped into smaller sizes and poured into airtight container. Sterile water was added and 2.5% of salt was added into the mix. A sterile weight was used to keep the vegetables under water inside the container and the container was tightly closed for 5 days. After 5 days, the fluid was decanted into sterile bottle and used for bacteriological analysis

Treatment 4 and 6were prepared using water hyacinth and duckweed respectively. Using the modified method of Wafula *et al. (*2023), each aquatic plant (Water hyacinth/ duckweed) collected from Jabi Lake, Abuja, was thoroughly washed and chopped into smaller sizes and poured into airtight container. Fermented rice water was added and 2.5% of salt was added into the mix. A sterile weight was used to keep the vegetables under water inside the container and the container was tightly closed for 5 days. After 5 days, the fluid was decanted into sterile bottle and used for bacteriological analysis.

Treatments 7, 8 and 9 were achieved using White guinea corn, Millet and Maize respectively. According to the method of Okeke *et al*. (2021), two hundred and fifty grams of each cereal was sorted to remove debris, washed using sterile water and then steeped in water for 48 hours. Afterward, it was wet-milled, sieved and the filtrate obtained was spontaneously fermented for 48 hours and decanted to recover the fermented cereal filtrate (pap) The decanted fluid was used for bacteriological analysis

Treatment 10 was carried out by modifying the method of Ikeda *et al.* (2013). Unpolished rice weighing 250 grams was measured and washed with sterile water of 500ml for about 5 minutes.After washing,the rice was sieved out and the water was collected and stored for 3 days in a tightly closed container. After 3 days, the fluid was decanted into sterile bottle and used for bacteriological analysis

**Bacteriological Analysis of Probiotics**
**Isolation and Identification of isolates**
MRS (De Mans, Rogosa and Sharpe) agar and broth medium in powdered form was weighed and reconstituted using sterile water according to manufacturer's instruction (TITAN Biotech Ltd., India) and sterilized at 121°C and 15PSI for 15 minutes before cooling. 25 ml each of the collected samples was homogenized in sterile normal saline. Serial dilution up to $10^{-6}$ was made using a sterile pipette by transferring 1ml from 10 ml of the normal saline culture into 9 ml of diluent in sterile test tubes. Enumeration of LAB was done by pipetting and plating out appropriate dilutions using MRS agar. Plates were incubated in an inverted manner at 37°C for 48hours. After incubation, colonies were counted and recorded as colony forming units (CFU). Morphologically distinct colonies were sub-cultured and purified by streaking on agar plates repeatedly. LAB culture were maintained on MRS agar slant at 4°C (Vantsawa, *et al.* 2017).

Using standard microbiological procedures of Cheesbrough (2006) and Erkmen (2015), bacterial characterization was done. Isolates were characterized after 48 hours of incubation using: macroscopic examination for shape, elevation, colony size, consistency and colour; microscopic examination by gram staining; growth at 15°C and 45°C and; biochemical tests (coagulase, oxidase, catalase, citrate-utilization, fermentation of carbohydrates, indole, urease, etc.) (Harrigan and McCance, 1976)

**Antimicrobial effect**
The antimicrobial effect of all isolated Lactobacilli species against *Aeromona hydrophila*, *Bacillus spp* and *Proteus mirabilis* was determined by the disc diffusion method. MRS agar plates were prepared with 0.1 ml for each of the identified Lactobacilli strains. Standard antimicrobial susceptibility test discs (Sigma-aldrich) was prepared and applied to the surface of the plates and incubated for 18 hours at 37°C. Following incubation, zones of inhibition surrounding the discs were measured (Vantsawa *et al.* 2017).

**Antibiotic sensitivity test**
The antibiotic susceptibility of LAB was determined by the disc diffusion method. Different discs of antibiotic used were: Cefotaxime, Meropenem, Sulphamethoxazole-Trimethoprim, Ceftazidime, Ampicillin, Gentamycin, Vancomycin, Tetracycline, Clindamycin, Piperacillin, Norfloxacin, Teicoplanin (Oxoid, Thermo Fisher Scientific Inc., Waltham, MA, USA).
Briefly, 200 $\mu$l of suspended culture in sterile water was taken and spread over the surface of Mueller-Hinton agar (Thermo Fisher Scientific Inc., Waltham, MA, USA) plate. After drying, the antibiotic discs were placed over the plates and incubated at 37°C for 24 hours. The degree of sensitivity of the LAB isolates to the antibiotics was determined by measuring the zone of clearance around the antibiotic discs (Bauer *et al.* 1966).

## RESULTS AND DISCUSSION
Table 1 shows the Identification of the Bacterial Isolates produced using the various methods. The table reveals that T1, T8, T9 and T10 yielded Lactobacillus species, (LABs). These results indicate that fermenting raw cow milk with rice-wash water (T1) and fermenting millet (T8) and maize (T9) gave substantial amount of LAB.

It was observed that fermenting boiled cow milk did not yield any LAB which suggests that beneficial organisms in the milk would have been destroyed or that the required enzymes and nutrients for LAB growth would have been deactivated in the milk due to the heat treatment. In line with the report of the present study, Ikeda *et al.* (2013) opined that fresh cow or goat milk, which is high in lactose (milk sugar), is an ideal food source for LAB proliferation, and it is best, if the milk is unpasteurized and does not contain any antibiotics.

The result of this work also shows that fermented rice-wash water (T10) contained a considerable amount of LAB, though the value was lower than that of the rice-water and milk fermented treatment (T1). Ikeda *et al.* (2013) presented clarity to this process while describing the procedure involved in the production of LAB. They reported that although colonies of LAB can be collected in rice-rinse water, other microorganisms other than LAB are also present, but allowing the rice rinse water to sit for 3 to 5 days will cause LAB to become the predominant species and the addition of milk serves as a food source for the LAB, Since the rice-rinse water is low in nutrients.

Fermentation of millet and maize produced substantial amounts of LAB, thus making the traditional pap a very healthy food. This is corroborated by the reported works of Ude *et al.* (2021) and Nwachukwu *et al.* (2010) who observed different strains of LABs in various fermented cereals.

Fermentation of aquatic plants (water hyacinth and duckweed) proved not to be good materials for producing LABs as most of them did not yield any LAB growth. This is at variance with the report of Wafula *et al. (*2023) who reported that a total of 57 LAB strains were isolated when African indigenous leafy vegetables were fermented using the same method as that of the present study. This difference may have resulted from the difference in the type of plant used, where aquatic plants were used in the present study and terrestrial plants were used in the work of Wafula *et al*. (2023).

**Table 1:** Identification of Bacterial Isolates produced using different materials

| Treatment | TBC (CFU/ml) | Bacteria Isolates |
|---|---|---|
| 1 | $1.50 \times 10^5$ | *Lactobacillus* spp, *Bacillus* species (spp) |
| 2 | $1.21 \times 10^5$ | *Proteus mirabilis, Aeromonas hydrophila* |
| 3 | $1.67 \times 10^5$ | *Proteus mirabilis, Proteus vulgaris* |
| 4 | $3.14 \times 10^5$ | *Bacillus* spp, *Escherichia coli* |
| 5 | $3.06 \times 10^5$ | *Proteus* spp.,*Klebsiella aerogenes* |
| 6 | $2.12 \times 10^5$ | *Lactobacillus* spp, *Escherichia coli* |
| 7 | $3.06 \times 10^5$ | *Staphylococcus aureus* |
| 8 | $2.11 \times 10^5$ | *Lactobacillus* spp |
| 9 | $1.08 \times 10^5$ | *Lactobacillus* spp |
| 10 | $3.0 \times 10^4$ | *Lactobacillus* spp |

**Table 2:** Biochemical Characterization of Isolates

| Biochemical test | *B. subtilis* | *E. coli* | *Proteus* spp | *S. aureus* | *Bacillus* spp | *Lactobacillus* spp | *A. hydrophila* |
|---|---|---|---|---|---|---|---|
| Gram stain | GPR | GNR | GNR | GPC | GPR | GPR | GNR |
| Catalase | + | + | + | + | + | - | + |
| Citrate | - | - | NA | - | - | - | - |
| Coagulase | NA | NA | NA | + | NA | NA | NA |
| Gelatin hydrolysis | - | - | - | - | - | - | - |
| Hemolysis | - | - | - | - | + | - | + |
| TSIA | NR | AAG | AAG | NA | NR | - | AAG |
| H2S | - | - | + | NA | - | - | - |
| Indole | - | + | - | - | - | - | - |
| Motility | + | + | + | - | + | - | + |
| Oxidase | - | - | - | - | - | - | + |
| Urease | + | - | + | + | + | - | + |
| Adonitol | - | - | - | | - | - | - |
| Arabinose | + | + | - | | + | + | + |
| Cellobiose | + | - | | - | + | + | + |
| Dulcitol | - | - | | | - | - | - |
| Glucose | + | + | + | | + | + | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Inositol | + | + | - | | + | - | + |
| Lactose | + | - | - | - | + | + | + |
| Maltose | + | - | - | + | + | + | - |
| Mannitol | + | - | | + | + | - | + |
| Mannose | + | - | - | + | + | + | + |
| Melibiose | - | + | + | | - | - | - |
| Raffinose | - | - | - | - | - | - | - |
| Rhamnose | + | - | - | | + | + | + |
| Salicin | - | - | + | - | - | + | - |
| Sorbitol | + | + | + | | + | | + |
| Sucrose | - | - | | + | - | + | - |
| Trehalose | + | + | + | + | + | - | + |
| Xylose | + | + | + | - | + | + | - |

Key: GPC = Gram positive cocci, GNR = Gram negative rod. GPR = Gram positive rod,
NA = Not applicable NR = Non reactive

**Table 3:** Antibiotic susceptibility testing of the Bacterial isolates

| Bacteria Isolates | Antibiotics and Diameter of Zones of Inhibition (mm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CTX (30 μg) | N (10 μg) | AMP (10 μg) | TE (30 μg) | P (100 μg) | CAZ (30 μg) | CD (2 μg) | MEM (10 μg) | SXT (23.75 /1.25 μg) | VAN (30 μg) | CN (10 μg) | TEC (30 μg) |
| *Lactobacillus* spp (TI) | 6(R) | 6(R) | 6(R) | 11(R) | 6(R) | 6(R) | 6(R) | 10(R) | 6(R) | 6(R) | 16(S) | 6(R) |
| *A.* Hydrophila (T2) | 18(R) | 10(R) | 6(R) | 16(S) | 6(R) | 6(R) | 6(R) | 16(R) | 15(R) | 6(R) | 17(R) | 13(R) |
| *Proteus mirabilis* (T2) | 22(R) | 13(I) | 6(R) | 18(S) | 6(R) | 19(I) | 6(R) | 16(S) | 6(R) | 6(R) | 19(S) | 6(R) |
| *Proteus mirabilis* (T3) | 28(S) | 13(I) | 6(R) | 16(S) | 6(R) | 6(R) | 6(R) | 19(S) | 6(R) | 6(R) | 20(S) | 6(R) |
| *Bacillus* spp (T4). | 20(R) | 6(R) | 6(R) | 6(R) | 6(R) | 6(R) | 6(R) | 14(I) | 13(I) | 6(R) | 15(S) | 6(R) |
| *Lactobacillus* spp (T6) | 16(R) | 14(I) | 6(R) | 15(S) | 6(R) | 6(R) | 6(R) | 28(S) | 10(R) | 6(R) | 22(S) | 6(R) |
| *S. aureus* (T7) | 21(R) | 12(R) | 6(R) | 10(R) | 6(R) | 6(R) | 6(R) | 20(S) | 6(R) | 11(I) | 22(S) | 13(R) |
| *Lactobacillus* spp (T8) | 14(R) | 6(R) | 20(S) | 6(R) | 6(R) | 6(R) | 10(R) | 6(R) | 6(R) | 16(I) | 6(R) | 12(R) |
| *Lactobacillus* spp (T9) | 23(I) | 9(R) | 6(R) | 6(R) | 6(R) | 6(R) | 6(R) | 12(R) | 22(S) | 6(R) | 16(S) | 10(R) |
| *Lactobacillus* spp (T10) | 6(R) | 6(R) | 6(R) | 15(S) | 6(R) | 18(I) | 6(R) | 6(R) | 6(R) | 6(R) | 6(R) | 6(R) |

Key: CTX=Cefotaxime, MEM=Meropenem, SXT=Sulphamethoxazole-Trimethoprim, CAZ= Ceftazidime,
AMP=Ampicillin, CN = Gentamycin, VA = Vancomycin, TE = Tetracycline, CD = Clindamycin,
P = Piperacillin, N = Norfloxacin, TEC = Teicoplanin, S=Sensitive, I=Intermediate, R=Resistant

**Table 4:** Antimicrobial activity of *Lactobacillus* species against pathogenic bacteria

| Bacterial isolate | Antimicrobial activity of *Lactobacillus* species/Diameter of zones of inhibition (mm) | | |
|---|---|---|---|
| | LAB(T1) | LAB (T8) | LAB (T9) |
| *Aeromonas hydrophila 1* | 16 (S) | 13 (S) | 0 (R) |
| *Aeromonas hydrophila 2* | 12 (S) | 0 (R) | 0 (R) |
| *Bacillus species* | 11 (S) | 0 (R) | 13 (S) |
| *Proteus mirabilis* | 10 (S) | 15 (S) | 16 (S) |

Table 2 shows the biochemical characterization of the isolates.

Table 3 shows the antibiotic susceptibility testing of the Bacterial isolates. The table reveals that *A. hydrophila* was resistant to all the antibiotics except tetracycline and *lactobacillus spp* as resistant to all the antibiotics except for Gentamycin. This is an indicator of the antibiotic resistivity of many bacterial strains majorly due to indiscriminate use of antibiotics.

Table 4 shows the antimicrobial activity of *Lactobacillus* species against pathogenic bacteria. The result reveals that *A. hydrophila* showed sensitivity to some of the LAB strains isolated while *Proteus mirabilis* was sensitive to all of the LAB strains isolated. This concurs previous assertions that probiotics produce bacteriocins and other antibacterial substances capable of inhibiting pathogenic bacteria. In line with this, Maulianawati *et al.* (2022) deduced that the use of some strains of probiotics (*Lactobacillus acidophilus* and *Staphylococcus*) could prevent the Motile *Aeromonas septicemia* disease on C. *gariepinus* after observing that the combined use of these probiotics significantly increased the survival rate of C. *gariepinus* infected by the Motile *Aeromonas septicemia* disease.

The application of LAB in aquaculture is profound. Jackson *et al.* (2022) reported that *Probiotics (Lactobacillus and Leuconostoc)* inclusion in the diet of C. *gariepinus* improved growth performance of the fish above non-inclusion. Similarly, Nwanna, *et.al.* (2017) concluded in their study that *Lactobacillus plantarum* can be used as a growth promoter in C. *gariepinus* juveniles.

## CONCLUSION

Fermentation of rice-rinse water and milk; fermentation of millet and the fermentation of maize are practical ways of producing probiotics and are thus recommended. These materials can be used by local farmers to produce these beneficial microorganisms and harness their benefits.

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# ADDENDUM I- OMISSIONS FROM ABUJA 2023

# WILLINGNESS TO ADOPT PRIVATE EXTENSION BY CAT FISH FARMERS IN LAGOS STATE, NIGERIA

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**ABSTRACT**
*This study examined the willingness of fish farmers to adopt private extension services in Lagos State. The study in particular investigated their socio-economic characteristics, their awareness of private extension, the aquaculture services they were willing to pay for, and factors influencing their willingness to adopt private extension in aquaculture services. A sample size of 85 Catfish farmers was used for the study and a structured questionnaire was used to elicit information from the respondents. Descriptive (percentages and frequencies) and inferential statistics (regression) were used to analyse the data. The result showed that that more than two-third of the respondents were >50 years of age, above average (52.9%) were females, majority were married (89.4%), agro-dealers (69.4%) and had tertiary education (90.6%). Above average (55.3%) of the respondents were aware of private extension, majority (85.9%) were willing to adopt and pay (88.2%) for private extension. They were mostly willing to pay for training on digital/social media marketing of fish (1st) and fish feed formulation (1st), information on where to get viable brood stock (3rd), and information on where to buy fish feeds at affordable rate (4th). The factors inhibiting the farmer's willingness to pay and adopt private extension were poor knowledge/lack of competence of the extension staffs (1st), cost of service (2nd) and lack of ready market to sell proceeds of farm output resulting from improved extension service (4th). It was revealed that farm income ((β=0.459) and farm experience (β=0.317) were positively correlated (p<0.05) with the respondent's willingness to pay for private extension in the study area. The study recommends that more training on digital marketing should be provided for these farmers to enable them access ready markets most of the time and also the cost of service could be subsidized for the farmers by the appropriate bodies.*

**Keywords:** Private extension, Catfish farmers, willingness to adopt/pay

## INTRODUCTION

Agricultural extension service delivery has been an age-long practice that involves extension agents educating farmers about innovations in their enterprise. In Nigeria, public extension service delivery has been the common practice, though faced with numerous challenges (Rico et al, 2023)

According to (FAO, 2024), the term "Extension" is an informal educational process directed toward the rural populace or agrarian communities to offer advice and information to them to change farmers' outlook on their challenges to improve their overall livelihood and well-being. Extension service is offered in the form of knowledge, skills, and information. There are two forms of extension service delivery: public and private. Agricultural extension is the basic mechanism for enhancing agricultural productivity, rural development, poverty reduction, and food security (Adebe, 2023; Chayot, 2022; Davis et al., 2020).In Nigeria, the public extension service has been the most common, it's usually funded and delivered by government agencies or non-governmental organizations but it comes with several challenges. However, such a system is characterized by financial unsustainability due to high cost of extension personnel, supply driven, top-down approach, limited geographical coverage, limited-service outreach and not demand driven without the participation of the farmers (Adebe, 2023; Atiso et al., 2021; Rajkhowa et al., 2021).

Nigerian public extension faces underperformance due to inadequate funding, the disproportionate number of agents, poor staff training, low education, poor farmer-extension relationship, low technology adoption, and lack of mobility (Camillone et al., 2020; Harry and Abudu, 2022; Tafida et al, 2024). In a bid to proffer solution to the aforementioned challenges came the sprouting of private extension.

Private extension is the dissemination of innovations to farmerstotackle their challenges and improve their livelihood activities and well-being in general. It'susually carried out by private institutions or entities, where the end users bear the cost. The private extension was introduced to tackle the numerous challenges of the public-based extension service delivery such as lack/inadequacy of funds, poor knowledge base of the extension agents, and, poor number of extension agents among others. Adjebor et al (2024) added that public-based extension is characterized by a top-bottom approach, with poor linkages between the end-users and the research institutes. All farmers seek new information to improve their enterprise and the catfish farmers are not left out.

Catfish farming is an important sector of aquaculture in Nigeria and it is typically the rearing of fish under controlled conditions. According to Enwelu et al (2023), fish is a common food in Nigeria due to its high protein content, hence itshuge demand despite its poor production as a result of several challenges, such as poor knowledge base of its farmers, high cost of feeds, scarcity of viable brood stock, poor digital marketing skills, poor extension coverage, high cost of fingerlings and lack of organized market among others, thereby leading to fish deficit and large fish importation in the country. This posits that the catfish farmers are in dire need of efficient and effective extension service delivery in Nigeria, which the public-based extension cannot offer and hence the need for private extension service delivery adoption.

This study is therefore carried out to ascertain the willingness of catfish farmers to adopt private extension service delivery.

## METHODOLOGY

This study was carried out in the Ikorodu local government area of Lagos State, which is predominantly home to catfish farmers. Purposive random sampling of 100 farmers, who already owned fish farms as businesses, were selected across 20 communities namely: Elepe, Itamaga, Idiroko, Ibeshe, Oluodo, Erunwen, Agbede-Igbol, Offin, Agura-Gberigbe, Gberigbe, Ishawo, Ijede, Baiyeku, Agunfoye, Omitoro, Odogunyan, Oreyo/Igbogbo, Imota/Agbowa, Ogolonto/Majid, and Oreta. Five farmers were selected from each community. Interviews and questionnaire administration were employed during the farmers' monthly meetings, utilizing a participatory approach that included question-and-answer sessions as well as focus group discussions. However, only 86 questionnaires were eventually retrieved, representing an 86% response rate. The respondents were selected by the president of the Lagos State Catfish and Allied Farmers Association of Nigeria (LASCAFAN), Ikorodu branch, and the extensionist from the Nigerian Institute for Oceanography and Marine Research (NIOMR). The results were analyzed using descriptive statistics and multiple regressions. The farmers were asked questions regarding their years of farming experience, total pond size, average number of fish harvested per pond, awareness of private extension services, and which services they would prioritize and be willing to pay for. Factors inhibiting the farmers' willingness to pay for and adopt private extension services were also explored, among other questions.

## RESULTS AND DISCUSSION

### Socioeconomic characteristics

Table 1 showed that more than two-third of the respondents were >50 years of age, above average (52.9%) were females, majority were married (89.4%) and agro-dealers (69.4%). About 50.6% had a household size of 1-4, majority (90.6%) had tertiary education, more than half (61.2%) had a total farm income of >#500.00 with less than half (42.6%) having 11-15 years of farming experience. Above

average (57%) had a stocking density of 1001-2000, above average (58.5%) sourced their labour from family, majority (92.2%) purchased their ponds, were all members of cooperatives (100%) and belonged to farmers group, almost half (47.05%) sourced their credit from families, more than half (52.94%) used concrete ponds and (64.72%) reared clarias species of fish.

**Table 1:** Socio-economics characteristics

| Socio-economics characteristics | F | % |
|---|---|---|
| **Age** | | |
| <30 | 9 | 10.6 |
| 31-40 | 19 | 22.4 |
| 41-50 | 21 | 24.7 |
| >50 | 36 | 42.4 |
| **Sex** | | |
| Male | 40 | 47.1 |
| Female | 45 | 52.9 |
| **Marital status** | | |
| Married | 76 | 89.4 |
| Widowed | 9 | 10.6 |
| Other occupation | | |
| Agro dealer | 59 | 69.4 |
| Trader | 26 | 30.6 |
| **Household size** | | |
| 1-4 | 43 | 50.6 |
| 5-8 | 42 | 49.4 |
| Religion | | |
| Christian | 81 | 95.3 |
| Islam | 4 | 4.7 |
| **Educational Status** | | |
| Secondary | 8 | 9.4 |
| Tertiary | 77 | 90.6 |
| **Total farm income** | | |
| <200 | 7 | 8.2 |
| 201-300 | 5 | 5.9 |
| 301-400 | 10 | 11.8 |
| 401-500 | 11 | 12.9 |
| >500 | 52 | 61.2 |
| Years of farming experience | | |
| 1-5 | 13 | 15.9 |
| 6-10 | 24 | 29.3 |
| 11-15 | 35 | 42.6 |
| >15 | 10 | 12.2 |
| Stocking density | | |
| <1000 | 43 | 53.1 |
| 1001-2000 | 38 | 57.0 |
| Source of labour | | |
| Family | 50 | 58.5 |
| Friends | 7 | 8.2 |
| Hired | 28 | 34.0 |
| **Source of pond** | | |
| Inherited | 3 | 3.5 |
| Purchased | 78 | 92.2 |
| Rented/leased | 4 | 4.7 |

| | | |
|---|---|---|
| **Membership of cooperative** | | |
| Yes | 85 | 100 |
| **Type of group** | | |
| Farmers group | 82 | 96.5 |
| Others | 3 | 3.5 |
| **Source of credit** | | |
| Bank | 5 | 5.88 |
| Co-operatives | 10 | 11.76 |
| Family | 40 | 47.05 |
| Self | 30 | 35.20 |
| **Rearing facilities** | | |
| Concrete pond | 10 | 11.76 |

**Table 2:** Awareness of private extension

| | Yes (F) | % |
|---|---|---|
| Are you aware of private extension (PE) | 47 | 55.3 |
| Are you willing to adopt PE | 73 | 85.9 |
| Are you willing to pay for PE | 75 | 88.2 |

The table revealed that above average (55.3%) of the respondents were aware of private extension, majority (85.9%) were willing to adopt and pay (88.2%) for private extension.

**Table 3: Willingness to pay for private extension**

| Agric. extension services willing to pay for based on priority | F | % | Rank |
|---|---|---|---|
| Training on earthen pond construction and liming | 51 | 59.05 | 14th |
| Training on how to breed fish/ fish spawning | 41 | 47.05 | 15th |
| Information on where to get viable brood stock | 77 | 90.58 | 3rd |
| Training on digital/social media marketing of fish | 78 | 91.76 | 1st |
| Information on where to buy fish feeds at affordable rate | 73 | 85.88 | 4th |
| Training on fish feed formulation | 78 | 91.76 | 1st |
| Information fish health and mgt | 64 | 75.29 | 13th |
| Training on value addition to their fish produce | 72 | 84.70 | 5th |
| Organizing of exhibition and displays | 69 | 81.17 | 8th |
| Information on how and where to source for funds | 70 | 82.35 | 7th |
| Training on record keeping and farm diary | 67 | 78.82 | 10th |
| Information on where and how to source for subsidized farm input | 68 | 80.00 | 9th |
| Information on prevalence of disease and its outbreak | 65 | 76.47 | 12th |
| Training on construction and use of modern kilns for improved fish smoking | 71 | 83.52 | 6th |
| Training on tranpoleen installation | 67 | 78.82 | 10th |

Table 3 showed that the respondents were most willing to pay for training on digital/social media marketing of fish (1st) and fish feed formulation (1st), information on where to get viable brood stock (3rd), and information on where to buy fish feeds at affordable rate (4th). This could buttress that the farmers were in dire need of skills in digital marketing, since it's the current trend of marketing nowadays. This could also explain their constraints in marketing as seen in table 4.

**Table 4:** Factors inhibiting the farmer's willingness to pay and adopt private extension

| Items | F | % | Rank |
|---|---|---|---|
| Cost of service | 66 | 82.35 | 2nd |
| Poor knowledge/lack of competence of the extension staffs | 81 | 95.29 | 1st |
| Exploitation by extension service providers | 59 | 69.41 | 10th |
| Low income of farmers | 63 | 74.11 | 6th |
| Lack of ready market to sell proceeds of farm output resulting from improved extension service | 69 | 81.17 | 3rd |
| Instability of national agricultural extension policies | 63 | 74.11 | 6th |
| Small scale holding by the respondents | 61 | 71.76 | 8th |
| Unfavourable govt. policies on privatization and commercialization | 64 | 75.29 | 5th |
| Irresponsiveness of extension service providers to clients' needs | 70 | 77.60 | 4th |
| Corruption and nepotism among extension staff | 61 | 71.76 | 8th |

Table 4 revealed the respondents constraints to willingness to adopt and pay for private extension as poor knowledge/lack of competence of the extension staffs (1st), cost of service (2nd), lack of ready market to sell proceeds of farm output resulting from improved extension service (3rd) and irresponsiveness of extension service providers to clients' needs (4th).

**Table 5:** Regression analysis for determinants of farmer's willingness to pay for extension services.

| Independent variables | Beta coefficient | T value | Prob. level |
|---|---|---|---|
| (Constant) | | 0.87 | 0.387 |
| Age | 0.236 | 1.68 | 0.096 |
| Sex | 0.189 | 1.61 | 0.112 |
| Household size | 0.178 | 1.70 | 0.093 |
| Farm income* | 0.459 | 4.03 | 0.000 |
| Farming experience* | 0.317 | 2.29 | 0.024 |
| Farm size | -0.022 | 0.18 | 0.851 |
| Stock density | 0.134 | 1.12 | 0.265 |

***Adjusted coefficient of determination = 0.22; F value = 4.08; p<0.05***

Hypotheses 1: Regression analysis was used to ascertain the contributions of the independent variables to the farmer's willingness to pay for private extension services in the study area.
Table 5 revealed that farm income ((β=0.459) and farm experience (β=0.317) were positively correlated (p<0.05) with the respondent's willingness to pay for private extension in the study area.

## CONCLUSION

In conclusion the farm income ((β=0.459) and farm experience (β=0.317) were positively correlated (p<0.05) with the respondent's willingness to pay for private extension in the study area. The study recommends that more training on digital marketing should be provided for these farmers to enable them access ready markets most of the time and also the cost of service could be subsidized for the farmers by the appropriate bodies.

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# EFFECT OF PICKLE CURING ON HETEROCLARIAS (*Clarias gariepinus* ♀ × *Heterobranchus bidorsalis*♂) DURING AMBIENT STORAGE

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**ABSTRACT**

*Effect of pickle curing on Heteroclarias during ambient storage was studied. Muscle pH, conductivity, fish weight and microbiological quality changes that occured during pickle curing when stored at ambient temperature (27±3°C) were assessed. Samples of fish were collected on Day 15, 29, 43, 57, 71 and day 84. The conductivity of pickle cured Heteroclarias increased significantly ($p<0.05$) within the first 28 days of storage after which an irregular pattern was observed while no significant change ($P>0.05$) was observed in the average weight of the fish for 84 days. However, the microbial quality of the pickle cured fish showed that it was good for human consumption throughout the period of storage (84 days). Pickle curing method of fish preservation is therefore recommended for elongation of the shelf-life of fish, especially in communities where steady electricity supply is a challenge.*

**Keywords:** Fish preservation, Pickle curing, Heteroclarias, Ambient storage

## INTRODUCTION

Global fish consumption has increased in recent years. While 88% of global fish output is consumed by man, 44% of these fishes are consumed in fresh or frozen form (Umer *et al.*, 2022). High consumption rate of fish could be due to its easy accessibility and affordability (Adeyeye *et al.*, 2015). Ayeloja (2019), reported that fish is an important food in the world today due to its high-quality protein, presence of polyunsaturated fatty acids, vitamins, minerals, fats, and it is highly digestible. Despite the usefulness of fish, it is a highly perishable food product, its quality deteriorates rapidly during handling and storage thereby limiting the shelf life of the product (Sallam, 2007). Fish freshness is lost shortly after death due to autolytic and microbial spoilage (Ayeloja *et al.*, 2020; Dehghani *et al.*, 2018). In tropical regions, conservation of fresh fish remains a problem because of the lack of adequate infrastructures environmental and climatic conditions that contribute to its spoilage within few hours (Anihouvi *et al.*, 2012). To prevent fish spoilage and reduce postharvest losses, various preservation methods including: frying, fermentation, drying, salting, and smoking are used (Ayeloja *et al.*, 2021; Ikutegbe and Sikoki, 2014). Salting as a means of fish preservation is gaining more popularity in recent times due to lack of social amenities such stable electricity in many developing countries (Alsaban *et al.*, 2014). Thorarinsdottir *et al.* (2011), on the other hand define salting as a traditional method that uses osmotic pressure to cause cell rupture of bacteria in order to inhibit or kill pathogenic and spoilage bacteria. It is used to maintain food quality and prolong the shelf-life of food, such as fish that are difficult to preserve and easily spoilt. Giuffrida *et al.* (2017), also stated that salting is one of the oldest, most frequently used preservative; and fish preservation method used worldwide. The technique impact positively on fish taste, it is less costly and it requires little technical knowhow. However, there is dearth of information on the use of pickle curing method of fish preservation in elongating the shelf life of heteroclarias which is one the fish that is mostly cultured in the study area thus the need for this study which is aimed at providing baseline information on the effect of pickle curing on fish stored at ambient temperatures.

## MATERIALS AND METHODS

### Sample collection

Thirteen (13) samples of *Heteroclarias* were collected by dragging with a drag net from an earthen pond at Asa-Dam road, Ilorin, Kwara State Nigeria. The samples were then conveyed using sterile polythene nylon to the Faculty of Agriculture Central Laboratory, University of Ilorin, Ilorin Kwara state within 48 minutes.

At the laboratory, the fish were gutted by opening the belly and remove the intestine and washed under running water after which the initial microbial load of the samples were assessed for the microbial analysis carried out includes Total viable count, Total fungal count, Total coliform count, Total mesophilic count, Total psychrophilic count following standard experimental procedures as described by Olutiola et al. (1991); Fawole and Osho (1995). Thereafter, Pickle curing (wet salting) method of fish preservation was done by collecting 7 litres of clean water which was put in a clean plastic container, after which 13 heteroclarias were put in the water. Thereafter, a muslin cloth containing 7kg of salt (making 1:1 water to salt) which allows free flow of water to create an isotonic solution of a high salt-water concentrate was inserted; the salt dissolved till saturation in the container was done while the remaining salt remain in the muslin clothe till the end of the experiment. The fish was kept in this state at ambient temperatures ($27 \pm 3^{\circ}C$) throughout the period of this study (84 days).

### Sample Collection

Samples were collected at every fortnight (0, 14, 28, 42, 56, 70 and 84 days) for 84 days for physicochemical (pH, conductivity and average weight) and microbiological quality changes (Total volatile count (TVC), Total mesophilic bacteria count (TMBC), Total psychrophilic bacteria count (TPBC), Total coliform count (TCC) and Total fungal count (TFC).

### Statistical Analysis

Microbiological data obtained were logarithmically transformed (log cfu/g) and then subjected to Analysis of Variance (ANOVA) while means of the significantly different indices were separated using Duncan Multiple Range Test (DMRT) at $p < 0.05$.

## RESULTS AND DISCUSSION

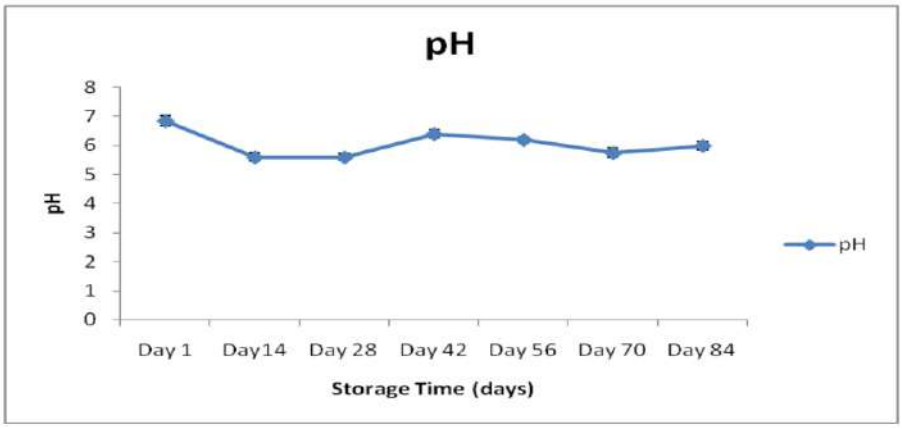



**Figure 1:** pH of pickle curing (wet salting) on Heteroclarias during ambient storage

The pH of wet salted fish (Fig. 1) did not follow a regular pattern. similar result was observed by Binici and Kaya (2018), who reported that there was no regular increase or decrease in the pH measurements of chub (*Squalius cephalus*) when brine and dry salting methods of preservation were adopted. The pH range observed in this study (5.6 - 7.0) is similar to that reported by Al-Asous and Al-Harbi (2016) who

reported a pH range of 5.6 to 6.2 for salted fish that was stored at ambient temperature. pH value is used as an indicator of degree of freshness or spoilage of a fish. In the case of a fresh fish, the pH is close to neutral, while it decreases as the level lactic acid formation increases due to the conversion of glycogen present in the fish muscle into lactic acid in the absence of oxygen (fish muscle enzymes are responsible for these activities).

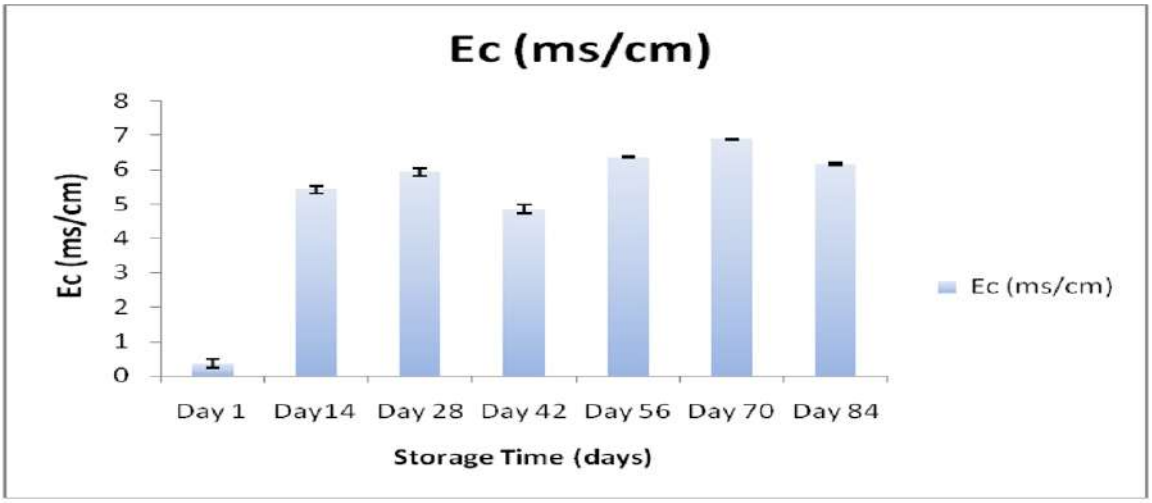



**Figure 2:** Conductivity (Ec) of pickle cured (wet salting) Heteroclarias during ambient storage

The study also indicated that the conductivity of pickle cured heteroclarias increased significantly ($p<0.05$) within the first 28 days of storage (Fig. 2) after which an irregular pattern was observed. The initial increase in the conductivity could be as a result of the absorption of salt molecule by the fish flesh during the early stage of wet salting preservation, this is in line with the opinion of Wiroonsri *et al.* (2022) who opined that there is correlation between increase in salt content and electrical conductivity of fish. Shi *et al.* (2014) also stated that the electrical conductivity of food will change as the ionic concentration and ionic properties of the food changes. Therefore, the higher the ionic concentration of the fish muscle, the higher the conductivity value that will be observed on the fish muscle.

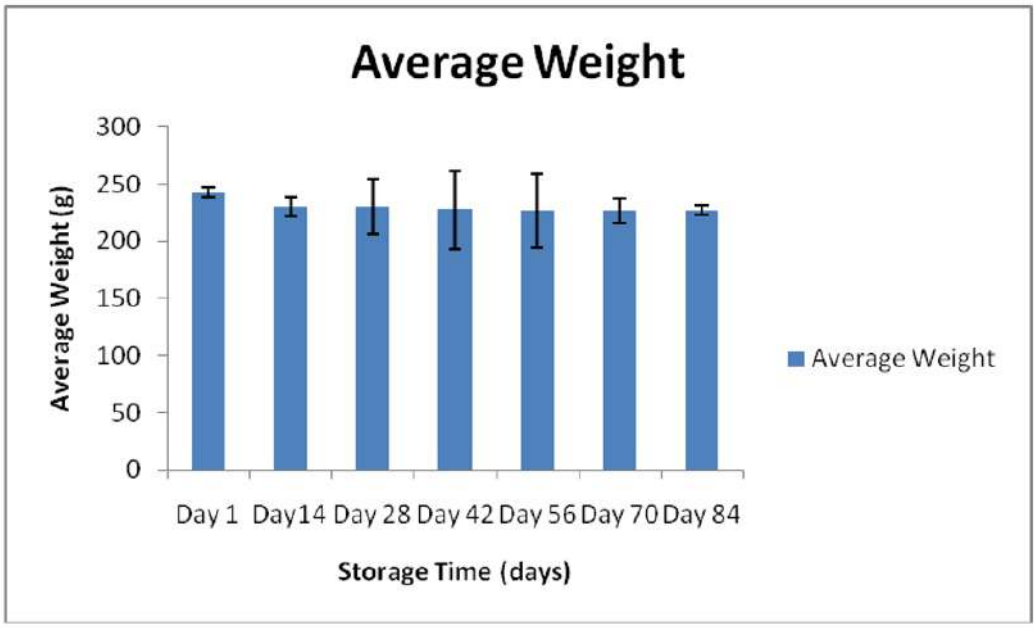



**Figure 3:** Average Weight (g) of wet- salted Heteroclarias during ambient storage

**Table 1:** Effect of pickle curing on the microbiological quality of Heteroclarias during ambient storage

| Microbial load | Day 1 | Day 14 | Day 28 | Day 42 | Day 56 | Day 70 | Day 84 |
|---|---|---|---|---|---|---|---|
| TVC (log Cfu/g) | $2.739\pm0.06^{g}$ | $3.504\pm0.04^{f}$ | $3.845\pm0.02^{e}$ | $3.973\pm0.01^{d}$ | $4.900\pm0.02^{c}$ | $4.978\pm0.01^{b}$ | $6.035\pm0.03^{a}$ |
| TMBC (log Cfu/g) | ND | $3.016\pm0.09^{d}$ | $3.078\pm0.05^{d}$ | $3.484\pm0.03^{c}$ | $4.657\pm0.03^{b}$ | $4.707\pm0.02^{b}$ | $5.505\pm0.02^{a}$ |
| TPBC (log Cfu/g) | ND | $2.753\pm0.21^{d}$ | $2.827\pm0.18^{d}$ | $3.311\pm0.05^{c}$ | $4.462\pm0.12^{b}$ | $4.562\pm0.09^{b}$ | $5.332\pm0.01^{a}$ |
| TCC (log Cfu/g) | ND | $2.628\pm0.21^{d}$ | $2.724\pm0.17^{d}$ | $3.188\pm0.06^{c}$ | $4.385\pm0.09^{b}$ | $4.467\pm0.07^{b}$ | $5.175\pm0.04^{a}$ |
| TFC (log Cfu/g) | ND | ND | ND | ND | ND | ND | ND |

** Values with different superscript in the row indicates significant difference at P<0.05*

TVC Total volatile count
TMBC Total mesophilic bacteria count
TPBC Total psychrophilic bacteria count
TCC Total coliform count
TFC Total fungal count
ND No detection
Log Logarithm

The Total volatile count (TVC) recorded in pickle cured Heteroclarias (Table 1) ranged between 2.739±0.06 - 6.035±0.03 log cfu/g during the period of storage while the total mesophilic bacteria count (TMBC) ranged between 3.016±0.09 and 5.505± 0.02 log cfu/g . The microbial load increased significantly ($P < 0.05$) as the period of storage increases in line with the observation of Ayeloja *et al.* (2011) on fresh C*larias gariepinus* kept unpreserved at ambient temperatures but the result of microbial load observed in this study exceeded the maximum recommended bacterial counts for marginally acceptable products which is $10^7$ ($7\log_{10}$ Cfu/g) according to the International Commission on Microbiology Safety for Foods, ICMSF, (1986). This indicate that wet salting (pickle curing) is effective to keep fish quality for longer time, similar opinion was expressed by Tsai *et al.* (2022) who reported that treating fish fillet with brine salting is capable of reducing microbial load on the fish immediately due to the ability of brine to release bacteria attached to the surface of fish flesh, wet salting also bacteriostatic and bactericidal effects on fish fillet. The microbial load observed on pickle cured fish in this study is similar to that observed by other scientist that worked on wet salting preservation of fish such as Gassem (2019) as well as Binici and Kaya (2018).

## CONCLUSION

This study established that pickle curing method of fish preservation have bactericidal and bacteriostatic effect on fish microorganisms as the microbial load is still within recommended value for marginally acceptable products by International Commission on Microbiology Safety for Foods, ICMSF. The salting method employed in this study keep the fish quality to still be wholesome for human consumption up till the last day of storage under dry salting condition ($84^{th}$ day). Pickle curing method of fish preservation is therefore recommended to elongate fish shelf life in villages and other environments that lack steady electricity supply without it having any significant effect ($P>0.05$) on the fish weight.

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# ADDENDUM II - OMISSIONS FROM BAYELSA 2022

# TRAINING NEEDS OF CATFISH FARMERS IN IKORODU LOCAL GOVERNMENT AREA LAGOS STATE, NIGERIA

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***ABSTRACT***

*This study investigated the training needs of fish farmers in Ikorodu Local Government Area, Lagos State. The aims of the study were to examine the training needs of catfish farmers, identify improved production management practices, ascertain the biosecurity measures utilized by the farmers, and determine the constraints to production in the study area. Random sampling techniques were employed to select 120 catfish farmers from LASCAFAN. The data were analysed using descriptive statistics (frequency distribution and percentage). The results revealed that the training needs of catfish farmers in the study area were mostly in fish marketing (mean =1.45), fish care, transfer, and feeding (mean =1.21), brood-stock production (mean=1.18), and disease prevention, control, and management (mean=1.16). The most practiced improved production management practices were pond cleaning and water quality maintenance and management, with equal means of 0.87, respectively. The most utilized biosecurity measures by these respondents were the usage of salt (mean=0.92), proper handling and storage of feeds, and proper waste management, each with an equal mean of 0.87. The constraints to production included middlemen dictating the price of table fish (mean=1.76), a lack of access to agricultural loans (mean=1.68), a high cost of fish feed (mean=1.66), and inefficient extension services (mean=1.63).The paper concludes that despite government interventions in Nigeria's aquaculture sector, the growth rates of aquaculture output have remained low, leading to significant fish imports. The study recommends proper engagement with ERLS-NIOMR by ensuring training in fish marketing, fish care, transfer, and feeding. Emphasis should be placed on additional training for developing a brood-stock bank of improved catfish strains, as well as effective disease management and control.*

**Keywords:** *fish farmers: training needs: Ikorodu LGA*

## INTRODUCTION

Nigeria stands as the second-largest aquaculture producer in Africa, driven by a robust demand for fish among consumers (Rohana et al., 2021). Aquaculture has gained increasing significance on a global scale, contributing over half of the fish consumed by humans, valued at approximately 232 billion USD in 2016 (FAO 2018). The sector employs an estimated 19.3 million people, with 14% being women directly involved in fish farming and an additional 7 million engaged in post-harvest stages (processing, trade, and retail), with women constituting between 62% and 99% of this workforce, depending on the country (Kruijssen, McDougall, and van Asseldonk 2018). However, Nigeria remains Africa's largest importer of fish (Oluwarore, 2018). Nigeria's population figure in 2015 was 187.3 million, the total fish demand is 3.25 Mt, and fish production from aquaculture is 316,727.00 metric tons. There is a huge deficit in local production, and only 806,000 metric tons of fish are imported to meet the annual demand in Nigeria. (NBS, 2017-2018). While the aquaculture sector is considered of key importance to supply the global population with animal proteins and important micro-nutrients, the sector has also been associated with a range of inefficient aquaculture production management practices; level of skill acquisition, and performance of improved production management practice.

Training needs is one of the most important steps in the development of the performance and factors that will effect on the performance, Saleh J. M, (2019). As such, ensuring food security and assigning priority are imperative. This underscores the significance of agricultural extension, which plays a crucial role through providing guidance and fostering awareness. Addressing the need for capacity building, Olaitan et al. (2009) define it as the acquisition of information, skills, and attitudes necessary for a specific task. Adisa (2011) emphasizes that Nigeria's agricultural extension sector must meet the competency requirements of its clientele. The Nigerian Institute for Oceanography and Marine Research (NIOMR) plays a non-research role by providing vocational training in fisheries, oceanography, and aquaculture. Over the years, the institute has trained fish farmers in various catfish production value chains of catfish. The federal government, through their constituency projects in conjunction with the NIOMR, jointly renewed the program on aquaculture development for training unemployed youth and women in aquaculture and post-harvest technology in six geopolitical zones. The trainees' catfish farmers were trained in Badore research farm and equipped with starter packs. About 43 training programs were carried out during this period. This program is in line with the events organized by the African Developmental Bank (2012) and the World Bank (2014), and most specifically, between 2017-2020, 1,366 fish farmers and prospective fish farmers were trained, out of which male were (69%) and female were (31%)). And they were equipped with starter packs to kick-start catfish production. Matanmi et al (2022). Training and education in aquaculture is a continuous process of learning new skills and, new innovations keep evolving that are more profitable and user-friendly. Empowering farmers on capacity building through training will go a long way toward eradicating poverty, boosting production, and increasing profit. One of the goals of the ERLS-NIOMR is to constantly consult with farmers and solve their felt needs in the aquaculture industry through training, which is in the area of her mandate. The objective of the study is to address the specific training needs of catfish farmers in Ikorodu Local Government Area; identify the improved production management practices of the respondents; ascertain the biosecurity measures utilized by the farmer's and. examine the constraints to production.

## MATERIALS AND METHODS

This study was carried out in Ikorodu local government area Lagos, in 2022, using purposively random sampling of 120 farmers in 5 communities who already owned fish farms as businesses. The training was done on farmer's monthly meeting days and utilized a participatory approach, which include lectures, question and answer sessions, discussion groups, and interactions amongst the subject matter specialists. The trainees were chosen by the Lagos State Catfish and Allied Farmers Association of Nigeria (LASCAFAN) members. The result was analysed using descriptive statistics. The trainees were trained on fish marketing, fish disease management and control, brood-stock production, and biosecurity measures in catfish farming. The resource person adopted a combination of lectures, class exercises, use of audio and visual materials, and mostly practical demonstration to impact knowledge efficiently on the participants. At the end of the training, the participants were given questionnaires to respond to their specific areas of need.

## RESULTS AND DISCUSSION

### Training needs of fish farmers in the study area

As shown in Table 2, the training needs of fish farmers in the study area were mostly in fish marketing (mean = 1.45), fish care, transfer, and feeding (mean = 1.21), brood stock production (mean = 1.18) and disease prevention control and management (mean = 1.16). This implies that the farmer requires training in fish marketing. This corroborates the findings of Ndem and Ogbonna (2016), who discovered that all respondents need training on distribution and marketing of fish in Ebonyi State. Also, Omeje et al (2020) stated that fish farmers operate within an imperfect market structure as most sales take place at farm gate level (80%), with the owners (80%) as the main contact persons, thereby placing the farmers at the mercy of the middlemen. Also, in Table 2, it was observed that they performed less brood stock

production which implies that they require training in this regard. This affirms Michael and Konekan (2020) findings, that fish farmers need training on fish breeding.

**Table 2:** Training needs of fish farmers in the study area

| SN. | Training Needs | NN (%) | N (%) | EN (%) | Mean |
|---|---|---|---|---|---|
| 1 | Pond/fibre glass/tank cleaning | 28.9 | 57.9 | 13.2 | 0.84 |
| 2 | Water quality maintenance and management | 15.8 | 57.9 | 26.3 | 1.11 |
| 3 | Pond construction | 31.6 | 55.3 | 13.2 | 0.82 |
| 4 | Pond fertilization | 21.1 | 63.2 | 15.8 | 0.95 |
| 5 | Brood stock production | 21.1 | 39.5 | 39.5 | 1.18 |
| 6 | Spawning/breeding | 23.7 | 52.6 | 23.7 | 1.00 |
| 7 | Fingerlings sourcing/production | 26.3 | 55.3 | 18.4 | 0.92 |
| 8 | Disease prevention, control and management | 15.8 | 52.6 | 31.5 | 1.16 |
| 9 | Feed formulation and production/sourcing | 23.7 | 44.7 | 31.6 | 1.08 |
| 10 | Record keeping | 23.7 | 35.3 | 40.0 | 1.00 |
| 11 | Fish feeding | 34.2 | 57.9 | 7.9 | 0.74 |
| 12 | Fish processing | 26.3 | 47.4 | 26.3 | 1.11 |
| 13 | Fish storage | 15.8 | 63.2 | 21.1 | 1.05 |
| 14 | Fish sorting/sampling | 26.3 | 65.8 | 65.8 | 0.82 |
| 15 | Fish marketing | 10.5 | 34.2 | 55.3 | 1.45 |
| 16 | Fish transportation | 34.2 | 55.3 | 10.5 | 0.76 |
| 17 | Pest and predator control | 26.2 | 47.4 | 26.3 | 1.00 |
| 18 | Fry care, transfer and feeding | 10.5 | 57.9 | 31.6 | 1.21 |
| 19 | Siphoning | 18.4 | 57.9 | 23.7 | 1.05 |
| 20 | Fish transportation | 21.1 | 55.3 | 23.7 | 1.03 |

Field survey, 2023
Note: NN: Not Needed, N: Needed and EN: Extremely Needed

The improved production management most practiced; were pond cleaning and water quality maintenance and management with an equal mean of 0.87 respectively. The most biosecurity measures utilized by these respondents were in usage of salt (mean=0.92), proper handling and storage of feeds and proper waste management with an equal mean of 0.87 respectively.

**Constraints on fish production**

The major constraints to fish production were middlemen dictating the price of table fish (mean = 1.76), lack of access to agricultural loans (mean = 1.68), high cost of fish feed (mean = 1.66) and inefficient extension services (mean = 1.63). The farmers majorly sold at farm gates, which imply that their major buyers were the middlemen, and hence they would dictate the prices at the farmer's detriment. This confirms the findings of Michael and Koyenikan (2020) that farmers need training in advertising fish products, creating awareness, and identifying profitable markets and prospective fish buyers.

## CONCLUSION

The paper concludes that despite government interventions in Nigeria's aquaculture sector, the growth rates of aquaculture output have remained low, leading to significant fish imports. The study recommends proper engagement with ERLS-NIOMR by ensuring training in fish marketing, fish care, transfer, and feeding. Emphasis should be placed on additional training for developing a brood-stock bank of improved catfish strains, as well as effective disease management and control. Also, the major constraints to fish production by the respondents were middlemen dictating the price of table fish, lack of access to agricultural loans, the high cost of fish feed. The farmers should be equipped with the

knowledge of how to produce local feeds, and trained on how to use the newly installed blast freezers, provided by the Lagos APPEALS project, to preserve the fish at harvest , and a collaborative effort should be in place to link farmers to Agricultural loans.

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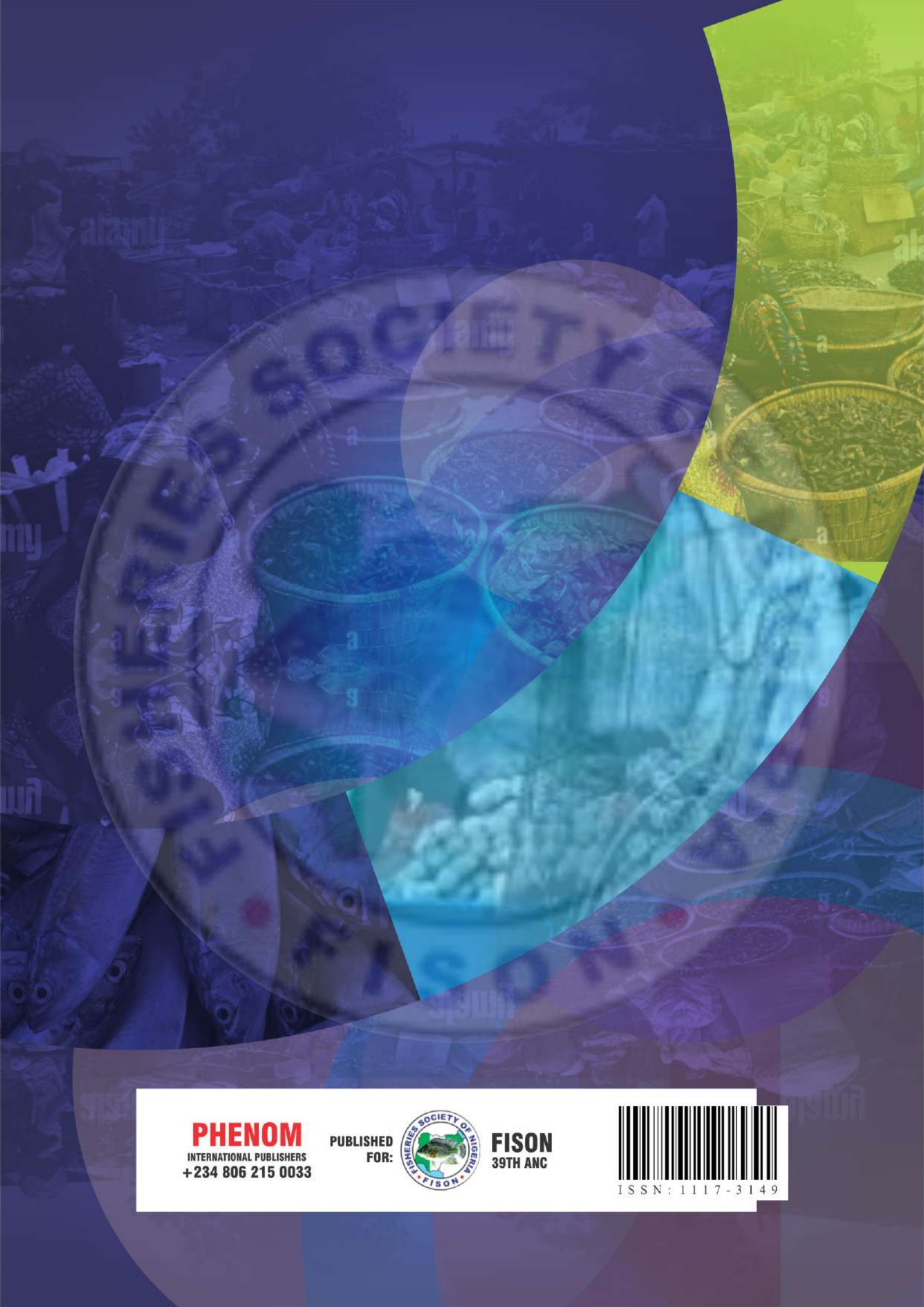
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