NIGERIAN WOMEN IN AGRICULTURAL RESEARCH FOR DEVELOPMENT (NiWARD)

13th HYBRID CONFERENCE/ EXHIBITION

THEME:

TRANSFORMING AGRICULTURE THROUGH INNOVATION FOR ENHANCED FOOD SECURITY IN NIGERIA

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COMMUNIQUÉ FROM THE 13TH HYBRID CONFERENCE/EXHIBITION OF NIGERIAN WOMEN IN AGRICULTURAL RESEARCH FOR DEVELOPMENT (NiWARD)

Theme: Transforming Agriculture through Innovation for Enhanced Food Security in Nigeria

The 13th Hybrid Conference/Exhibition of the Nigerian Women in Agricultural Research for Development (NiWARD) was held at the Nigerian Stored Products Research Institute (NSPRI), Ilorin, Kwara State, from November 4th – 7th, 2025. The event focused on promoting innovation, inclusion, and research-driven strategies for transforming agriculture and strengthening food security in Nigeria.

Introduction

The 2025 NiWARD Conference officially commenced on Tuesday, November 4th, with courtesy visits to key dignitaries, including the Vice-Chancellor, University of Ilorin (Prof. Wahab Egbewole), Commissioners for Agriculture and Livestock Development (Dr. Afeez Abolore and Hon. Oloruntoyosi Thomas), the Emir of Ilorin (HRH Alhaji Dr. Ibrahim Sulu Gambari, CFR), and the Executive Director of NSPRI (Prof. Lateef Sanni). The event brought together 111 participants from academia, research, government, and private sectors. A total of 80 manuscripts were presented, with 21 paper presentations delivered during the technical and plenary sessions.

Conference Theme and Sub-Themes

The central theme of the conference was:

"Transforming Agriculture through Innovation for Enhanced Food Security in Nigeria." The conference featured discussions and presentations across eleven (11) sub-themes:

I. Innovative Farming Practices
II. Agricultural Technology and Digitalization
III. Enhancing Food Security through Value Chain Development
IV. Climate-Smart Agriculture and Environmental Sustainability
V. Women and Youth Empowerment in Agriculture
VI. Policy and Regulatory Frameworks for Agricultural Innovation
VII. Innovative Financing Mechanisms for Agriculture

VIII. Sustainable Wildlife Management, Livestock, Fisheries, and Aquaculture Development

IX. Gender Issues in Agricultural Research for Development

X. Food Quality and Safety in the Agricultural Value Chain

XI. Biodiversity Conservation, Agroforestry, and Sustainable Land Use

Opening Ceremony and Welcome Address

The opening session on Wednesday, November 5th, featured a welcome address by Prof. Lateef Sanni, Executive Director, NSPRI, who acknowledged NiWARD's contributions to women's empowerment and gender inclusiveness in agricultural innovation. Dignitaries present included Prof. (Mrs.) Stella Williams (Founder, NiWARD), Prof. R.O. Arise (representing the VC, University of Ilorin), Prof. AbdulGaniyu Salau (representing the VC, KWASU), Prof. Olayinka Ramota Kareem (VC, Fountain University, Osogbo), Dr. Ebinimi Joe Ansa (National President, NiWARD), and Prof. Oluyemisi Fawole (Immediate Past President, NiWARD).

Keynote and Lead Paper Presentations

The Keynote Address by Prof. Olayinka Ramota Kareem, titled "Transforming Agriculture through Innovation for Enhanced Food Security in Nigeria," emphasized the five pillars of food security—availability, accessibility, utilization, stability, and sustainability. She highlighted biotechnology, digital agriculture, and climate-smart practices as key drivers of progress and underscored the vital role of women as change agents, advocating for gender equity in access to land, finance, and technology. The address also showcased innovative Agritech initiatives such as FarmCrowdy, ThriveAgric, AgroMall, BASICS-II, Hello Tractor, and CoolCycle as models for improving productivity and building a resilient, inclusive food system.

The Lead Paper, "From Ideas to Impact: Entrepreneurship as a Catalyst for Food Security," was delivered by Prof. Joy Eke-Ejiofor (Rivers State University), highlighting entrepreneurship as a driver of innovation and food system resilience. She referenced the RSU–NSPRI Post-Harvest Storage Hub (commissioned May 2025), featuring the Parabolic Solar Dryer (PSSD), Inert Atmosphere Silo (IAS), and Hermetic Drums.

Other plenary papers included:

"Support to Women Seed Entrepreneurs" by Dr. Mercy Diebiru-Ojo (Cassava BASICS-II Project, IITA, Ibadan) and "Unlocking Nigeria's Agricultural Potential: Leveraging Technology and Innovation for Food Security and Economic Growth" by Mr. Andrew Humber-Osofisan, CEO, Humber One Limited.

Resolutions and Recommendations

Participants made the following key recommendations:

I. Strengthen public–private collaboration and ensure gender-sensitive inclusiveness.
II. Enhance capacity building and monitoring of innovation platforms that translate ideas into impact.
III. Promote household food security through reduction of postharvest losses.
IV. Foster synergy, networking, and community-based solutions for food system resilience.
V. Encourage practical application of knowledge to drive creativity and innovation.
VI. Adopt climate-smart agriculture, artificial intelligence, and precision farming.
VII. Utilize digital tools (drones, satellites, soil sensors) for data-driven farm management.
VIII. Promote collective responsibility among government, academia, and industry.
IX. Increase investment in women-led research and youth inclusion through agripreneurship.
X. Expand access to farm mechanization via Equipment-as-a-Service models.
XI. Support financial and policy innovations including digital loans, climate insurance, and smart subsidies.

Conclusion

The conference reaffirmed NiWARD's and NSPRI's commitment to fostering innovation, empowering women, and promoting sustainable agricultural practices for national food security.

Issued this 7th day of November 2025, at the Nigerian Stored Products Research Institute (NSPRI), Ilorin, Kwara State.

OPENING ADDRESS BY THE NiWARD NATIONAL PRESIDENT, DR. EBINIMI ANSA AT THE OPENING CEREMONY OF THE 13TH ANNUAL HYBRID CONFERENCE/EXHIBITION

Protocols

The Executive Director of the Nigerian Stored Products Research Institute (NSPRI) and Chief Host, Prof. Lateef Oladimeji Sanni; the Honourable Commissioner for Livestock Development, Kwara State, Hon. Toyosi Thomas, the Honourable Commissioner for Agriculture and Rural Development, Kwara State, Dr. Afeez Abolore; the Royal Father of the Day, the Emir of Ilorin; the Vice Chancellor of the University of Ilorin; the Vice Chancellor of Kwara State University; the Vice Chancellor of Summit University, our dear Founder, Prof. Stella Williams; our esteemed Keynote Speaker, Prof. Olayinka Ramota Karim; our distinguished Lead Paper Presenters, Prof. Joy Eke-Ejiofor and Mr. Andrew Humber-Osofisan; members of the NiWARD Executive Committee; the Chairman and Members of the Local Organizing Committee; distinguished researchers, scientists, innovators, and professionals; partners from government, academia, industry, and civil society; ladies and gentlemen—all protocols duly observed.

It is with profound gratitude to God Almighty that I warmly welcome you to the 13th Annual Hybrid Conference and Exhibition of the Nigerian Women in Agricultural Research for Development (NiWARD). Welcome to Kwara State — the State of Harmony! This year's theme, "Transforming Agriculture through Innovation for Enhanced Food Security in Nigeria," reflects the urgent call to accelerate scientific breakthroughs, embrace modern technologies, and promote inclusive innovation to strengthen our nation's food systems.

As Nigeria and the world continue to grapple with the challenges of food insecurity, climate change, and an evolving global agricultural landscape, this conference serves as an inspiring platform to share knowledge, forge partnerships, and drive impactful solutions. Women remain central to this mission as researchers, innovators, producers, and leaders shaping the future of agriculture and ensuring a sustainable, food-secure Nigeria.

NiWARD Milestones over the Past Year

Over the past year, NiWARD has continued to grow in influence, impact, and strategic contribution to agricultural research and gender empowerment in Nigeria. Allow me to highlight key accomplishments:

The present executive members came on board on 21st November 2024, and we have worked tirelessly to uphold the goals and aspirations of our Association.

Capacity Development & Empowerment Initiatives

We delivered training on tips for successful AWARD Fellowship application on 16th January 2025. The event was organized by the National Executive Committee. The training session provided participants with valuable insights and skills for their professional development. I am happy to announce that one of the participants won the AWARD fellowship.

Other training activities that were carried out include a webinar on "Leveraging AI for advancements in agricultural and scientific research in Nigeria, facilitated by NiWARD partner, Prof. Sunny Cookey Ekpo, on 29th July 2025 with so many examples on artificial intelligence applications in agriculture production and research. Other activities at the zonal level showcased a meeting held by the South-South region at the University of Port Harcourt, Choba, Rivers State. A hybrid event held in the North Central zone hosted by the University of Ilorin NiWARD branch. The theme of the one-day conference which took place on 22nd September 2025 was "Sowing the seed of Impact: Mentorship and Leadership Training for Women in Research and Academia" all these activities went a long way in boosting the profile of our members and invited participants. The hosting of the 13th Annual Conference was taken up again by the North Central zone and graciously hosted by the Nigerian Stored Products Research Institute (NSPRI) our very strong ally, under the leadership of Professor Lateef Sanni. We are also grateful to the local organizing committee Chairperson, Dr. Olatilewa Mufuliat Oladuntan and her formidable team for doing a great job in bringing the hosting of the conference to reality.

Strengthened Institutional Partnerships

We have continued to deepen the collaboration with NGOs, universities, research institutes, ministries, and development partners to expand opportunities and visibility for women in agricultural science and agricultural innovation. Today we appreciate all our collaborators and partners for their support in ensuring we have a good conference.

Editorial Board

NEC constituted a functional editorial board to ensure that are publications remain of high quality and visibility. We are grateful to all those who have accepted to serve on the board.

Visibility of our Members

We have continued to celebrate our NiWARD Scientist of the month. This was formerly only published on the website www.niward.org.ng as prose but now you can watch a video of the Scientist of the month on NiWARD YouTube channel.

Strategic Collaboration and Networking

This year, NiWARD South West region, advanced meaningful collaboration with NWiSTEM Network of Nigerian Women in STEM in a jointly hosted workshop for well over 100 women and girls in Ibadan, Oyo State on 11th February 2025. The theme of the workshop was "Women and girls in science leadership: a new era for sustainability. The feedback from the attendees was encouraging with requests for more of such workshops in future.

International Recognition – WWSF Award

A proud moment for NiWARD came with the Women's World Summit Foundation (WWSF) Award 2025, awarded to our nominee, Prof. Juliana Amaka Ugwu, the prestigious WWSF - PRIZE FOR WOMEN'S CREATIVITY IN RURAL LIFE – 2025 for her "creative project in favour of advancing rural women's rights to sustainable development, equality and lasting peace" and her "good work in her community and country. Prof. Ugwu was celebrated by WWSF on 15th October 2025 the International Day of Rural Women. We shall be celebrating her today along with others who have all left indelible marks in the lives of many women across various works of life.

As we begin this conference, I encourage us all to engage deeply and think innovatively. Let our conversations and outputs here inspire solutions that will improve food security, elevate research excellence, empower women, and youth, and transform communities across Nigeria.

NiWARD remains committed to fostering a future where women lead in research, policy, agribusiness, and rural development driving inclusive growth and national prosperity.

I warmly welcome you once again, and I wish us a very productive, inspiring, and impactful conference.

Thank you.

Dr. Ebinimi Ansa

National President, NiWARD

Transforming Agriculture through Innovation for Enhanced Food Security in Nigeria

Keynote Address

By
Prof. Olayinka Ramota Karim FNIFST, FCOFP, LFICWLS
Vice-Chancellor, Fountain University, Osogbo, Osun State, Nigeria
At the 13th Conference of the Nigerian Women in Agricultural Research for Development (NiWARD)
Held at the Nigerian Stored Products Research Institute (NSPRI), Ilorin, Kwara State.

Preambles

It gives me immense pleasure to stand before you at this 13th Conference of the Nigerian Women in Agricultural Research for Development (NiWARD), a formidable platform that has consistently championed the cause of women in science, research, agricultural innovation, and development.

I heartily congratulate the leadership and members of NiWARD for sustaining this noble vision and for making this year's theme "Transforming Agriculture through Innovation for Enhanced Food Security in Nigeria" both timely and thought-provoking.

Allow me to also express my profound appreciation to the Local Organising Committee (LOC) for the excellent planning and warm hospitality extended to all participants. Your dedication and meticulous efforts have made this gathering a success.

I must also sincerely thank my mentor and Ph.D. co-supervisor, Professor Lateef Sanni, the Executive Secretary of the Nigerian Stored Products Research Institute (NSPRI), for his visionary leadership, steadfast mentorship, and unwavering commitment to research excellence and innovation in agricultural development. Sir, your continued guidance and professional example have greatly shaped my academic and leadership journey. Thank you for hosting us in this reputable institution and for your consistent contribution to Nigeria's agricultural transformation.

This gathering is not just another academic meeting; it is a strategic conversation about survival, the survival of our nation, our economy, our people, and our future generations.

The Nigerian Agricultural Paradox

Nigeria is richly blessed with 84 million hectares of arable land, diverse agro-ecological zones, abundant water resources, and an energetic youth population. Yet, paradoxically, our nation continues to grapple with rising food prices, import dependency, post-harvest losses, and nutritional insecurity. According to the National Bureau of Statistics (NBS, 2025), food inflation in Nigeria rose above 30% in 2025, driven by low productivity, supply chain disruptions, and the impacts of climate change. The truth is simple but uncomfortable: we cannot achieve national prosperity when the foundation of our survival food security is fragile. The way forward is to explore agricultural innovation through precision and smart farming, digital marketplaces, mobile technology, mechanisation, biotechnology, and biofortification using these innovations as catalysts for transformation.

Understanding Food Security

Food security, as defined by the Food and Agriculture Organization (FAO, 2020), exists when all people at all times have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and preferences for an active and healthy life.

This concept rests on five key pillars:

a) Availability – Is food being produced and made available?

b) Accessibility – Can people afford and reach it?

c) Utilization – Is the food nutritious and safe?

d) Stability – Is the supply consistent?

e) Sustainability – Is the process environmentally and economically viable?

In Nigeria, each of these pillars is under strain — from low productivity and weak infrastructure to fragile value chains and inadequate innovation uptake.

The Imperative of Innovation

Distinguished colleagues, if we must feed over 220 million Nigerians and reduce our growing import bill, innovation must become the heartbeat of our agricultural system.

Innovation transcends technology — it encompasses sustainable farming practices, value chain optimization, and enabling policies. By integrating these, Nigeria can improve productivity, reduce post-harvest losses, strengthen rural livelihoods, and build resilience against climate and socio-economic shocks.

In practical terms, innovation in agriculture means:

a) Using biotechnology to develop high-yield, disease-resistant, and drought-tolerant crops.

b) Applying digital technologies — drones, sensors, and data analytics — for soil and crop monitoring.

c) Promoting climate-smart agriculture for sustainable adaptation.

d) Expanding value addition and agro-processing to reduce waste and create jobs.

e) Building research–industry linkages to commercialize innovations.

Women as Catalysts of Agricultural Transformation

Nigeria's women are the unsung heroines of the agricultural economy. They contribute between 60–70% of agricultural labour, yet face barriers in land access, finance, and technology.

Research by the FAO shows that if women had equal access to productive resources, yields could increase by up to 30%, significantly reducing hunger.

NiWARD's mission, therefore, goes beyond gender equality; it is about unlocking the nation's full productive potential. Empowered women researchers and farmers are pivotal to transforming agriculture into a tool for economic emancipation and food security

Nigeria's Emerging Innovation Landscape

The last decade has seen remarkable progress:

i. Digital agriculture platforms like Farm Crowdy, Thrive Agric, and AgroMall connect farmers to markets and investors.
ii. Research institutions and universities are developing improved crop varieties, bio fortified foods, and novel processing technologies.

iii. Private sector investments in mechanization, cold-chain logistics, and precision agriculture are expanding.

However, these efforts remain fragmented. To achieve national impact, Nigeria must establish an innovation ecosystem that links research, entrepreneurship, finance, and policy with women and youth at the centre.

Lessons from Fountain University: Innovation in Action

Permit me to share briefly from our experience at Fountain University, Osogbo, where innovation drives our teaching, research, and community engagement.

Through our Centre for Entrepreneurship and Skills Acquisition, students receive practical training in agribusiness management, food processing, and value addition.

The Fountain University Centre for Research, Innovation, and Technology (FUCRIT) provides a structure for patenting and commercializing research outputs.

Our Smart Agricultural System on campus involves the cultivation of various vegetables in sacks by 200-level students as part of a compulsory course. This innovative practice ensures a steady supply of fresh vegetables on campus at all times.

These experiences affirm that with vision and institutional support, universities can become powerful engines of agricultural innovation in Nigeria.

Technological Pathways to Food Security

Areas of promising innovation include:

i. Digital and Smart Farming — leveraging IoT, drones, and mobile data platforms.
ii. Precision Fertilization and Irrigation — optimizing inputs for yield and sustainability.
iii. Biotechnology and Genetic Improvement — developing resilient crop varieties.
iv. Post-Harvest and Value Chain Technologies — reducing waste and enhancing processing.
v. E-Extension Platforms — expanding access to advisory services.
vi. Agroforestry, Organic Farming, Water Conservation, Integrated Pest Management, and Conservation Agriculture — all vital for ecological balance and sustainable productivity.

Climate-Smart Agriculture: A Necessity, Not an Option

With erratic rainfall, flooding, and droughts, Nigeria's agriculture is highly vulnerable to climate change. Climate-smart agriculture integrates soil health, water management, renewable energy, and early warning systems. For example, solar-powered irrigation and agroforestry systems are already improving productivity and resilience.

- **AI and Data Analytics:** AI can be used for advanced crop disease diagnosis, soil condition analysis, and personalized farming recommendations. AgriGrow Analytics in Lagos provides data-driven solutions to optimize farm operations.
- **Drone and Satellite Technology:** The use of drones for crop spraying and monitoring, combined with satellite imagery for real-time assessments, is a major area for growth. The CropWatch program has shown the potential for this technology in Nigeria.
- **Climate-Resilient Crops:** Continued research into crops that are resistant to pests, drought, and flood will be crucial for protecting harvests against the effects of climate change, which already causes frequent crop failures

We must therefore support research that promotes locally adaptable and gender-responsive climate innovations.

Youth and Women Inclusion: Securing the Future

If agriculture must thrive, it must become attractive to youth and accessible to women innovators.

- Rebrand agriculture as a profitable, knowledge-driven sector.
- Create agripreneurship incubation hubs across universities and research institutes.
- Provide mentorship and seed funding for young women researchers.
- Strengthen STEM education to prepare the next generation of innovators. Through NiWARD, we can build a sustainable network of women scientists and mentors for intergenerational leadership continuity.

Policy and Institutional Imperatives

i. Innovation thrives in a supportive ecosystem. Government and policymakers must:
ii. Strengthen linkages between universities, research institutions, and industry.
iii. Provide incentives for research commercialization.
iv. Promote gender-responsive land and finance policies.
v. Invest in rural infrastructure — transport, energy, irrigation, and storage.
vi. Support long-term agricultural research beyond donor cycles.

Without coherent policy, innovation remains trapped in our laboratories instead of transforming our communities.

Success Stories and Emerging Opportunities

Innovations for enhanced food security in Nigeria include leveraging technology like satellite imagery and drones for monitoring, adopting modern irrigation and farming techniques, and implementing bio-fortification and improved crop varieties. Other key innovations involve improving post-harvest management through better storage and transportation, developing accessible financing mechanisms for farmers, and promoting climate-smart and organic farming practices. Across Nigeria, we see encouraging examples:

- Cassava value chain innovations in the South-West improving incomes for women processors.
- CropWatch Program: UNCTAD reports that Nigeria's participation in the CropWatch program has improved its capacity for agricultural monitoring, disease identification, and yield prediction through satellite imagery and remote sensing
- CoolCycle: This solar-powered cold storage solution for farmers in Epe has helped significantly reduce post-harvest losses, with projected savings of up to 60% for crops like tomatoes. By providing affordable, accessible cold storage, it addresses a major challenge for farmers and supports a circular economy.

- Youth-Led Agribusinesses: Programs like the IITA initiatives have supported over 12,500 youth-led agribusinesses, fostering entrepreneurship in production and processing that increases local food availability and creates jobs.
- BASICS-II Project: The successful completion of this project, which focused on building a resilient cassava seed system, resulted in the production and distribution of high-quality cassava planting materials, improving yields and incomes for farmers.
- Hello Tractor: This Company provides an online platform that connects smallholder farmers with tractor owners, allowing farmers to access mechanization services on a pay-per-use basis via SMS. With funding from organizations like Heifer International, it now serves over 800,000 farmers across Africa and beyond
- Fintech and Financial Inclusion: Platforms like MamaPesa use AI and USSD technology to provide financial services, including loans and savings plans, directly to women entrepreneurs in agriculture, overcoming barriers like lack of collateral and formal documentation, says Farming First.
- Vertical Farming and Controlled Environment Agriculture (CEA): Indoor, climate-controlled farming offers a way to achieve year-round production, reduce water usage, and minimize pesticide use, particularly in urban areas where land is limited.
- Rice mechanization clusters in Kebbi and Nasarawa enhancing local production.

And of course, NiWARD itself, building a vibrant network of women scientists influencing national and global policies.

The Way Forward: Our Collective Responsibility

Transforming agriculture into food security demands multi-stakeholder commitment — from government to academia, the private sector, and local communities. We must:

- Invest more in women-led agricultural research.
- Encourage public–private partnerships to translate discoveries into practical solutions.
- Support technology diffusion from labs to farms.
- Build innovation clusters and mentorship networks.

- Establish sustainable financing models for women entrepreneurs.

Conclusively, Nigeria's agriculture stands at a defining crossroads. The convergence of climate change, insecurity, infrastructure deficits, and financial exclusion threatens not just our food systems but our very stability as a nation. The transformation of our agricultural sector is therefore not a choice, it is an absolute necessity, a national duty, and a moral responsibility. Success in this transformation will depend on vision, science, inclusion, and institutional commitment. Innovation, in this context, goes beyond technology — it is about rethinking possibilities, embracing creativity, and forging resilient collaborations that bridge research, policy, and practice.

As women in agricultural research and development, we are not mere participants — we are torchbearers of change, custodians of food security, and catalysts of innovation. Our intellect, creativity, and leadership must illuminate the path toward a future where no Nigerian goes hungry, where farmers prosper, and where science truly serves humanity.

Let me take a moment to express my heartfelt appreciation to the leadership and members of NiWARD, for your unwavering dedication to advancing the role of women in agricultural science and development. You have proven that when women rise, agriculture thrives. My profound gratitude also goes to Professor Lateef Sanni, Executive Secretary of the Nigerian Stored Products Research Institute, my mentor and Ph.D. co-supervisor for his invaluable guidance, inspiration, and belief in excellence. I equally commend the Local Organising Committee for their diligence in hosting this impactful 13th Conference.

As we leave here today, may we remember that:

"*The future belongs to those who innovate, collaborate, and persevere.*" *"Food security is not achieved by chance — it is built through knowledge, courage, and collective action*." And most importantly, "*Innovation in agriculture is innovation for humanity — because food is life. And when women lead innovation, societies flourish*."

Thank you for your kind attention.

May Allah bless our efforts, bless NiWARD, and bless the Federal Republic of Nigeria**.**

From Ideas to Impact: Entrepreneurship as a Catalysts for Food Security

Professor Joy Eke-Ejiofor, *MNIFST, MISTRC, MWAAFOST*
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Director, Entrepreneurship Development Centre,
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Abstract: This paper considered the impact of entrepreneurship as a powerful catalyst in driving food security innovation, agricultural and economic transformation and innovative technological solutions as well as entrepreneurial success stories. It further examines the relationship between entrepreneurship, innovation, economic development and food security**.**

Introduction

Food security remains a pressing global challenge with millions of people facing severe hunger, starvation and malnutrition with limited access to food. The concept of human rights and the advancement of society are intricately intertwined with the idea that food is the most fundamental of all human needs. In developing countries like Nigeria, one of the most challenging aspects is the prevalence of food scarcity, both in terms of quantity and quality. According to the Food and Agriculture Organization of the United Nations (FAO), food security is a scenario that exists when all people always have physical, social, and economic access to sufficient, safe, and nutritious food that satisfies their dietary needs and food preferences for a life that is both vibrant and healthy. If the concept of "food security" refers to always having access to sufficient and acceptable foods, then the term "food insecurity" refers to the uncertainty of having access to sufficient and adequate meals.

Food security and entrepreneurship are closely related as entrepreneurial initiatives play a significant role in addressing food challenges through innovative business models, technology adoption and product development.

The four main dimensions of food security:

Physical availability of food: Food availability addresses the “supply side” of food security and is determined by the level of food production, stock levels and net trade.

- ***Economic and physical access to food***: An adequate supply of food at the national or international level does not in itself guarantee household level food security. Concerns

about insufficient food access have resulted in a greater policy focus on incomes, expenditure, markets and prices in achieving food security objectives.

- **Food *utilization*:** Utilization is commonly understood as the way the body makes the most of various nutrients in the food. Sufficient energy and nutrient intake by individuals are the result of good care and feeding practices, food preparation, and diversity of the diet and intra-household distribution of food. Combined with good biological utilization of food consumed, this determines the nutritional status of individuals.

- ***Stability*** of the other three dimensions over time: Even if your food intake is adequate today, you are still considered to be food insecure if you have inadequate access to food on a periodic basis, risking a deterioration of your nutritional status. Adverse weather conditions, political instability, or economic factors (unemployment, rising food prices) may have an impact on your food security status.

Entrepreneurship

Entrepreneurship serves as a powerful catalyst for food security by driving innovation in agriculture, developing creative business models to enhance food access and affordability, and advocating for supportive policies that create sustainable and resilient food systems. Through initiatives like social enterprises, food courts, and agri-tech startups, entrepreneurs empower farmers, reduce food waste, improve supply chain efficiency, and foster economic growth, all of which contribute to ending hunger and improving nutrition globally. As a catalyst, entrepreneurship has the ability to address food security, leveraging innovative solutions to improve food production, distribution and access. This has a multiplier effect creating new businesses and expands existing ones, more jobs translating into increased consumer spending, which drives demand for goods and services

Food entrepreneurship refers to the process of creating, developing and scaling businesses (agribusiness) that brings innovation solutions and re-creates the food industry. This could encompass a wide range of business types, from starting up catering business to being a culinary entrepreneur in food retail and delivery, food service etc.

The four main types of entrepreneurships are Small Business, Scalable Startup, Large Companies, and Social Entrepreneurship. These categories are defined by the size, growth trajectory, and overall goals of the venture, from a local service provider to a globally focused enterprise.

From Ideas to Impact on Food Security

From ideas to impact on food security involves developing, implementing, and scaling up solutions like improving sustainable agriculture, reducing food waste, enhancing infrastructure, strengthening food distribution networks, and promoting nutrition education to build resilient and accessible food systems. This process requires a multi-faceted approach through the identification of a problem, combining brainstorming solutions and breakthroughs, technological innovations, pilot studies, policy changes, community engagement, and investment to ensure everyone has enough safe and nutritious food

Ideas to Impact-Challenges

1. **Innovation and Research:** Investing in research and development to discover new sustainable food production methods, climate-smart techniques, and technologies are remotely achieved.
2. **Policy, Governance and implementation:** Implementing national strategies that prioritize increased agricultural food production, healthy diets, promotion of gender equality in agriculture, strengthening of social safety nets for vulnerable households, and consolidating access to financing of small holder farmers still remains a concern
3. **Partnerships and collaboration:** Fostering collaboration of common interest between governments, private sector actors/businesses, NGOs, and local communities to share resources and expertise are still under exploited.
4. **Community-Based Solutions:** Supporting local initiatives, such as community gardens and local food production that strengthen local food systems and build resilience is not encouraged.

5. **Finance and Resource Mobilization:** Ensuring adequate funding and access to available resources are a major challenge at both public and private sectors investor to support food security initiatives remains a problem.

Examples of Nigerian Food Entrepreneurs & Businesses

- **Ebele Enunwa (Sundry Foods/Marketsquare):** Enunwa started Sundry Foods, a company with dozens of outlets offering local and international dishes, alongside a corporate catering division and two factory bakeries. He later expanded into modern grocery retail with the Marketsquare supermarkets.
- **Henry Nneji (FoodCourt):** Nneji developed FoodCourt, a company that operates multiple in-house, delivery-only restaurant brands (like Jollof & Co. and Good Greens) from a single, centralized "dark kitchen". This model streamlines operations for food delivery services.
- **Debby Lawson (Fastizers):** Lawson founded Fastizers, a snack food company known for its cookies, with an initial investment of just 960 naira, demonstrating how even small capital can lead to a national food business.
- **Unnamed Female Entrepreneur (YouTube Video):** This entrepreneur started a food business with just 30,000 naira by purchasing small quantities of ingredients and selling tasty food, reinvesting the profits to expand her operations and build a customer base.
- **Femi Eniola (founder Osky):** Specialized in cat fish farming and processing for both domestic and international market.
- **Ego Farms:** Expert in cassava flour production and value addition.
- **Cake O' Clock:** A young graduate who started with #10,000 and now making waves in the cake and confectionery space

About Entrepreneurship Development Centre, Rivers State University: Rivers State University has an Entrepreneurship Development Centre that is strategically repositioned to provide support services to entrepreneurs, training and capacity building, business

incubations partnerships and collaborations to promote entrepreneurial skills among students and staff. These initiatives aim to foster self-reliance, move students away from solely seeking white-collar jobs, and drive economic growth and sustainability in Nigeria.

Rivers State University (RSU) has partnered with the Nigerian Stored Products Research Institute (NSPRI) to establish a Post-Harvest Storage Hub at the university, which was commissioned in May 2025. The hub includes a Parabolic Shaped Solar Dryer (PSSD), an Inert Atmosphere Silo (IAS), and a processing unit housing equipment like Hermetic Drums and Multi-Crop Dryers.

The facility offers opportunities for undergraduate and postgraduate research and training in engineering and agriculture, fostering the development of low-cost, locally adapted post-harvest technologies.

How Entrepreneurship Catalyzes Food Security

- **Drives Innovation:** Entrepreneurs introduce new technologies, products, and services that can increase agricultural productivity, create nutrient-rich foods, and make farming more efficient.
- **Enhances Food Systems:** Businesses like Twiga Foods and food hubs improve supply chains, reduce food waste, and connect smallholder farmers to larger markets, ensuring food availability and reducing costs.
- **Boosts Farmer Livelihoods:** By commercializing farming practices and creating new markets, entrepreneurs can increase the profitability and income of smallholder farmers, improve their lives and contribute to national food security.
- **Fosters Economic Growth:** Entrepreneurship creates new economic opportunities, stimulates competition, and leads to lower food prices and higher quality products, making food more accessible to consumers.

- **Addresses Food Insecurity Holistically:** By focusing on both supply-side and demand-side factors, entrepreneurs develop comprehensive solutions to food insecurity, creating sustainable food systems that benefit vulnerable populations.

- **Food availability:** Entrepreneurship is and can still improve food availability through innovative urban agriculture (such as vertical farms, community and rooftop gardens), sustainable farming (organic farming), efficient food hubs (connecting farmers to markets) as well as e-commerce platforms
- **Accessibility:** Entrepreneurship has potential to significantly improve food accessibility in underserved rural communities through innovative food delivery services, mobile markets, community supported agriculture-based programs, food cooperatives and more aimed at improving healthy and nutritious foods for all
- **Utilization:** Entrepreneurship can promote healthy eating habits through nutrition education and catering classes, healthy fortified food products, better meal plans for more convenient option, food recovery to reduce waste as well as solutions that improve food storage, handling and safety practices
- **Reduced unemployment:** This has shown to bring about new business ventures, small and medium enterprises, training and mentorship ultimately reducing job seeking and increasing economic empowerment and improved livelihood
- **Self-reliance:** Entrepreneurship is a powerful tool for making individual take control of their of their lives, create personal opportunities by being independent, owning a business, generating income, creating wealth, developing digital/vocational skills etc

Examples of Entrepreneurial Impact

- **Agripreneurship & AgriFood Tech:** Entrepreneurs and startups in the agri-food tech sector are developing innovative solutions for sustainable agriculture, addressing challenges from climate change to food waste.

- **Social Entrepreneurship:** Social enterprises are particularly effective in tackling food insecurity, using innovative business models to address social and environmental problems while creating economic value.

- **Food Hubs:** These entrepreneurial ventures increase access to fresh, healthy, and locally sourced food, especially for marginalized communities, and provide training and support to farmers.

Key Factors for Success

Governments and policymakers can foster entrepreneurship by formulating policies that encourage innovation and provide financial support, training, and access to information for entrepreneurs. Entrepreneurs and farmers need access to timely information on weather patterns, market prices, and government incentives to make informed decisions and improve their operations. Collective efforts among international donors, governments, NGOs, professional institutions, and the private sector are crucial for supporting entrepreneurial initiatives and achieving food security.

Conclusion

As women in Agricultural research and development, let us inculcate the practicality of our innovations from ideas to impact. Expand beyond laboratory results. Collaborate on pilot and viability testing of our innovations. Be ready to commercialize those ideas and serve as catalysts for Food Security.

Strengthening Value Chain and Agribusiness for Climate-resilient food systems

Diebiru-Ojo, Elohor Mercy
Seed Systems Specialist, IITA

NIWARD Conference
Nigerian Stored Products Research Institute (NSPRI),
Ilorin, Nigeria
4th November 2025



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Agenda

- Key Elements
- Climate-Resilient Food System Benefits
- Strategies for strengthening value chains
- Example of climate-resilient crops
- Supply chain or value chain?
- How does it not work
- Opportunities along the Agribusiness value chain
- Potentials and opportunities in cassava
- Initiative and conclusion

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Key Elements

1. Climate-Resilient Crops — Focus on crops like cassava, sorghum, millet adaptation to stress condition.
2. Value Chain Integration — Linking production, processing, marketing for efficiency.
3. Agribusiness Models — Innovative approaches enhancing sustainability and inclusivity.
4. Adaptation Strategies — Practices addressing drought, flooding and pest pressure.

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Climate-Resilient Food Systems Benefits

1. Food security — Stable supply of staple foods under climate variability.



Eating of balanced diets (Dietary Diversity)

2. Nutrition — Diverse, climate-adapted foods supporting health.



Eating food that have been engineered into have greater amount of nutrients (Biofortification)



Taking a vitamin tablet (Supplementation)



Through addition of micronutrients to already consumed staple products (Food Fortification)

3. Income generation — Opportunities for farmers, processors, and traders.





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Strategies for Strengthening Value Chains

The 5 key features

1. Digital Agriculture: Tech for market access, weather information, advisory services.
2. Partnerships: Collaboration among stakeholders (farmer groups, agribusinesses, research).
3. Capacity building: Training on climate-smart practices, business skills.
4. Financial inclusion: Access to credit/insurance for climate-resilient investments.
5. Innovative processing: Adding value to climate-resilient crops (e.g cassava starch)

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Example of Climate-Resilient Crops



Adaptable to Semi-Arid Conditions.



Hardy in challenging environments.

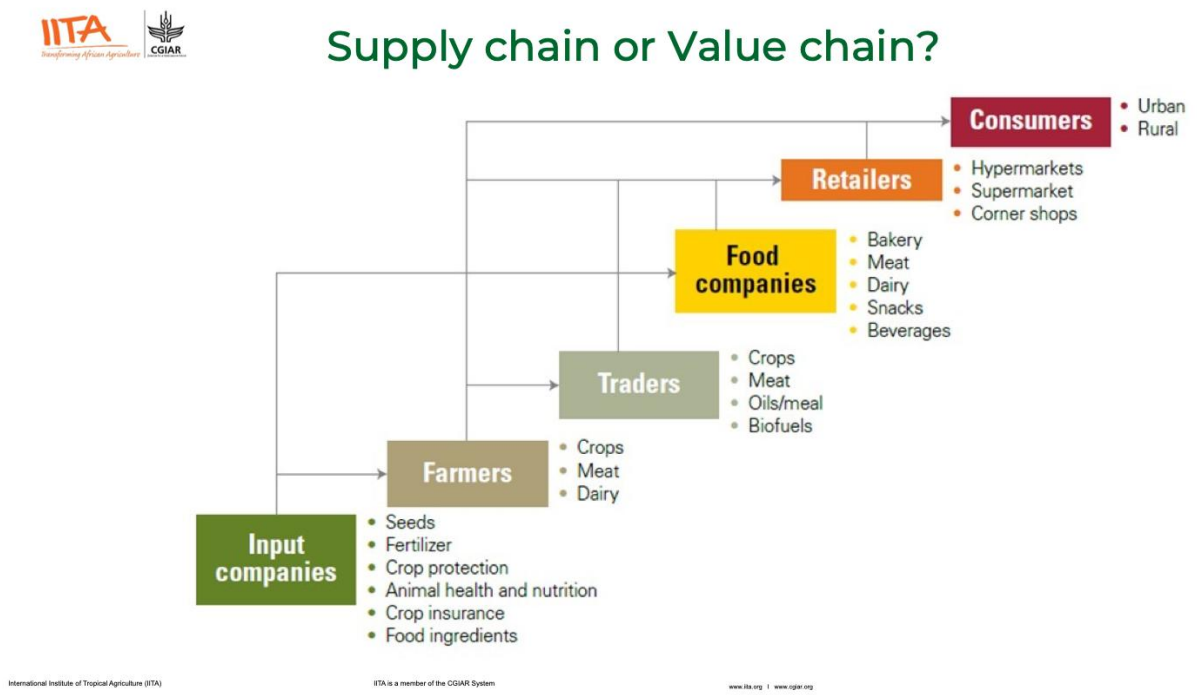


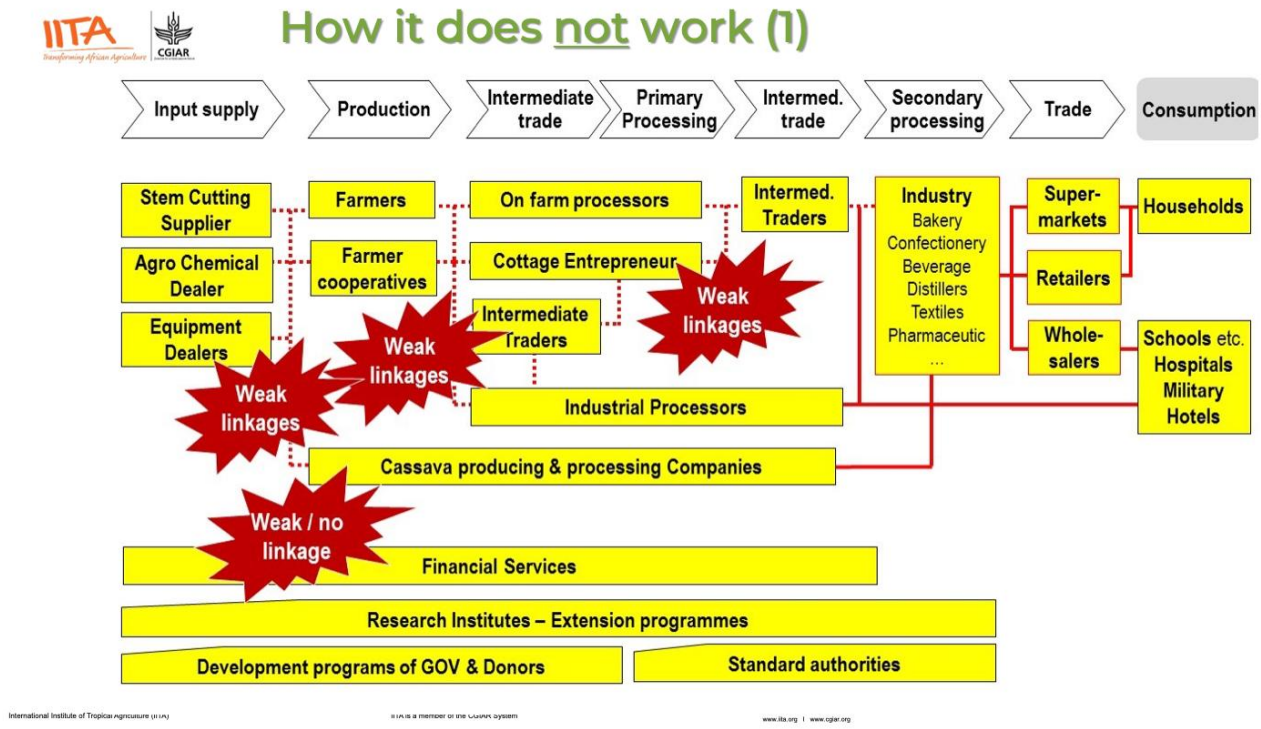
Drought tolerance; versatile uses.



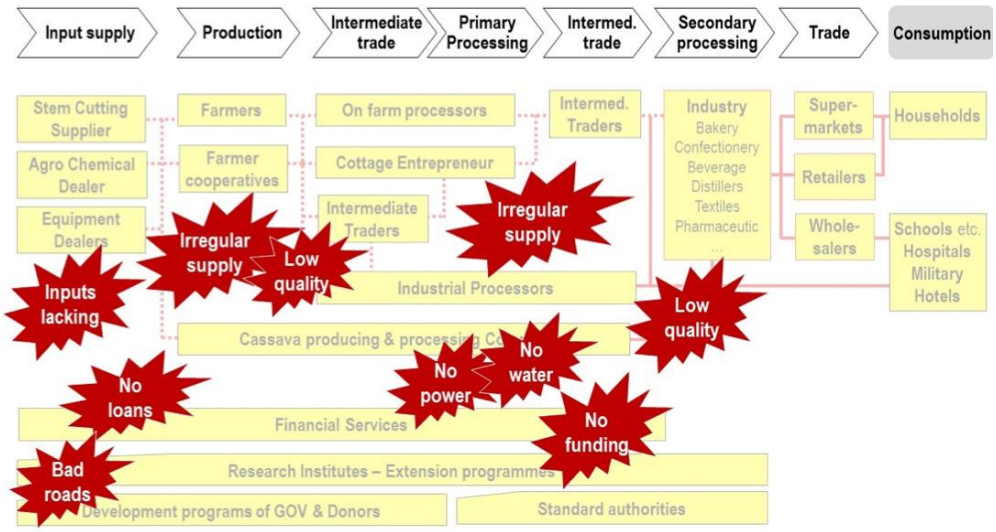
Drought and stress tolerance.

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Supply chain or Value chain?
Consumers
Urban
Rural
Retailers
Hypermarkets
Supermarket
Corner shops
Food companies
Bakery
Meat
Dairy
Snacks
Beverages
Traders
Crops
Meat
Oils/meal
Biofuels
Farmers
Crops
Meat
Dairy
Input companies
Seeds
Fertilizer
Crop protection
Animal health and nutrition
Crop insurance
Food ingredients
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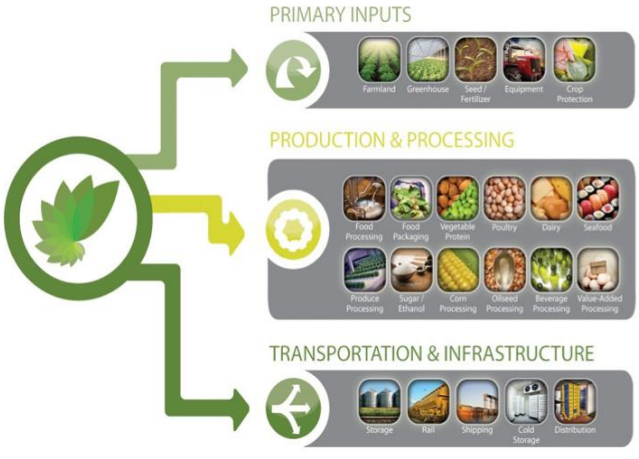

How it does not work (1)
Input supply
Production
Intermediate trade
Primary Processing
Intermed. trade
Secondary processing
Trade
Consumption
Stem Cutting Supplier
Agro Chemical Dealer
Equipment Dealers
Farmers
Farmer cooperatives
On farm processors
Cottage Entrepreneur
Intermediate Traders
Intermed. Traders
Industrial Processors
Cassava producing & processing Companies
Financial Services
Research Institutes – Extension programmes
Development programs of GOV & Donors
Standard authorities
Weak linkages
Weak linkages
Weak linkages
Weak / no linkage
Industry
Bakery
Confectionery
Beverage
Distillers
Textiles
Pharmaceutic
…
Super-markets
Retailers
Whole-salers
Households
Schools etc.
Hospitals
Military
Hotels
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How it does not work (2)

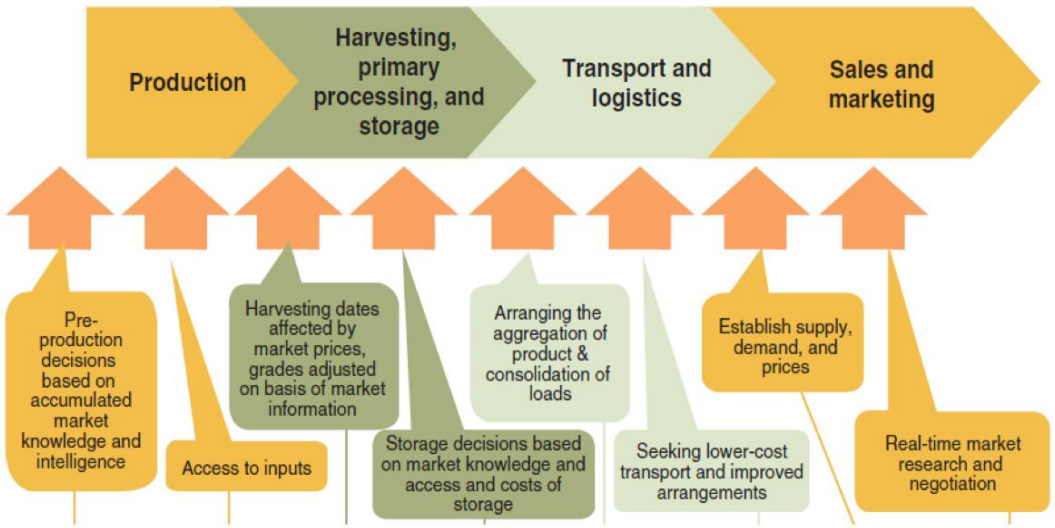


Opportunities along the agribusiness value chain

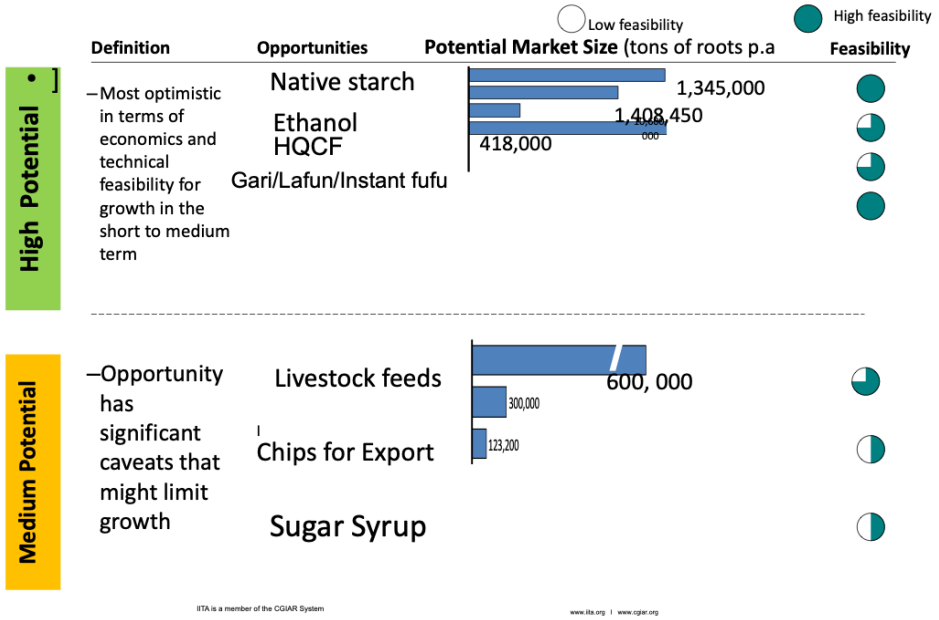
- Production
- Harvesting
- Processing – adding value
- Packaging
- Transportation
- Storage/Warehousing
- Marketing (Digital)
- Exportation –boost the country's GDP



Features along the value chain



Potentials of the Cassava Value Chain



Opportunities in cassava early-generation seed production

- Early Generation Seed Companies established in Nigeria (IITA Go Seeds; Umudike Seeds).
- Nigeria: IITA Go Seeds & Umudike Seeds
- Private seed entrepreneurs now own SAHs (Obasanjo Farms, Abass Farms, 2 NCIA)

Established in 2026 – production of early-generation cassava climate-resilient, high-yielding, and high starch varieties covering south-west and northern region

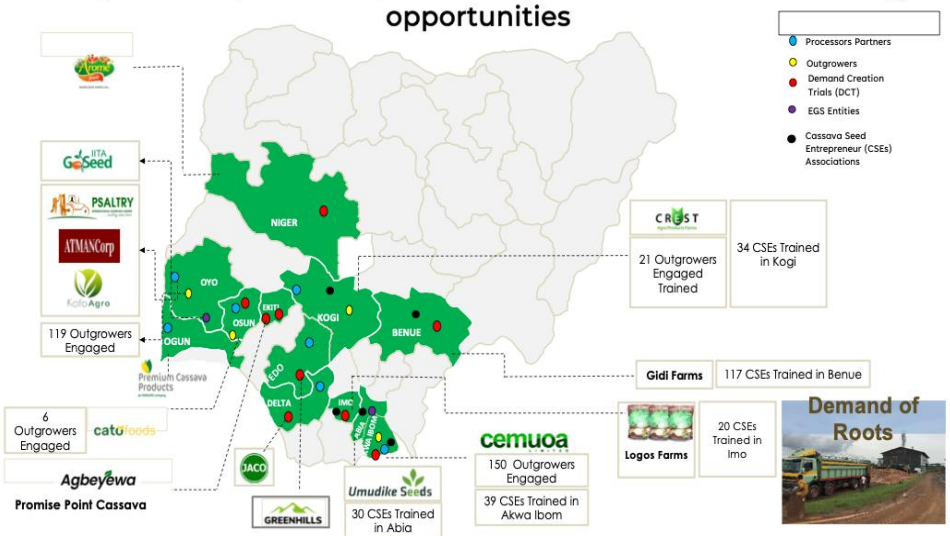
IITA GoSeed

Established in 2017 – production and sales of early-generation seed of improved cassava varieties for demand in the Southern region

Umudike Seeds ...the hub of quality seeds

Registered private companies in early-generation seed production

GoSeed strengthens its partnership with the private sector to advance agribusiness opportunities



Opportunity in certified seed production by CSEs

In Nigeria, Cassava Seed Entrepreneur is currently registered with the Corporate Affairs Commission as the Association of Cassava Seed Entrepreneurs Network of Nigeria (ACSEN).

ACSEN covers 13 States of Nigeria - Abia, Akwa Ibom, Benue, Ebonyi, Enugu, Imo, Kogi, Nasarawa, Niger, Ogun, Rivers, Taraba and Delta State

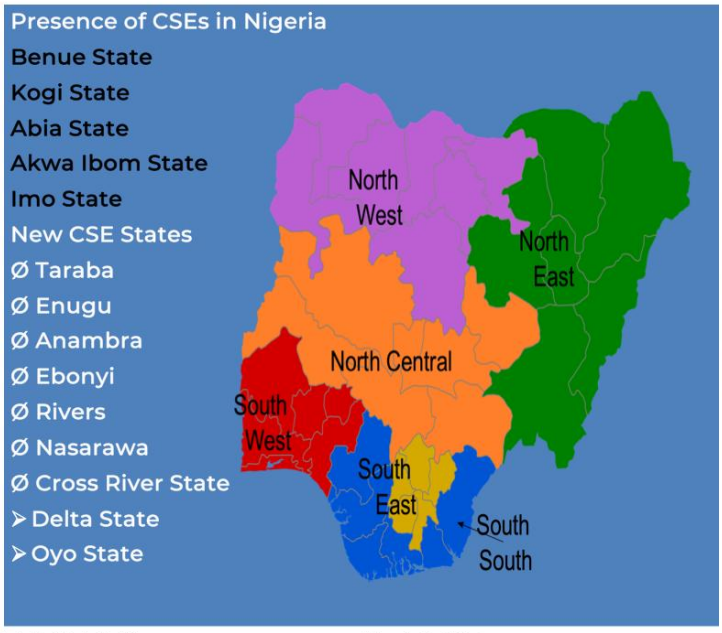
- ➢ Conduct monthly State CSE meetings
- ➢ Payment of registration and membership dues
- ➢ Awareness creation through social media advert

Set up of Criteria for selection of potential CSEs

- Adoption of improved cassava varieties
- Ownership of one hectare of seed farm
- He/she must have an android phone
- Willingness to abide by NASC regulations
- Willingness to participate in capacity building (ToT, step down training, Workshops etc)
- Networking for Business Case Development
- Willingness to adopt Orientation for self-support
- Willingness to train other farmers
- Willingness to participate in exchange/learning visits

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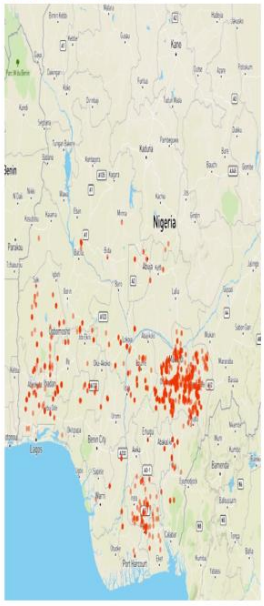
CSEs presence by locations in Nigeria

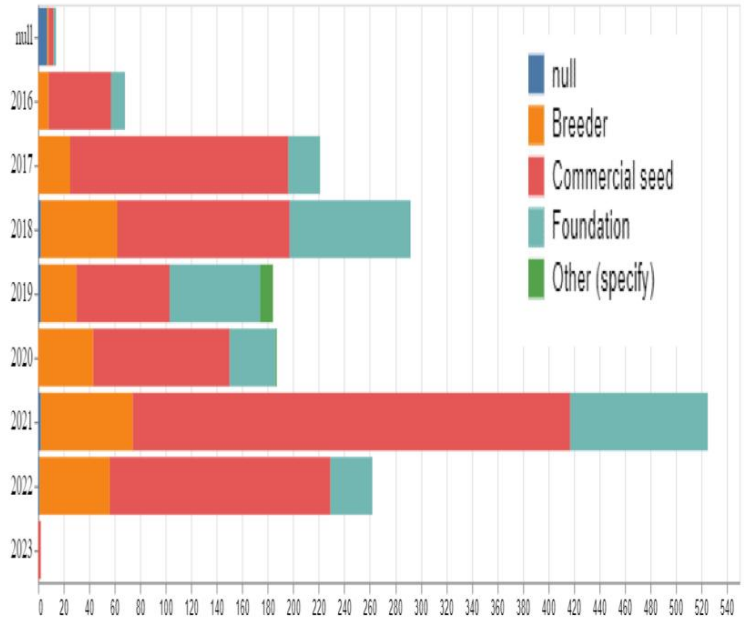




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Cassava Seed Production Outlook









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Strategies in Developing CSE Model

- Identification & recruitment of prospective CSEs
- Capacity building -ToT, Workshops etc)
- Training on GAP
- Business case development
- Orientation for self-support by CSEs
- Formal interaction
- Informal interaction (Village meetings
- Identification of farmer cooperatives
- Identification of women and youth coc
- Conduct exchange/learning visits



- Potential CSEs
- Women cooperatives
- Youth groups
- Special Government intervention projects

Potential collaborators for CSEs

- Industrial cassava stakeholders' association (ICSAN)
- Integrating the CSEs Model into the constituency project of the legislative members of the National Assembly in Nigeria
- NGOs and women cooperatives
- Integration of the community-based cassava cooperative

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Value proposition for modern cassava seed production

VALUE PROPOSITION

The main focus of a sustainable cassava seed systems is to provide improved varieties of Early Generation Seeds for seed companies and producers.

1. Improve the income and livelihoods of smallholder and commercial farmers by engaging them as seed producers
2. Engender the development of the cassava seed system in Nigeria by facilitating the downstream movement of quality cassava seeds
3. Create a sustainable cassava seed ecosystem through entrepreneurship, partnerships and trainings.

   Ensure sustainable penetration of new varieties in farmer's fields

INNOVATIVE APPROACH

BASICS Innovative strategies for scaling cassava seed production in Africa, including:



The SAH technology helps us to rapidly multiply 100% virus-free cassava planting materials in a short period of time to meet increasing demand



The pencil stem helps us to efficiently produced large volume of quality seed in a small space and reduced cost of logistics of transporting planting material



We leverage communications technology using the Cassava seed Tracker to monitor seed production across the country



We promote new varieties from the IITA & NRCRI breeding programs which are consistent with market demand



We form deep collaborations in the cassava root and seed system to develop and strengthen seed producer networks across the country



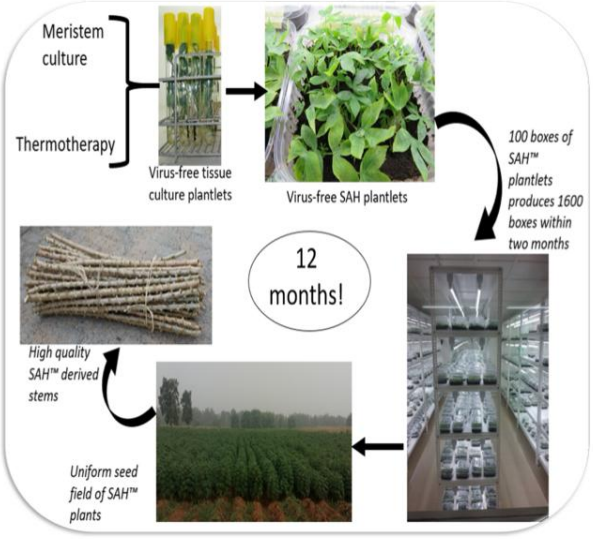
Six Steps to Cassava Weed Management toolkit for GAPs

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Climate-resilient Cassava Rapid Multiplication Technology





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Initiatives and conclusion

1. Feed the Future: US-led global food security initiative touching on resilience.
2. IITA's work: Research on climate-adapted crops, such as cassava, maize, and soybeans, led to the release of hundreds of varieties for broader adaptation.
3. Africa's climate-smart Agriculture: Efforts promoting resilient practices. Profitable business opportunities in early-generation and certified seed production.

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Thank you



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A New Era of Sustainable Prosperity

Unlocking Nigeria's Agricultural Potential through Technology & Regenerative Systems

"Leveraging Technology and Innovation for Food Security and Economic Growth"

Title: *Unlocking Nigeria's Agricultural Potential through Technology & Regenerative Systems*

Subtitle: *Leveraging Innovation for Food Security and Economic Growth*

By: *Andrew Humber-Osofisan, Founder, Onefarm™*

Foreword:

Good morning.

I want you to picture something with me. Picture a map of Nigeria. But not the map we usually see. I want you to picture a map of potential.

A map where the arid fields of the North are lush and green, where the plains of the Middle Belt are bursting with life, and the deltas of the South are hubs of sustainable prosperity, a map where our rural communities are not places of poverty, but engines of wealth creation.

This isn't a fantasy. This is a future that is absolutely within our grasp. But to get there, we must first confront a painful paradox.

Agriculture remains the foundation of Nigeria's prosperity and resilience. With 60% of its population engaged in agriculture, the opportunity to transform this sector into a technology-driven, regenerative, and globally competitive force has never been greater.

Onefarm™ envisions an agricultural revolution built on innovation, data, and regenerative systems—empowering farmers, restoring soils, and building national food security for generations to come. This vision calls for collaboration across government, private sector, and civil society to unleash the full potential of Nigeria's agricultural landscape.

Confronting the Nigerian Paradox

Nigeria's agricultural sector presents a national paradox of immense scale. With over 84 million hectares of arable land (only 40% cultivated), a large youthful population, and diverse agro-ecological zones, the potential is undeniable. Historically a leading agricultural exporter, the sector now contends with severe challenges: **over 25 million citizens face acute hunger**, productivity is hampered by rain-fed dependence and rudimentary tools, and post-harvest losses reach 40-60%, representing an estimated **N3.5 trillion in annual economic waste**. This reality, coupled with billions spent on food imports, underscores the urgent need for a transformative, integrated strategy.

Immense Potential vs. Persistent Challenges

On one hand, we are blessed with arguably the most fertile potential in Africa: over 84 million hectares of arable land, a vibrant, youthful population, and a history of being an agricultural powerhouse.

And on the other hand, the stark reality: over 25 million of our fellow citizens face acute hunger. We lose up to half of what we grow before it even reaches a plate. And we spend billions of dollars—precious foreign exchange—importing what our soil is perfectly capable of producing.

So, the billion-dollar question is this: How do we bridge this gap? How do we turn this immense potential into tangible prosperity?

The answer is not in doing more of the same. The answer lies in a fundamental transformation. A transformation built on three powerful, interconnected pillars, which I refer to as the 3 Pillars of Transformation.

The Three Pillars of Transformation (are)

First, **Cutting-Edge Technology;** —the tools for a new era.
Second, **Widespread Innovation**—in our business models and our policies.
And third, the non-negotiable foundation… a **Regenerative Agriculture System**.

Let's break this down.

The Technological Leap

Technology is our great leap forward. We're talking about drones and satellites that give a farmer the eyes to see pest outbreaks before they destroy his farm. Soil sensors that send data directly to his phone, telling him *exactly* what his crops need, not guesswork. We're talking about digital platforms that connect a woman in a rural village directly to a buyer in Lagos, cutting out the middlemen and putting more money in her pocket.

And perhaps one of the most powerful innovations? Equipment-as-a-Service.

Imagine a young graduate being able to lease a tractor through an app, just like you book a ride. He doesn't need to own it; he just needs access to it. This is how we democratize mechanization.

But… and this is a crucial "but"… technology alone is not a silver bullet. You cannot fix a broken foundation with a smart hammer.

Our soil is tired. Decades of unsustainable practices have depleted it. And that brings me to our second and most critical pillar.

The Regenerative Revolution

This is the paradigm shift. Regenerative Agriculture. Notice I didn't say "sustainable." Sustainable means we do less harm. Regenerative means we actively heal. We restore.

Core Principles of Regeneration

It's a simple, powerful set of principles:

- We stop violently tilling the land.
- We keep the soil covered, protected.
- We minimize the use of chemical fertilizers and pesticides.
- We plant a diversity of crops, working with nature, not against it.
- We bring livestock back into the cycle, letting them fertilize the land naturally.

Why is this game-changer for Nigeria?

Why Regeneration is a Game-Changer

It restores our degraded land, fighting desertification in the North.

It builds climate resilience healthy soil acts like a sponge, holding water during droughts and absorbing it during floods.

It sequesters carbon, turning our farms into weapons against climate change.

And it boosts yields and reduces costs for our farmers over time.

It is, quite simply, the smartest investment we can make in our future.

Now, some might say, "This sounds like going back to the past." And I say, no. This is about leaping forward, intelligently. And this is where the magic happens.

Tech + Regeneration: - *The Powerful Synergy*

This is where Pillar One and Pillar Two fuse together. Technology is the accelerator for regeneration.

Imagine a farmer using a soil scanner to see the exact health of her land, guiding her regenerative practices. Imagine satellites tracking the greening of her farm over the years, measuring the impact. Imagine mobile apps that connect her to a community of practice, extension services and research data where she can learn and share. *JUST IMAGINE!!!*

This isn't a choice between tech and tradition. It's the fusion of both to create something entirely new, and entirely powerful.

Regenerative + Digital Agriculture = Nigeria's Next Growth Frontier

- Regenerative agriculture rebuilds soil carbon, restores ecosystems, and enhances resilience.
- Digital tools (IoT, drones, AI, data analytics) increase efficiency and reduce waste.
- Nigeria's youth demographic (60% under 30) can power a green tech-driven agricultural economy.
- Carbon farming and biochar initiatives open access to billions in global carbon credit markets.

But to make this fusion work, we need our third pillar.

The Ecosystem of Innovation

We need an ecosystem of innovation. This is about financial innovation digital loans, climate insurance. It's about business model innovation farmer cooperatives, corporate off-take agreements. And it is absolutely about policy innovation government creating the environment for this to thrive, from land tenure rights to smart subsidies and investing in rural infrastructure.

This is not a task for one group alone. We need the layers like a solid /sturdy ladder.

A Multi-Stakeholder Action Plan

Government, your role is to be the enabler—create the policies, build the infrastructure.
Private sector, your role is to be the engine invest, scale, and build the markets.
Farmers, you are the heart of this we must embrace new knowledge and collaborate.
And **Academia and Developers**, you are the innovators—create the solutions that are affordable and locally relevant. When we align these forces, the projected impact will be breathtaking.

The Vision: Our Future Harvest

We see a **food-secure Nigeria**, self-sufficient and resilient.
We see **millions of new jobs** not just on the farm, but in tech, logistics, processing, and export.
We see **wealth generation** right here at home, and **high-value Nigerian products** commanding premium prices on the global stage.
And we see **environmental renewal**—our land healed, our water cycles restored.

So, I will leave you with this.

Conclusion - The Time is Now

We have a choice. We can continue on the current path, a path of dependency and depletion, or, we can choose a different path. A path where we **Feed Our Nation** with the fruits of our own land. A path where we **Grow Our Economy** from the ground up. A path where we **Heal our Land** for our children and grandchildren. Nigeria's transformation depends on collaborative effort. Policymakers, investors, and development partners must unite to support initiatives that bridge technology, training, and regeneration. Onefarm™ is ready to lead this transition empowering a new generation of "Agriticians™" to restore our soils, secure our food, and power our economy sustainably.

The tools are here. The knowledge is here. The need is urgent.

The time for a new harvest in Nigeria is now. It is time to unlock our potential together, let's **Regenerate.**

Onefarm™ Strategic Model

1. **Training & Capacity Building:**
   Through the *Onefarm Institute*, we train "Agriticians™"—modern agricultural professionals skilled in technology, climate action, and regenerative practices.
2. **Technology Adoption:**
   Use of precision tools, digital monitoring, and farm data platforms to optimize inputs and increase yields.
3. **Regenerative Systems:**
   Soil carbon restoration via biochar, composting, and rotational systems.
4. **Value Chain Integration:**
   Linking farmers to processing, logistics, markets, and export.
5. **Policy Engagement:**
   Supporting government and partners in creating frameworks for tech-driven regenerative growth.

Key Statistics & Impact Projection (Illustrative)

Metric	Current (2024)	Target (2030)	Source
Agricultural GDP Share	25%	35%	World Bank (2024)
Youth Employment in Agri-Tech	5%	20%	FAO / AfDB (2023)
Soil Carbon Restored	—	1.5 million tons	UNEP / Onefarm™ Model
Food Import Reduction	₦3 trillion	₦1 trillion	NBS
Post-Harvest Loss	35%	15%	FAO (2023)
Carbon Revenue Potential	—	$500M/yr.	Puro.Earth / Voluntary Carbon Market

- FAO (2023), World Bank (2024), AfDB (2023), AP News Agriculture Review (2024), Onefarm™ Insights

Appropriateness of Drama as a Tool for Agricultural Information Dissemination in Imo State, Nigeria

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Abstract

Information and communication are vital to achieving sustainable agriculture. A key barrier between research and sustainable food production is the poor and ineffective information delivery system. Although drama has proven effective in disseminating information, its use in agriculture remains limited. This study therefore, assesses the appropriateness of drama as a tool for agricultural information dissemination in Imo State, Nigeria. Specific objectives were to identify farmers' sources of agricultural information, the appropriateness of drama as an agricultural information dissemination tool and the preferred medium of drama. A multistage sampling procedure was used to select 180 respondents from Owerri, Orlu, and Okigwe agricultural zones. Data were analyzed using frequencies, percentages, mean scores and multiple regression. Most farmers (73.3%) sourced agricultural information from the listed sources, with drama ranking 16th. In-depth interviews showed that ADP staff in Orlu zone use drama for information dissemination, while those in Owerri do not. Respondents perceived drama (M = 3.1) as appropriate and effective. Picture story (90%) and storytelling (89.4%) were the most preferred forms. Most respondents were open to various participants in drama, with students (86.7%) and farmers from other communities (85.6%) most preferred. The study recommends increasing awareness, sensitization, and advocacy for the use of drama as a viable tool for disseminating agricultural information.

Keywords: Agricultural Extension, Agricultural Information Dissemination, Drama, Appropriateness.

Introduction

The agricultural sector is the most important sector of the Nigerian economy which holds a lot of potentials for the future economic development of the nation (Kenny, 2019). However, in recent years, its contribution to the nation's economy has been on the decline. This can be deduced from the statement

of Kenny (2019) that the sector's productivity estimates for Nigeria reveals a fall in agricultural productivity growth since 1970s. Part of the solution to this, is efficient dissemination of agricultural information, as it has been noted that, for agriculture in Nigeria to be sustainable, bring about economic growth, and improve the livelihoods of rural people, there is need for farmers to be informed about technologies and agricultural practices.

It has been observed however, that the problem is not lack of agricultural information, but its dissemination, as research has found out that, the missing link between research and sustainable production is lack of effective delivery services. Ajani and Onwubuya (2013) also stated that communication strategies used by extension agents in disseminating information to farmers seem to be ineffective, because field observations indicate that the desired results are yet to be achieved. There is therefore need for the use of a veritable tool for agricultural information dissemination.

Drama as an approach has been proven to be a powerful tool for teaching, learning, and entertainment as it arouses people's interest and fosters understanding, hence a veritable tool for information dissemination and education. As stated by Ojemudia (2013), drama acts as a medium for information dissemination, communication, entertainment, conscientization and education. For instance, most campaigns against AIDS, drug abuse, and so on are presented in form of drama. Drama compels peoples' interest because of the degree it appears to imitate real life. According to Wakesho *et al.* (2018), drama is used to educate, demonstrate a principle, and illustrate a point of practice.

Drama utilizes varied mediums such as stage performance of plays, dances, musicals, mimes, dramatic presentations, films and so on to communicate (Ojemudia, 2013). These mediums are forms through which drama can be performed. Some of them are audio drama/play, stage drama, storytelling (narrative drama), picture story (picture leaflet/book) with or without dialogue, and, agricultural video/movie clips.

The need for the incorporation of drama in agricultural information dissemination can be seen in Agric today (2020) that, to ensure adequate dissemination of information in agriculture value chain, the world Food Programme has urged stakeholders to use drama as a means of educating farmers and producers in the value chain. According to Lauds in Agric today (2020), the concept of integrating drama into the agricultural value chain could be used as advocacy to project topical messages like post-harvest losses, nutrition, and encourage the youth to venture into the sector. Though drama has been proved to be a veritable tool in communication and information dissemination, its application in dissemination of agricultural information has not been well explored. This therefore necessitates an investigation into the perception of farmers on the use of drama for agricultural information dissemination.

Methodology

Study Area

The study was carried out in Imo State, Nigeria. Imo State is in the South East zone of Nigeria. Imo State came into existence on February 3rd 1976 along with other new states created under the leadership of the late military ruler of Nigeria Murtala Muhammad. Imo State lies between latitude $5^{0}12^{1}$ and $5^{0}56^{1}$ North of the equator and between longitudes $6^{0}38^{1}$ and $7^{0}25^{1}$east of the Greenwich meridian. It is bordered by Abia State on the East, by Anambra State to the North and River State to the South (Imo State Government (IMSG), 2001).

Sampling Technique

Multistage sampling procedure was adopted in the selection of farmers. The first stage comprised a purposive selection of two (2) Local Government Areas (LGAs) each, from the three agricultural zones making a total of six (6) LGAs; this is because of their high involvement in agriculture. The second stage was the random selection of two (2) communities from each of the LGAs selected, making a total of twelve (12) communities. The third stage was a random selection of fifteen (15) farmers from the twelve selected communities, making a total of one hundred and eighty (180) farmers.

Data Collection

Structured questionnaire was used to collect primary data from the one hundred and eighty (180) selected farmers, and in-depth interview (IDI) was used in collecting data from ADP staff in the three agricultural zones. Data collected from ADP staff were to assist the researcher in cross-checking the answers obtained from the farmers on the use of drama for agricultural information dissemination in Imo State.

Data Analysis

Data collected were analyzed using descriptive statistics (frequency distribution, percentage and mean)

Result and Discussion

Sources of Agricultural Information

The result shows that the respondents received agricultural information from all the sources enumerated (Table 1). The result also shows that fellow farmers ranked 1st among sources of agricultural information. It further shows that radio ranked 2nd. This implies that incorporating audio drama (radio drama) in the use of radio for agricultural information dissemination will be productive and excellent. This can be

deduced from Perkins in Harvest Plus (2016) that radio drama can be an excellent way to share information with hundreds and thousands or even millions of small-scale farmers. The farmers can be entertained and learn alongside the character depicted in the story.

Table 1. Farmers' Sources of Agricultural Information

Sources of Agricultural information Options	*Frequency	Percentage	Rank
Radio	155	86.1	2nd
Television	138	76.7	4th
Friends/Neighbors	154	85.6	3rd
Fellow Farmers	170	94.4	1st
Agricultural Cooperatives	93	51.7	11th
Print Media example Newspapers, bulletins, leaflets	102	56.7	8th
Internet example Google	95	52.8	10th
NGO	88	48.9	12th
Family Members	133	73.9	5th
Private Sector	72	40.0	17th
Telephone	80	44.4	15th
Community Leaders	110	61.1	7th
Extension Agents	98	54.4	9th
Research Institutes	59	32.8	18th
Video	105	58.3	6th
Drama	75	41.7	16th
Social Media Apps: WhatsApp, Twitter, Instagram, LinkedIn etc.	85	47.2	13th

Source: Field Survey, 2023 *Multiple responses recorded

The result also shows that drama ranked 16thamong the sources of agricultural information listed, this implies that the use of drama for agricultural information is not totally foreign in the study area, but it is not very well utilized either. This can be deduced from the difference in the response of ADP Staff in Orlu agricultural Zone during the In-depth interview that: *We use drama for agricultural information dissemination,* and the response of ADP Staff in Owerri agricultural zone, that: *We do not use drama for agricultural information dissemination*

Appropriateness of drama as a tool for agricultural information dissemination

Farmers' perception of appropriateness of drama as a tool for agricultural information dissemination shown in Table 3. The respondents strongly agreed (3.6) that, with the use of drama, they will be more productive in agriculture, as the information shared will not be easily forgotten. This implies that drama

can encourage information retention. They strongly agreed (=3.6) that entertainment catches their attention, so the use of drama for agricultural information dissemination is welcome. Also, the respondents agreed (=3.4) that they usually do not have patience to listen to agricultural information, so the use of drama will make a difference. This implies that the respondents consider drama as interesting and a good tool for agricultural information dissemination. The respondents agreed (3.1) that picture story will make reading an agricultural content enjoyable. This implies that the respondents will be receptive of picture story for agricultural information dissemination. The respondents agreed (3.1) that they find storytelling engaging, and believe it will be nice if used in communicating agricultural information.

The table further shows that the grand mean was 3.1 and was accepted. This implies that, drama was perceived as a suitable tool for agricultural information dissemination. This is in consonance with CABI (2020) that art, music, dance, drama, humor, storytelling and other forms of entertainment can serve as effective tools for sharing information on agricultural best practices with small holder farmers.

Table 2. Appropriateness of drama as a tool for agricultural Information Dissemination

Appropriateness Options	4 SA	3 A	2 D	1 SD	2.5 Mean	Remark
Drama is not a new thing to us in the community so applying it to agriculture would be a good idea	116	72	6	2	3.9	Accept
There has been times drama has been used to communicate to us in other aspects of life	115	38	19	8	3.4	Accept
We do not see anything wrong with the use of drama as a community	128	35	10	7	3.6	Accept
I will prefer to be given information plainly; I do not care about the use of drama.	64	29	40	47	2.6	Accept
I see drama as a waste of time, why go through all that stress	56	19	52	53	2.4	Reject
Using drama to disseminate agricultural information will seem like child's play.	92	46	19	21	3.1	Accept
Entertainment catches my attention, so the use of drama for agricultural information dissemination is welcome.	129	36	8	7	3.6	Accept
Information sticks more when it is performed, so using drama for information dissemination will be appreciated.	106	49	17	8	3.5	Accept
I think we should maintain other means of agricultural information dissemination that has been in use.	50	37	39	54	2.5	Accept
We have been getting adequate agricultural information so I do not see any need for using drama	31	28	49	72	2.1	Reject

I think the best way to communicate to us as a community will be through drama	66	78	25	11	3.1	Accept
Drama allows for experimental learning as farmers can relate more with what is being communicated	116	42	14	8	3.5	Accept
The use of drama is not the solution to the challenges to agriculture in our community	79	64	35	2	3.2	Accept
I have a not forgotten most things I saw through drama so I believe using drama to disseminate agricultural information will help me remember it more.	84	46	30	20	3,07	Accept
Appropriateness Options	4 SA	3 A	2 D	1 SD	2.5 Mean	Remark
There are much to gain from the use of drama for agricultural information dissemination, so I like the idea.	93	63	14	10	3.3	Accept
I love it when drama is used to pass across information, especially when I am participating in it	96	75	7	2	3.5	Accept
The activities involved in the use of drama example participating in video productions will be detrimental to us, especially our young ones	40	40	55	45	2.4	Reject
The use of drama will give us exposure and better our lives	111	55	10	4	3.5	Accept
I am busy and will not have time for receiving agricultural information using drama, I will prefer to be communicated plainly	45	23	78	34	2.4	Reject
I believe using drama to communicate agricultural information will help me understand it more	120	32	21	7	3.5	Accept
I usually do not have patience to listen to agricultural information; I believe the use of drama will make a difference	110	49	10	1	3.4	Accept
I do care what is used in disseminating agricultural information	46	30	68	36	2.5	Accept
Drama is engaging. I believe applying it in agriculture will help me adopt more technologies	108	51	11	10	3.4	Accept
I understand things more when it is communicated through drama	97	69	14	0	3.5	Accept
I see drama as a good tool for agricultural information dissemination	86	59	30	5	3.3	Accept
Drama sounds childish and should not be used in a serious thing such as agriculture	51	22	69	38	2.4	Reject
Appropriateness Options	4 SA	3 A	2 D	1 SD	2.5 Mean	Remark
Drama does not engage me	17	23	67	73	1.9	Reject
Participating in drama during trainings will be entertaining.	62	76	33	9	3.1	Accept

I do not see any relationship between agriculture and drama	72	18	44	46	2.6	Accept
Participating in drama during agricultural trainings will be embarrassing.	49	35	50	46	2.4	Reject
I believe that participating together in drama will improve the relationship of farmers	77	62	35	6	3.2	Accept
The use of drama will not only positively affect our agricultural activities but our lives generally because it engages the mind	98	59	20	3	3.4	Accept
Using drama for agricultural information dissemination will engage farmers and stimulate self-activity and direction	129	51	0	0	3.7	Accept
I believe that drama arouses and sustains interest and curiosity throughout the process	114	52	10	4	3.5	Accept
I believe that drama encourages creativity	105	65	10	0	3.5	Accept
Picture story will make reading an agricultural content enjoyable	71	61	35	3	3.1	Accept
I find storytelling engaging. I believe it will be nice if used in communicating agricultural information.	73	67	25	15	3.1	Accept
Communicating agricultural information with videos will be impactful since it is a combination of audio and video	116	54	8	2	3.6	Accept
Total	3406	1914	1153	731	3.11	Accept

N = 180.Discriminatory index = 2.5, SA – Strongly Agreed, A – Agreed, D – Disagreed, SD – Strongly Disagreed Farmers preferred medium of drama Preferred medium of drama

The result indicates that the respondents will appreciate receiving agricultural information from all the listed mediums of drama (audio drama, video clips, storytelling, picture story, and stage drama) (Table 3). However, majority (90.0%) preferred picture story, this is followed by storytelling (89.4%)

Table 3. Farmers preferred medium of drama

Preferred medium/form of drama	*Frequency	Percentage %
Audio (from radio, podcast etc.)	138	76.7
Video Clips (from CDs, Memory cards, TV channels etc.)	130	72.2
Storytelling	161	89.4
Picture Story	162	90.0
Stage Drama	160	88.9

Source: Field Survey, 2023 *Multiple responses recorded

Preferred people to participate in drama

The result shows that the respondents would appreciate receiving agricultural information through drama from all the listed options (extension agents, farmers' resident in that community, a combination of both, farmers from other communities, research institutes, students, and professional actors). However, majority (86.7%) indicated interest in receiving agricultural information through drama from students (Table 4).

Table 4. Preferred People to Participate in Drama

Preferred people to participate in drama	*Frequency	Percentage %
Extension Agents	131	72.8
Farmers i.e. the resident farmers in the community	152	84.4
A Combination of the Both	145	80.5
Farmers from other communities, towns, nations, but with similar agricultural environment or content	154	85.5
Research institutes	137	76.1
Students (Secondary school or University)	156	86.7
Professional actors	150	83.3

Source: Field Survey, 2023 *Multiple responses recorded

Conclusion

The study shows that the farmers consider drama as a suitable and appropriate tool for agricultural information dissemination and will want to receive agricultural information through all the drama mediums used in this study. Furthermore, farmers will appreciate agricultural students participating in the drama production, and that farmers will be willing to participate as well. Increased awareness, sensitization, and advocacy for the use of drama as a viable tool for agricultural information dissemination is therefore recommended.

References

Centre for Agriculture and Biosciences International CABI (2020) "Banana and I": sharing better banana management in Uganda through Drama. blog.cabi.org.

Kenny, S. (2019). The role of agricultural sector performance on economic growth in Nigeria. MPRA.

Ajani, E. N., and Onwubuya, E.A (2013). Constraints to effective communication among extension agents in Anambra state, Nigeria. Journal of Agriculture and Food Information. Pub. Taylor and Francis Group LLC 14, 18 – 25.

Ojemudia C.C. (2013). Drama as an instrument for national identity formation. UJAH: Unizik *Journal of Arts and Humanities,* 14, 3, 33-44.

Wakesho, G., Pittcher, J., Midega, C., Zeyaur, K. (2018). An Assessment of the effectiveness of participatory video and drama in enhancing learning of "climate smart push-pull technology: a case study of Butere and Vihiga farmers in Western Kenya. International *Journal of Agricultural Extension,* 06(02), 109-115.

Agrictoday (2020). Engage drama to project messages across the agriculture value chain – WTP.agrictoday.com.gh.

Imo State Government (IMSG) (2001). Examination Ethics Commission, Imo State Government, Ministry of Education, Owerri Imo State.

Toxicity of Pawpaw Seed Oil to *Meloidogyne incognita* Parasitizing Okra Plants

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Abstract

The efficacy of pawpaw seed oil as a potential nematicide was compared with carbofuran in a two years screenhouse study. The seed oil was applied at various concentrations (15, 25 and 35 mL), while the growth of okra plants inoculated with *Meloidogyne incognita* was monitored for a space of ten weeks. A considerable reduction in *M. incognita* population was seen in the soil and root (12.09 and 9.23 respectively) of plants treated with the highest concentration (35 mL) of pawpaw seed oil in comparison with 956.34 and 585.06 recorded in control plants. Significantly ($p<0.05$) higher vegetative growth was also observed in treated plants as against untreated control plants. The pawpaw seed aqueous extract was not as effective as the seed oil in *M. incognita* management, but significantly better than the untreated plants. Pawpaw seed oil could be processed and harnessed into a bio nematicide, thus eliminating environmental pollution of synthetic nematicide and reducing epidemics of improper management of solid waste.

Keywords: Pawpaw seed oil, Nematicide, Carbofuran, Okra, *Meloidogyne incognita*

Introduction

Plant parasitic nematodes (PPN) constitute a significant problem in agriculture. They hinder the sustainable production of several crops (Kolombia and Fabiyi, 2023). The root knot nematodes (*Meloidogyne* spp) are known to cause an estimated loss of about 30% worldwide on crops. Total crop loss has been recorded in severe cases of infection with a direct effect on food production. Primarily, the control of nematodes is important to maintain high and optimal yield. However, the application of synthetic nematicides in nematode control is a threat to the environment, which has culminated into ecological disturbance, risk to human health and contamination of potable water (Fabiyi and Olatunji, 2021). It is however necessary to figure out a better way of control while maintain a healthy environment. In this regard, the toxicity of pawpaw seed oil was evaluated. Pawpaw (*Carica papaya*) is one of the most important fruits grown in the world. Nigeria is among the largest producer of *Carica papaya* in the world (Barroso et al., 2016). The fruit contains several seeds which are considered waste. The milky juice from the unripe fruit is known to be a powerful anti-helminthic in the treatment of round worms (Nagesh et al., 2002), while the fresh leaves are employed in management of gonorrhea, syphilis and amoebic dysentery

cases. Reports on application of pawpaw seed oil and pawpaw seed aqueous extract in the management of *M. incognita* is scarce in literature. Hence, the aim of this research is to examine the potential of unutilised pawpaw seeds which are hitherto considered waste in *Meloidogyne incognita* management.

Materials and Methods

Ripe pawpaw fruits were purchased from Ipata market, Ilorin, Nigeria in large quantities. The fruits were opened up and the seeds were removed manually from the hollow groove of fruits. A part was soaked in water for aqueous extraction, while the second part was extracted with petroleum spirit in a soxhlet extractor at 50 °C for five hours. After extraction, the solvent was distilled under reduced pressure and the pawpaw oil was recovered.

Nematicidal Assay

Collection and extraction of inoculum

Nematode eggs were extracted from galled roots by dissolving nematode egg masses in 0.5% sodium hypochlorite while constantly shaking for 4 min. Eggs released into the solution were separated from roots and debris by sieving first through a 2 mm, 75 µm and lastly through a 25 µm aperture sieve in which the eggs were retained. The eggs were thoroughly rinsed and collected in a clean beaker. The number of nematode eggs per mL of the extract was evaluated by counting under a stereomicroscope.

Pot Experiment

Pasteurized soil was distributed into 10 cm diameter experimental pots at 10 kg each. The experiment was a randomized complete block design (RCBD) with three treatments, four rates of application and three replicates each. The inoculated but untreated pots served as the control. Carbofuran served as a positive check. Okra cv local seeds were planted and inoculated with approximately 500 eggs of *Meloidogyne incognita* two weeks after seedling emergence. 1 mL of non-ionic surfactant was added to each concentration (15, 25 and 35 mL) of oil for solubilisation, while the aqueous seed extract was used directly. A week after inoculation, the treatments were applied in banded form around the base of each okra plant. Data taken in the course of the experiment include plant height, number of fruits per plant and fruit weight per plant. Number of egg masses, nematode population in plant root and soil were done in the laboratory after harvest. Root gall was rated following standard procedure.

Results

Table 1: Effect of pawpaw seed oil, aqueous extract and carbofuran on plant height (cm) of *Meloidogyne incognita* infected okra plants

Treatments	4th WAP	6th WAP	8th WAP	10th WAP
PSDO	18.11[a]	27.05[a]	33.06[a]	41.32[a]
PSAE	16.19[a]	23.10[b]	29.21[b]	36.22[b]
CBFN	12.00[b]	20.04[c]	26.39[c]	35.18[b]
Level/mL				
0	2.01[d]	4.13[d]	8.17[d]	10.06[d]
15	6.13[c]	9.12[c]	13.22[c]	20.00[c]
25	10.07[b]	14.11[b]	18.11[b]	24.08[b]
35	13.18[a]	17.09[a]	23.21[a]	29.14[a]

Means in a segment of a given column followed by the same letter are not significantly different at p<0.05 using the new DMRT. DMRT=Duncan's multiple range test. Each value is a mean of three replicates.

Table 2: Effect of pawpaw seed oil, aqueous extract and carbofuran on numbers of fruit per plant and fruit weight of *Meloidogyne incognita* infected okra plant

Treatments	Numbers of Fruit/plant	Fruit weight/plant (g)
PSDO	26.11[a]	363.13[a]
PSAE	17.13[b]	249.00[b]
CBFN	12.21[c]	214.32[c]
Level/mL		
0	2.00[d]	66.05[d]
15	5.16[c]	134.18[c]
25	9.05[b]	185.23[b]
35	15.00[a]	205.17[a]

Means in a segment of a given column followed by the same letter are not significantly different at p<0.05 using the new DMRT. DMRT=Duncan's multiple range test. *Each value is a mean of three replicates.*

Table 3: Effect of pawpaw seed oil, aqueous extract and carbofuran on nematode population in soil and root of *Meloidogyne incognita* infected okra plants

Treatments	Soil Nematode Pop	Root Nematode Pop
PSDO	9.75[a]	4.00[a]
PSAE	18.22[b]	9.12[b]
CBFN	21.19[c]	11.08[c]
Level/mL		
0	956.34[d]	585.06[d]
15	47.04[c]	29.00[c]
25	31.21[b]	20.18[b]
35	12.09[a]	9.23[a]

Means in a segment of a given column followed by the same letter are not significantly different at p<0.05 using the new DMRT. DMRT=Duncan's multiple range test. *Each value is a mean of three replicates.*

Table 4: Effect of pawpaw seed oil, aqueous extract and carbofuran on mean numbers of egg masses and root gall index of *Meloidogyne incognita* infected okra plants

Treatments	Mean number of egg masses	Root gall rating
PSDO	0.56[a]	0.40[a]
PSAE	2.00[b]	1.07[b]
CBFN	2.16[b]	1.32[c]
Level/mL		
0	59.00[d]	9.01[d]
15	2.16[c]	2.08[c]
25	0.75[b]	1.23[b]
35	0..43[a]	1.10[a]

Means in a segment of a given column followed by the same letter are not significantly different at p<0.05 using the new DMRT. DMRT=Duncan's multiple range test. *Each value is a mean of three replicates.* PSAE=pawpaw seeds aqueous extract; PSDO=pawpaw seed oil; CBFN=carbofuran

The effectiveness of pawpaw seed oil on *Meloidogyne incognita* infected okra plants is depicted in tables 1-4. Significantly tall plants were seen in okra plants treated with the highest concentration of pawpaw seed oil (Table 1). Number of fruits was more in plants treated with pawpaw seed oil with a corresponding heavier weight of fruits per plant. There is no significant difference in numbers of fruits per plants of okra plants treated with pawpaw seed oil and pawpaw seed aqueous extract. Significantly fewer numbers of fruit per plant was recorded in untreated plants, while the highest concentration of treatments produced significantly more fruits (Table 2). Soil and root nematode population was lower in treated okra plants as opposed to the untreated control plants. More numbers of egg masses were recovered from the untreated (control) plants; however, the highest dosage of control materials had fewer egg masses with a corresponding lower root gall rating (Tables 3&4).

Discussion

Pawpaw seeds are known to contain glucosinolates in very high proportions. The presence of benzyl isothiocyanate in pawpaw seeds has been widely reported (Barroso et al., 2016). The nematicidal activity recorded with the application of pawpaw seed oil and pawpaw seed aqueous extract may be associated with the toxic substances present in the seed (Okeniyi et al., 2007). Also, 2R prunasin and sambrunigin are known as the major cyanogenic glycoside in pawpaw seeds. The toxicity of pawpaw seed oil on *Caenorhabditis elegans* and *Meloidogyne incognita* was evaluated by Nagesh et al., (2016), they found the oil effective in reducing the population of the two nematodes tested, the nematicidal activity of the oil was concentration dependent. At 25 ppm, mortality was significantly higher in the pawpaw seed oil than carbofuran. The observations from this research are similar to the reports of Nagesh et al., (2016). The pawpaw seed oil was significantly more effective than the synthetic nematicide as exhibited by some of the parameters evaluated during the experiment and after harvest. Soil nematode populations were

fewer and there was a higher yield in the plants treated with the pawpaw seed oil. It is noteworthy that the pawpaw seeds are common household wastes, thus they are readily available for processing.

Conclusion

The use of pawpaw seed oil is a viable environmentally friendly alternative in *Meloidogyne incognita* management.

References

Barroso, P. T. W., Carvalho, P.P., Rocha, T.B.R., Pessoa, F.L.P., Azevedo, D.A., Mendes, M.F. (2016). Evaluation of the composition of *Carica papaya* L. seed oil extracted with supercritical CO_2. *Biotechnology Reports.* 10, 23-31

Fabiyi, O. A. & Olatunji, G. A. (2021). Environmental Sustainability: Bioactivity of *Leucaena leucocephala* Leaves and Pesticide Residue analysis in Tomato Fruits. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis.* 69, 473-480.

Kolombia, Y. A. & Fabiyi, O.A. (2023). Nematode problems in tuber crops and their sustainable management. In *Nematode Diseases of Crops and their Sustainable Management*. Khan, M.R and Quintanilla, M. (Eds). pp 251-278. Elsevier. https://doi.org /10.1016/ B978-0-323-91226-6.00023-7

Nagesh, M., Chandravadana, M.V., Sreeja, V.G. & Bujji Babu, C.S. (2016). Benzyl isothiocyanate from *Carica papaya* seeds -a potential nematicide against *Meloidogyne incognita. Nematologia Mediterranean.* 30, 155-157.

Okeniyi, J. A., Ogunlesi, T. A. & Oyelami, O. A. (2007). Effectiveness of Dried *Carica papaya* seeds against human intestinal parasitosis: A Pilot Study. *Journal of Medicinal Food.* 10(1):194-196. DOI: 10.1089/jmf.2005.065.

Replacement Value of Mango Leaves for Corn Bran in Broiler Diets with or without Antibiotics

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Abstract

The escalating demand for animal products has led to widespread antibiotic usage in broiler diets to maintain health and productivity. Given the emergence of antibiotic-resistant bacteria and potential negative impacts on animal welfare, public health, and consumer preferences for natural alternatives, there is an urgent need for safer and sustainable approaches. The potential of mango leaves as a corn bran replacement and antibiotic substitute has not been fully evaluated. This study assessed the influence of dietary supplementation of mango leaf meal (ML) and antibiotics on growth and nutrient retention in broilers. A total of 192-day-old broilers of the Arbor Acres commercial strain was used for this trial. Birds were housed in battery brooders. The experimental diets consisted of a 4×2 factorial combination of dietary levels of mango leaf meal (0, 2, 4, and 6%) with or without antibiotics (Gentamycin at 50 mg/kg feed). Thus, there were 8 treatments, each with 3 replicates of 8 chicks. Experimental diets and water were supplied ad libitum for 6 weeks. Results showed no significant interaction ($p>0.05$) between dietary mango leaf meal and antibiotic supplementation in replacement for corn bran on performance, nutrient retention, and carcass characteristics. Dietary mango leaf inclusion above 2% resulted in significantly higher feed intake (103.27 g/bird/day), decreased weight gain, and reduced crude protein retention. It was concluded that 2% mango leaf dietary inclusion level is most effective and can serve as a viable antibiotic alternative in broiler production.

Keywords: Mango leaf meal, antibiotic alternatives, corn bran replacement, broiler performance.

Introduction

The large-scale usage of antibiotics that has enabled intensive livestock production has also led to the development of antimicrobial resistance in livestock and humans, which is a growing threat to sustainable food production and public health in recent times (O'Neill, 2015; WHO, 2015). Eradicating or reducing antibiotic usage in livestock is a pragmatic step toward minimizing the antimicrobial resistance scourge (O'Neill, 2015). However, antibiotic-free animal production is often characterized by low productivity and high morbidity and mortality rates (Smith, 2011). Therefore, exploring suitable antibiotic alternatives is a worthwhile research endeavor.

Considerable evidence suggests that medicinal plants may be good candidates as alternatives to synthetic additives. Their effects on immunity, gut microbiota, and antioxidant status in broiler chickens have been documented (Zhang *et al*., 2017; Vase-Khavari *et al*., 2019; Adu *et al*., 2020). Nonetheless, research outcomes have been largely inconsistent. Against this background, the investigation of antimicrobial and antioxidant potentials of medicinal plants requires systematic trials across various production systems.

Mango leaves contain numerous bioactive chemicals, making them useful for therapeutic and medical applications. Their antioxidant potential is attributed to considerable amounts of phenolic compounds, including quercetin, gallic acid, and catechins (Sundararajan *et al*., 2019). Mango leaves are also rich in flavonoids, such as luteolin and kaempferol, which possess various biological properties, including antibacterial and anti-inflammatory activities (Yadav *et al*., 2018). Additionally, mango leaves contain alkaloids and terpenoids, which have been linked to numerous health benefits, including anti-inflammatory, anti-cancer, and antidiabetic effects (Elshikh *et al*., 2018).

Despite these promising properties, the potential of mango leaves as a corn bran replacement and antibiotic substitute in broiler diets has not been fully evaluated. Therefore, the objective of this study was to investigate the effect of dietary inclusion of mango leaf meal, with or without antibiotic supplementation, as a replacement for corn bran on the performance, nutrient retention, gut microbial profile, and carcass parameters of broilers.

Materials and Methods

Preparation of Mango Leaf Meal

Fresh mature mango leaves of local cultivars (Sherry mango) were collected from Ilorin, Nigeria. The leaves were rinsed with clean water and air-dried under shade for 7 days. The dried leaves were ground using a hammer mill to pass through a 2 mm sieve. The mango leaf meal was mixed with maize at (0%, 2%, 4%, and 6% inclusion levels, respectively) and ground together to ensure uniformity in particle size and distribution.

Experimental Design and Bird Management

A total of 192-day-old broiler chicks of the Arbor Acres commercial strain (mixed sex, initial mean body weight 42.5 ± 2.1 g) were used for this trial lasting 6 weeks. Birds were housed in battery brooders with adequate ventilation and lighting. The experimental diets consisted of a 4×2 factorial arrangement of dietary levels of mango leaf meal (0%, 2%, 4%, and 6%) as replacement for corn bran, with or without antibiotics (Gentamycin at 50 mg/kg feed). Thus, there were 8 treatments, each with 3 replicates of 8 chicks. Experimental diets and water were supplied ad libitum throughout the trial period. Standard

brooding temperature (32-35°C for the first week, gradually reduced to 24-26°C by week 4) and management practices were maintained.

Performance Parameters

Feed Intake: Daily feed intake for each replicate was determined by recording the amount of feed offered and subtracting the leftover feed using a digital weighing scale (±0.01 g accuracy).

Weight Gain: Individual body weights were recorded at the beginning and end of the trial. Birds were weighed in the morning before feeding using a digital scale.

Feed Conversion Ratio: This was calculated for each replicate using the formula:

FCR = Total feed consumed (g) / Body weight gain (g)

Statistical Analysis

Data collected were subjected to two-way analysis of variance using the Generalized Linear Model procedure of SAS (SAS, 2004). Means were separated using Duncan's Multiple Range Test at a significance level of $p<0.05$ (Duncan, 1955).

Results and Discussion

Table 1 Composition of Diet (%DM)

Ingredients (%)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8
Maize	42.00	42.00	42.00	42.00	42.00	42.00	42.00	42.00
Fish meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Soya bean Meal	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00
Wheat offal	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Corn bran	6.00	4.00	2.00	0.00	6.00	4.00	2.00	0.00
Mango leaf Meal	-	2.00	4.00	6.00	0.00	2.00	4.00	6.00
Palm oil	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Bone Meal	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Broiler Premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Antibiotics	+	+	+	+	-	-	-	-
Total	100	100	100	100	100	100	100	100

*Vit A: 12,000 IU, Vit D3: 2,500 IU, Vit E: 30 mg, Vit K3: 2 mg, Vit B1: 2.25 mg, Vit B2: 6 mg, Vit B6: 4.5 mg, Vit B12: 0.015 mcg, niacin: 40 mg, pantothenic acid: 15 mg, folic acid: 1.5 mg, biotin: 0.05 mcg, manganese: 80 mg, iron: 20 mg, zinc: 50 mg, copper: 5 mg, cobalt: 0.5 mg, iodine: 1 mg, selenium: 0.2 mg, choline chloride: 300 mg, and antioxidants: 125 mg)), salt (2.5 g), methionine (1 g), and lysine (2 g).

Performance

Table 2 shows the effect of dietary levels of mango leaf meal with or without antibiotic supplementation on the performance of broilers. Antibiotic supplementation had no significant effects on feed intake, weight gain, and feed conversion ratio ($p>0.05$). Feed intake of birds fed the control diet and those fed 2% mango leaf meal in replacement for corn bran were comparable and significantly lower ($p<0.05$) than those of birds fed diets with 4% and 6% mango leaf meal. Feed intake of birds fed diets with 4% and 6% mango leaf meal were comparable ($p>0.05$). Increasing dietary levels of mango leaf meal resulted in decreased weight gain while increasing feed conversion ratio ($p<0.05$). There was no significant interaction between dietary mango leaf meal and antibiotic supplementation on feed intake, weight gain, and feed conversion ratio ($p>0.05$). These results are consistent with earlier research showing no discernible effect of antibiotics on broiler performance (Barton *et al*., 2018; Hasan *et al*., 2020). The lack of antibiotic effect in this study may be attributed to good management practices and low pathogen exposure in the experimental environment, which minimized the need for antibiotic growth promotion. The increased feed intake observed at higher mango leaf inclusion levels (4% and 6%) may represent a compensatory mechanism by birds attempting to meet their nutrient requirements, as mango leaf meal has lower protein and energy content compared to corn bran. However, this compensatory feeding was insufficient to maintain optimal weight gain, resulting in poorer feed conversion ratios.

Table 2: Effect of Dietary Level of Mango leaf and Antibiotic Supplementation at the expense of Corn bran on Performance of Broilers

ANTIBIOTICS (I)	Feed Intake(g/bird/day)	Weight Gain (g/bird/day)	Feed/Gain Ratio
NEGATIVE -	99.91	53.13	1.90
POSITIVE +	100.59	53.57	1.92
Dietary Level of Mango Leaf			
0%	97.55^{b}	60.22^{a}	1.62^{d}
2%	97.63^{b}	55.93^{b}	1.75^{c}
4%	103.27^{a}	51.78^{c}	2.00^{b}
6%	102.56^{a}	45.48^{d}	2.26^{a}
A*M	NS	NS	NS
SEM ±	0.881	1.707	0.073
P. Value	0.0807	0.0948	0.0648

Means within factor and column followed by different superscripts are significantly different {p,0.05}. SEM: standard error of the means: NS: Not Significant; S: Significant.

The decline in performance at higher inclusion levels may be attributed to anti-nutritional factors present in mango leaves, such as tannins and phytic acid, which can interfere with nutrient digestion and

absorption (Asaolu *et al*., 2021). In contrast, Adeyemi *et al*. (2021) found no evidence of nutritional interventions impacting feed conversion ratio across the entire production cycle, including the finisher phase, suggesting that responses to feed additives may vary with experimental conditions and bird genetics.

Conclusion

This study demonstrated that mango leaf meal can partially replace corn bran in broiler diets with varying effects on performance, nutrient utilization and carcass characteristics. The 2% dietary inclusion level of mango leaf meal was most effective, maintaining acceptable performance. At this inclusion level, birds exhibited optimal feed efficiency. This suggests that 2% mango leaf meal inclusion can reduce feed costs through partial corn bran replacement without compromising productivity.

References

Adeyemi, K. D., Olanrewaju, S. M., Adewunmi, P. S., & Abdulqadir, Z. (2021). Mango leaf and synthetic additives in broiler diet: Impact on growth, caecal microbiota, immunity, blood chemistry, and meat quality. *Journal of the Saudi Society of Agricultural Sciences*, 20, 482–489. https://doi.org/10.1016/j.jssas.2021.06.006

Adu, O. A., Gbore, F. A., Oloruntola, O.D., Falowo, A. B., & Olarotimi, O. J. (2020). The effects of Myristica fragrans seed meal and Syzygium aromaticum leaf meal dietary supplementation on growth performance and oxidative status of broiler chicken. *Bulletin of the National Research Centre*, 44(1), 1–10. https://doi.org/10.1186/s42269-019-0261-8

Asaolu, V. O., Akinmoladun, S. I., & Adeyemo, G. O. (2021). Nutritional evaluation and anti-nutritional factors of Moringa oleifera leaf meal in the diets of broiler chickens. Journal of Agricultural Science and Food Technology, 7(3), 39–43. https://doi.org/10.36630/jasft_21009

Barton, M. D., Pratt, R., & Hart, W. S. (2018). Antibiotic resistance in food animals and the environment: An overview. Center for Infectious Disease Research and Policy, University of Minnesota. https://www.cidrap.umn.edu/antimicrobial-stewardship

Duncan, D. B. (1955). Multiple range and multiple F tests. Biometrics, 11(1), 1–42. https://doi.org/10.2307/3001478

Elshikh, M. S., Ahmed, S., & Fun, H. K. (2018). Phytochemical screening and antimicrobial activity of Mangifera indica L. leaves extracts. International Journal of Chemical Technology Research, 11(1), 142–150. https://doi.org/10.20902/IJCTR.2018.110116

Hasan, F., Islam, M. R., Rahman, M. S., Islam, M. A., & Rahman, M. T. (2020). Effects of antibiotic growth promoter on growth performance and carcass characteristics of broiler chicken. International Journal of Animal Biology, 6(1), 1–6.

O'Neill, J. (2015). Antimicrobials in agriculture and the environment: Reducing unnecessary use and waste. WellcomeTrust.https://amrreview.org/sites/default/files/Antimicrobials%20in%20agriculture%20and%20the%20environment%20-%20Reducing%20unnecessary%20use%20and%20waste.pdf

SAS Institute. (2004). SAS/STAT user's guide: Statistics, Version 9.1. SAS Institute Inc.

Smith, J. A. (2011). Experience with drug-free broiler production. Poultry Science, 90(11), 2670–2678. https://doi.org/10.3382/ps.2011-01543

Sundararajan, B., Mahesh, R., & Sharada, A. C. (2019). A comprehensive review on phytochemical profile of Mangifera indica L. *Pharmacognosy Reviews*, 13(25), 67–77. https://doi.org/10.5530/phrev.2019.13.11

Vase-Khavari, K., Mortezavi, S. H., Rasouli, B., Khusro, A., Salem, A. Z., & Seidavi, A. (2019). The effect of three tropical medicinal plants and superzist probiotic on growth performance, carcass characteristics, blood constituents, immune response, and gut microflora of broiler. *Tropical Animal Health and Production*, 51, 33–42. https://doi.org/10.1007/s11250-018-1659-5

World Health Organization. (2015). Global action plan on antimicrobial resistance. WHO. http://www.wpro.who.int/entity/drug_resistance/resources/global_action_plan_eng.pdf

Yadav, D., Yadav, K. S., & Singh, S. P. (2018). Mango: Taxonomy and botany. Journal of Pharmacognosy and Phytochemistry, 7(2), 3253–3258.

Zhang, Y. N., Wang, J., Qi, B., Wu, S. G., Chen, H. R., Luo, H. Y., Yin, D. J., Lü, F. J., Zhang, H. J., & Qi, G. H. (2017). Evaluation of mango saponin in broilers: Effects on growth performance, carcass characteristics, meat quality and plasma biochemical indices. Asian-Australasian *Journal of Animal Sciences*, 30(8), 1143–1149. https://doi.org/10.5713/ajas.16.0847

Optimizing Malabar Spinach (*Basella alba)* Growth and Yield Using Composite Agro-Waste Compost

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Abstract

This study investigated the effects of composite agro-waste compost on the growth and yield of Malabar spinach (*Basella alba*), an Indigenous African Vegetable (IAV) facing threats from poor soil fertility. The experiment was conducted under screenhouse conditions at the Federal College of Forestry, Ibadan, Nigeria, with a compost prepared from a mixture of poultry manure and fruit waste. Compost was applied at six different rates (0, 6, 12, 18, 24 and 30 g) to pots containing 3kg depleted topsoil. The experiment was laid out in a Completely Randomized Design with four replications. The study assessed vine length, stem diameter, number of leaves, and fresh leaf weight. The results showed that compost application significantly improved all measured growth and yield parameters. The highest application rates of 18 g/pot (T3), 24 g/pot (T4) and 30 g/pot (T5) consistently led to superior performances. Specifically, T5 produced the longest vines (16.50 cm) while T3 resulted in the thickest stems (0.608 cm). The highest leaf counts were observed in T4 (20.7) and T3 (19.3) at 10 Weeks after Transplanting. The T4 treatment yielded the highest fresh leaf weight (23 g), followed by T3 (20.5 g). This study concludes that fruit waste compost is a viable organic fertilizer for enhancing the productivity of *Basella alba*, offering a sustainable way to improve soil fertility and promote the cultivation of this valuable indigenous crop.

Keywords: Composite; Agro-waste, compost, *Basella alba*, Organic fertilizer, Soil fertility.

Introduction

Vegetables are essential components of a balanced diet, providing vital nutrients and antioxidants necessary for maintaining good health (Aune et al., 2017). Africa is home to a rich diversity of indigenous vegetables (IAVs) that have supported local food systems for centuries. These species, which include African nightshade, amaranth, and *Basella alba*, are well-suited to tropical climates and hold deep cultural significance (Maseko et al., 2017). Despite their value, IAVs are increasingly endangered by neglect, poor soil fertility, and the dominance of exotic crops (Abukutsa-Onyango, 2010).

Tropical soils, particularly in Sub-Saharan Africa, are often characterized by low organic matter, nutrient depletion, and poor structure, which hinder crop productivity (Aiyelari et al., 2011; Ayeni, 2020). Organic compost, derived from agro-waste, offers a sustainable alternative to chemical fertilizers by improving soil organic carbon and promoting long-term soil fertility (Adekiya et al., 2020). *Basella alba*, commonly known as Malabar spinach, is a fast-growing perennial vine consumed as a leafy vegetable in West Africa. It is nutritionally rich and resilient, but its cultivation is declining due to soil degradation and urbanization (Gbile and Adesina, 2018).

The increasing global emphasis on sustainable agriculture has renewed interest in organic inputs like compost, which enhance soil fertility while reducing environmental degradation (Diacono and Montemurro, 2010). Compost from fruit waste is particularly promising as it utilizes biodegradable waste and provides a balanced mix of nutrients (Yusof et al., 2009). This study, therefore, investigated the influence of different application rates of fruit waste compost on the growth and yield of *Basella alba*.

Materials and Methods

Experimental site

The experiment was conducted at the screenhouse of the Federal College of Forestry Jericho, Ibadan, Nigeria (latitude 7°23'N, longitude 3°51'E) between March and September 2021. The topsoil was collected from a depleted farmland that had been continuously cropped for over 20 years.

Composting of agrowaste

Compost was prepared using the aerated window method over 12 weeks. The pile consisted of poultry manure, fruit waste, and rice husk mixed in a 3:1:1 ratio on a fresh volume basis (Adeniran et al., 2017). The pile was turned every 3 days for aeration. After 12 weeks, the compost was analyzed for nitrogen (N), phosphorus (P), and potassium (K) content.

Compost application and experimental design

Compost was thoroughly incorporated into 3kg of topsoil two weeks before transplanting *Basella alba* seedlings. The application rates were: T0 (0g/pot), T1 (6g/pot), T2 (12g/pot), T3 (18g/pot), T4 (24g/pot), and T5 (30g/pot). The experiment was laid out in a Completely Randomized Design (CRD) with three replications.

Data collection and analysis

Data on vine length, stem diameter, number of leaves, and fresh leaf weight were collected. The data were subjected to analysis of variance (ANOVA) at a 5% significance level.

Results and Discussion

The composite compost had a balanced nutrient profile, containing 1.5% N, 1.09% P, and 1.26% K. The moderate nitrogen content helps minimize leaching losses, while the high phosphorus is beneficial for overcoming phosphorus fixation in tropical soils. This composition is effective for addressing soil constraints and supporting crop growth (Diacono and Montemurro, 2010). The result of the mean vine length (Table 1) showed that compost application rate significantly influenced vine length from 4 Weeks after Transplanting (WAT) onward. The T5 treatment (30g/pot) consistently produced the longest vines, reaching a maximum of 16.50 cm at 10 WAT, which was significantly higher than the control (11.27 cm). This superior performance at higher compost rates (T4, T5) suggests a more favorable nutrient environment for biomass accumulation, corroborating findings by Kebede et al. (2023) on *Beta vulgaris*. The lower growth in T1 and T2 indicates that suboptimal compost levels are insufficient to meet the crop's nutrient demand, a phenomenon also observed in amaranth by Motsa et al. (2015).

Table 1: **Effect of compost application on the vine length of *Basella alba***

Treatment	**Weeks after transplanting (cm)**				
	2	4	6	8	10
T0	3.50	5.60	7.83	9.67	11.27
T1	3.43	4.67	6.17	8.00	9.07
T2	3.50	4.50	6.00	7.17	9.07
T3	3.83	5.67	8.67	10.73	13.00
T4	3.40	5.00	9.50	13.10	14.67
T5	3.83	6.17	9.17	13.33	16.50
Mean	3.58	5.27	7.89	10.33	12.26
F prob.	0.235	0.007	<0.001	<0.001	<0.001
L.S.D.	-	0.853	1.167	1.590	1.855
CV (%)	7.6	9.1	8.3	8.6	8.5

Stem diameter was significantly influenced by compost treatment (Table 2). From 6 WAT onwards, T3 consistently produced the thickest stems, reaching 0.608 cm at 10 WAT, significantly higher than the control (0.341 cm). This enhancement is attributed to improved soil fertility and nutrient mineralization, which promote stronger vegetative development (Kebede et al., 2023). Similar improvements in stem diameter from organic fertilizers have been reported in Indian spinach (Islam et al., 2018).

Table 2: Effect of compost application on the stem diameter of *Basella alba*

Treatment	Weeks after transplanting (cm)				
	2	4	6	8	10
T0	0.120	0.161	0.260	0.309	0.341
T1	0.131	0.171	0.297	0.312	0.349
T2	0.107	0.174	0.236	0.292	0.351
T3	0.124	0.189	0.414	0.511	0.608
T4	0.109	0.215	0.326	0.464	0.519
T5	0.135	0.245	0.402	0.491	0.538
Mean	0.121	0.193	0.322	0.397	0.451
F prob.	<0.001	<0.001	<0.001	<0.001	<0.001
L.S.D.	0.006	0.014	1.167	0.028	0.025
CV (%)	2.7	4.2	10.4	3.9	3.1

Differences in leaf count were not statistically significant until 10 WAT (Table 3). At this stage, T4 (20.7) and T3 (19.3) produced the highest leaf counts, significantly exceeding the control (14.0). This delayed effect indicates that the impact of compost on leaf production becomes more pronounced during the rapid vegetative growth phase, a trend supported by research on other leafy vegetables (Olabode *et al.*, 2017). The improvement under T3 and T4 confirms that optimal compost levels enhance nutrient availability for leaf initiation and expansion.

Table 3: Effect of compost application on the number of leaves of *Basella alba*

Treatment	Weeks after transplanting				
	2	4	6	8	10
T0	7.0	9.7	11.0	12.3	14.0
T1	5.7	7.3	9.3	10.3	11.3
T2	6.0	7.7	9.3	11.0	13.7
T3	6.0	8.7	11.7	15.0	19.3
T4	6.0	8.7	11.3	15.3	20.7
T5	6.0	7.7	11.0	13.0	15.0
Mean	6.1	8.3	10.6	12.8	15.7
F prob.	0.401	0.559	0.608	0.068	0.002
L.S.D.	-	-	-	-	4.1
CV (%)	12.2	20.3	19.4	16.5	14.6

Fresh leaf weight varied significantly among treatments (Table 4). T4 yielded the highest fresh leaf weight (23 g), followed by T3 (20.5 g). These values were significantly higher than the control (18.5 g) and T2 (12.5 g). The slight drop at T5 relative to T4 suggests a potential over-application effect, consistent with findings that very high compost rates can depress growth (Raza et al., 2024). Overall, appropriate compost application substantially enhances leaf biomass by improving nutrient supply and soil conditions (Kebede et al., 2023).

Table 4: Effect of compost application on fresh leaf weight of *Basella alba*

Treatment	T0	T1	T2	T3	T4	T5
Fresh leaf weight (g)	18.5	19.0	12.5	20.5	23	19.5

Note: F-test: p = <0.001; $LSD_{0.05}$ = 3.74

Conclusion

The application of fruit waste compost significantly enhanced the growth and yield performance of *Basella alba*. Higher compost rates (18g, 24g, and 30g per pot) promoted vine elongation, stem thickening, and increased leaf biomass. The optimal rate for fresh leaf yield was 24 g/pot (T4). This study confirms that fruit waste compost can improve soil fertility and crop performance on degraded tropical soils, while addressing waste management challenges. Promoting compost use in indigenous vegetable production supports food security and aids in conserving threatened species like *Basella alba*.

References

Abukutsa-Onyango, M.O. (2010). *African indigenous vegetables in Kenya: Strategic repositioning in the horticultural sector.* Nairobi, Kenya: Jomo Kenyatta University of Agriculture and Technology Press.

Adekiya, A. O., Dahunsi, S. O., Ayeni, J. F., Aremu, C., Aboyeji, C. M., & Ogunmekun, O. (2020). Effects of biochar and poultry manure on soil properties, growth, yield, and quality of cocoyam. *Scientific Reports*, 10, 16774.

Adeniran, K. A., Akinyemi, B. A., & Akinbode, O. A. (2017). Evaluation of compost from different organic wastes on soil properties and growth of celery. *Nigerian Journal of Soil Science*, 27(2), 1-11.

Aiyelari, E. A., Nwoke, O. C., and Oshunsanya, S. O. (2011). Nutrient Leaching from Selected Organic Amendments and Soil in Tropical Alfisols. *Journal of Agricultural Science*, 3(4), 245-254.

Aune, D., Giovannucci, E., Boffetta, P., Fadnes, L. T., Keum, N., Norat, T., Greenwood, D. C., Riboli, E., Vatten, L. J., & Tonstad, S. (2017). Fruit and vegetable intake and the risk of cardiovascular disease, total cancer and all-cause mortality. *International Journal of Epidemiology*, 46(3), 1029–1056.

Ayeni, L. S. (2020). Integrated Nutrient Management: A Panacea for Enhanced Cassava Production and Sustainable Agriculture in Nigeria. *International Journal of Agriculture and Environment*, 1(1), 1-13.

Diacono, M., & Montemurro, F. (2010). Long-term effects of organic amendments on soil fertility. A review. *Agronomy for Sustainable Development*, 30(2), 401–422

Gbile, Z. O., & Adesina, A. A. (2018). Ethnobotanical and nutritional importance of underutilized leafy vegetables in Southwestern Nigeria. *Journal of Ethnobiology and Ethnomedicine*, 14(1), 1-12.

Islam, M. M., Halim, G. M. A., Sarkar, M. A. R., & Rahman, M. M. (2018). Effect of organic and inorganic fertilizers on growth and yield of Indian spinach (*Basella rubra* L.). *Journal of Bangladesh Agricultural University*, 16(1), 21–28.

Kebede, M., Tadesse, T., and Mengistu, A. (2023). Effects of compost and inorganic fertilizer on growth, yield, and quality of Swiss chard. *Heliyon*, 9(6), e16871.

Maseko, I., Mabhaudhi, T., Tesfay, S., Araya, H. T., Fezzehazion, M., & du Plooy, C. P. (2017). African Leafy Vegetables: A Review of Status, Production and Utilization in South Africa. *Sustainability*, 10(1), 16.

Motsa, M. M., Modi, A. T., & Mabhaudhi, T. (2015). Sweet potato as a drought tolerant and food security crop. *South African Journal of Science*, 111(11/12), 1–8.

Olabode, O. S., Sola, O., Akanbi, W. B., Adesina, G. O., & Babajide, P. A. (2017). Evaluation of Tithonia biomasa and soybean milk residue as soil amendments for growth and yield of kale. *International Journal of Vegetable Science*, 23(2), 149–159.

Raza, S., Anjum, S. A., & Abbas, T. (2024). Organic amendments and their influence on growth, yield, and soil health in vegetable production systems. *Journal of Plant Nutrition*, 47(5), 679–692.

Yusof, N., Hafid, H. S., & Halim, M. R. A. (2009). Composting of fruit wastes: Nutrient content, microbial activity, and application prospects. *Journal of Environmental Biology*, 30(5), 727–732.

Effect of Combined Poultry Manure and NPK Fertilizer on Growth and Yield of Sweet Potato

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Abstract

Sweet potato (*Ipomoea batatas L*.) is drought drought-tolerant crop being planted in Sub-Saharan Africa, where Nigeria ranks as the third-largest producer. Recently, declining yields due to poor soil fertility and suboptimal nutrient management have posed significant challenges. This study aimed to evaluate the growth and yield responses of two sweet potato varieties (Orange-fleshed and cream-fleshed) to combined applications of poultry manure (PM) and NPK fertilizer to optimize sustainable production. A trial was conducted at the University of Ilorin, Nigeria, during the 2025 rainy season, a 2 x 6 factorial laid out in a randomized complete block design with five replicates. Treatments were two varieties of sweet potato and six fertilizer levels (300kg NPK/ha, 225kg NPK/ha + 1.5t PM/ha). Data on vine length, leaf number, branch number and tuber yield were taken. Soil samples were obtained before planting and after harvest, air-dried and analysed in the laboratory for chemical and physical properties. Data was analyzed using ANOVA. Results showed that variety 'Orange-fleshed Sweet Potato' (OFSP) at 300kg NPK/ha had the best vegetative growth, while variety 'Cream Flesh Sweet Potato' (CFSP) at 225kg NPK/ha + 1.5t PM/ha produced the highest number and tuber yield. The study concluded that 225kg NPK/ha + 1.5t PM/ha, which supported high tuber yield, should be adopted.

Keywords: Poultry manure, NPK fertilizer, sweet potato and integrated agricultural practice

Introduction

Sweet Potato (*Ipomoea batatas*) is the seventh most important staple in the world (FAO, 2009), and ranks fifth, after rice, wheat, maize, and cassava. Sweet Potato is the second after cassava among the root and tuber crops cultivated globally (PMC). The top four global producers of sweet Potato, after China, are all sub-Saharan African countries: Malawi, Nigeria, Tanzania, and Uganda (FAOSTAT, 2021). Nigeria was ranked as the third largest producer in the world with over four million tonnes of annual production (FAO, 2019).

Sweet Potato is drought-tolerant once established. It has the potential to improve food and nutrition security in the most rain-fed agriculture in the developing world, where droughts could severely affect

yields of other staples such as cereals. It is one of the most important root and tuber crops in sub-Saharan Africa with both domestic and industrial uses such as sweeteners, citric acid, beverages, noodle production and industrial alcohol (Ukom et al., 2009). Its nutritional value far exceeds yams, cassava and cocoyams (Bhuyan et al., 2022). Orange-fleshed sweet potatoes are particularly rich in vitamin A and can contribute significantly to vitamin A, considered vital, in the human diet. Its deficiency often leads to serious public health problems in many developing countries (Nurzaman et al., 2025).

Sweet potatoes are high in beta-carotene, which is essential for vision, immune function, and skin health. The orange and purple varieties are also rich in antioxidants that protect the body from free radicals, thereby potentially reducing the risk of chronic diseases. Sweet potatoes contribute to overall health benefits due to their high fiber content, aiding digestion and promoting satiety. Their rich vitamins and minerals composition support various bodily functions, making it a valuable addition to a balanced diet (Przybył et al., 2022).

Sweet potatoes may be adapted to grow on poor soils; as such, most farmers do not apply fertilizer to their crop, resulting in low tuber yield as low as 7 tonnes per hectare compared with yield potentials of 18-24 tonnes per hectare. This is largely due to low soil fertility due to deforestation, erosion and poor agronomic practices such as improper soil management, inappropriate weed control methods and non-crop rotational practices (CRI, 2002).

The concept of combined nutrient management utilising all available organic and inorganic resources has become a dominant pattern for improved yield in the agricultural systems of Sub-Saharan Africa to ensure both efficient and economic use of scarce nutrient resources (Vauhuaweer, 2001). Therefore, the use of inorganic mineral fertilizer to supplement manure use, as a combined management strategy, is of paramount importance in reducing the cost of soil mineral input, maximising yields and sustaining sweet potato production.

There is a need to explore the huge benefits of identifying and selecting an appropriate combination of poultry manure and NPK fertilizer, which will increase the production level of sweet potato, ensure soil sustainability, improve food security, improve nutritional quality, reduce poverty and contribute significantly to reducing the importation of food products. Therefore, this study aimed to evaluate the growth and yield response of two varieties of sweet potatoes (*Ipomoea batata L.*), to combined application rates of poultry manure and NPK fertilizer for sustainable production.

Materials and Methods

The experiment was carried out during the onset of the early rainy season in 2025 at the nursery pavilion of the Department of Agronomy, Faculty of Agriculture, University of Ilorin, Ilorin, Kwara State, Nigeria. The plant material consisted of two varieties of sweet potato: Orange-Fleshed Sweet Potato (OFSP) and Cream-Fleshed potato (CFSP). The fertilising materials used for the experiment comprised: of Poultry manure (PM) and NPK (15:15:15) fertiliser applied at six different levels as; 300kgNPK/ha, 225kgNPK/ha+ 1.51 PM/ha, 150kgNPK + 2.3tPM/ha, 75kgNPK/ha + 3.45tPM/ha, 4.61/ha and control (zero application). The potted experiment was a 2 x 6 factorial laid out as a randomised complete block design (RCBD) with five replicates. The field was cleared manually using hand hoeing before placing the sacks filled with soil. The sacks were arranged in five (5) blocks, with twelve (12) treatment combinations, different levels of Poultry manure and NPK randomly within the blocks (replicates). The soil was irrigated a day before planting, after which the vines measuring 30cm were transplanted into the sacks in the evening hours. Irrigation was done manually by watering in the morning, which was used to supplement rainwater. Manual weeding was carried out two, four and seven weeks after planting (WAP). Insect pests were controlled by using 5g of Aceta Force containing active ingredient (ai): Acetamiprid 20% SP, into 15 litres of water. This was sprayed directly on the vines, while root knot nematode disease was controlled by drenching the base of each sweet potato plant with Neem (*Azadiracta indica*) leaves extract. The poultry manure was incorporated into the soil according to the treatment two weeks before planting. The NPK (15:15:15) fertiliser was applied according to treatment, 3 weeks after planting, using the side placement method.

The following data were collected from each sack at two-week intervals starting from 2 weeks for vine length, leaf area, number of leaves per plant, branch number, number of tubers per plant, tuber weight, number of marketable tuber size and non-marketable tuber. Data were subjected to analysis of variance. Laboratory analyses were carried out to determine: Soil pH in H_2O and KCL, Organic Carbon, Total Acidity, Exchangeable Bases, Available Phosphorus in poultry manure, Total Nitrogen, Available Nitrogen in poultry manure, Available Potassium, Calcium, Magnesium, and Sodium in poultry manure.

Results and Discussion

Table 1: Physical and chemical properties of the soil and poultry manure before planting

Physical properties		
Clay (%)	8.48	
Silt (%)	3.72	
Sand (%)	87.8	
Textural Class (USDA)	Sandy Loam	
Chemical Properties	**Soil Value**	**Poultry Manure**
pH (H_2O)	6.64	
pH (KCl)	4.79	
Available Phosphorous (mg/kg)	5.93	8.00
Total Nitrogen (mg/kg)	0.15	1.95
Organic Carbon (%)	1.57	
Organic Matter (%)	2.88	
Exchangeable Bases (cmol/kg)		
Calcium (Ca^{2+})	8.21	
Magnesium (Mg^{2+})	5.10	
Sodium (Na^{+})	8.49	
Potassium (K^{+})	8.75	4.93
Exchangeable Acidity	2.20	

Table 2: Effect of combined Poultry Manure and NPK fertilizer on vegetative parameters

Variety + Treatment	**Leaf Area (cm^2)**	**Number of Branches**	**Number of Leaves**	**Vine Length (cm^2)**	**Vine Girth (cm^2)**
(Orange-fleshed) 300kgNPK/ha	52.12	5.20	191.80	460.20	2.74
(Orange-fleshed) 225kgNPK/ha+1.5tPM/ha	57.68	6.00	194.80	421.60	2.24
(Orange-fleshed) 150kgNPK/ha+2.3tPM/ha	65.08	5.20	209.40	395.20	2.48
(Orange-fleshed) 75kgNPK/ha+3.5tPM/ha	63.98	6.20	248.80	392.40	2.54
(Orange-fleshed) 4.6tPM/ha	70.54	7.00	261.80	428.80	2.54
(Orange-fleshed) Control	42.92	4.00	152.00	358.00	2.44
(Cream-fleshed) 300kgNPK/ha	58.04	9.60	216.61	293.80	2.78
(Cream-fleshed) 225kgNPK/ha+1.5tPM/ha	57.60	9.40	182.00	273.00	2.46
(Cream-fleshed) 150kgNPK/ha+2.3tPM/ha	66.08	9.40	187.20	268.60	2.68
(Cream-fleshed)75kgNPK/ha+3.5tPM/ha	63.26	8.80	276.60	266.40	2.56
(Cream-fleshed) 4.6tPM/ha	88.06	10.40	270.40	219.60	2.32
(Cream-fleshed) Control	70.44	5.80	175.80	276.20	2.72
LSD (0.05%)	**17.30**	**1.95**	**35.00**	**44.00**	**0.24**

The soil is Sandy Loam in texture, while the soil chemical properties indicate a slightly acidic condition, with a pH in water (pH (H2O)) of 6.64 and a pH in potassium chloride (pH (KCl)) of 4.79. The soil exhibits low fertility characterized by low total nitrogen (0.15 mg/g), organic carbon (1.57%), and organic matter (2.88%). The poultry manure (PM) used was richer in required nutrients compared to the soil used, with a total nitrogen content of 1.95 mg/g, phosphorus of 8 mg/kg, and a potassium (K^{+}) level of 4.93 cmol/kg

(Table 1). The result confirms the poor nutrient status of the soil, justifying the need for external nutrient application to support crop growth.

Table 3: Effect of combined poultry manure and NPK fertilizer on yield parameters

Variety + Treatment	Number of Tuber	Tuber Weight (kg)	Marketable Tuber	Non-Tuber Marketable
(Orange-fleshed) 300kgNPK/ha	3.80	197.92	0.80	3.00
(Orange-fleshed) 225kgNPK/ha+1.5tPM/ha	4.80	329.22	1.00	3.80
(Orange-fleshed) 150kgNPK/ha+2.3tPM/ha	3.60	224.06	0.60	3.00
(Orange-fleshed) 75kgNPK/ha+3.5tPM/ha	4.40	309.88	1.00	3.40
(Orange-fleshed) 4.6tPM/ha	4.40	342.84	1.20	3.20
(Orange-fleshed) Control	2.60	162.40	0.40	2.20
(Cream-fleshed) 300kgNPK/ha	3.8	431.94	2.20	1.60
(Cream-fleshed) 225kgNPK/ha+1.5tPM/ha	5.60	514.32	2.00	3.60
(Cream-fleshed) 150kgNPK/ha+2.3tPM/ha	4.00	417.36	2.00	2.00
(Cream-fleshed) 75kgNPK/ha+3.5tPM/ha	3.20	494.80	1.80	0.60
(Cream-fleshed) 4.6tPM/ha	5.20	484.56	1.60	3.60
(Cream-fleshed) Control	4.00	285.84	2.20	1.80
LSD (0.5%)	**0.51**	**61.8**	**0.23**	**0.38**

LSD: Least significant difference at 0.5%

The application of combined poultry manure and NPK fertilizer had a highly significant ($p<0.005$) positive effect on all measured vegetative growth parameters for both sweet potato varieties when compared to the unfertilized control. As shown in Table 2, the Orange-fleshed variety achieved its longest vines (460.2 cm) under the 300kg NPK/ha treatment. In the case of the Cream-fleshed variety, 300kg NPK/ha also resulted in the greatest vine length (293.8 cm). This suggests that higher NPK rates effectively promote vine elongation.

The highest number of leaves for both varieties was consistently observed in treatments with a higher proportion of poultry manure. Specifically, the 4.6t PM/ha treatment yielded the highest leaf count for both Orange-fleshed (261.8) leaves and Cream-fleshed (270.4) leaves. Correspondingly, this treatment also resulted in the largest leaf area for both Orange-fleshed (70.54 cm^2) and Cream-fleshed (88.06 cm^2). The robust development of foliage and larger leaf area in PM-treated pots indicates enhanced photosynthetic capacity, crucial for subsequent tuber development (Table 2).

Branching and vine thickness, as shown on Table 2, followed similar trends. The highest number of branches was recorded for the Cream-fleshed variety with 4.6t PM/ha (10.4 branches). The thickest vines were observed in the control and NPK-only treatments for the Cream-fleshed variety (2.72 cm and 2.78 cm, respectively). This indicates that while poultry manure promotes a greater number of lateral shoots, inorganic NPK might contribute more significantly to the girth and robustness of the main vines. Overall, the enhanced vegetative growth in treated pots can be attributed to the synergistic effect of NPK fertilizer, providing readily available macronutrients for initial vigor, and poultry manure improving soil health, water retention, and ensuring a sustained release of a broader spectrum of nutrients.

The sweet potato yield was significantly ($p<0.005$) influenced by the fertilizer treatments (Table 3). All combined treatments outperformed the control in terms of tuber number, total tuber weight and the number of marketable tubers. For the Orange-fleshed variety, the highest tuber weight (329.22 g) was achieved with the combined application of 225kg NPK/ha + 1.5t PM/ha. This treatment also produced the highest number of tubers, which shows an optimal balance of inorganic and organic inputs for this variety's tuberization (Table 3).

As for the Cream-fleshed variety, the results were even more significant: 300kg NPK/ha alone produces a high tuber weight (431.94 g) while the combination of 75kg NPK/ha + 3.5t PM/ha resulted in a comparable total tuber weight (494.80 g) and the highest number of marketable tubers (1.8). This underscores the critical role of balanced organic-inorganic nutrition in maximizing not just the total yield but also the quality and marketability of tubers for the Cream-fleshed variety.

Integrated nutrient management yield performance in pots, confirms the benefits of combining NPK fertiliser with the sustained nutrient supply and soil-ameliorating properties of poultry manure. This synergistic interaction facilitated the robust vegetative development observed earlier, providing the necessary photosynthetic capacity to support the development of a higher quantity and quality of sweet potato tubers.

Conclusion

Sweet potato varieties cultivated in nutrient-deficient sandy loam soil have significant yield and vegetative growth for both poultry manure (PM) and NPK fertilizer, while all fertilizer treatments outperformed the controls in this study, emphasizing the critical need for soil amendments to achieve optimal production.

The integrated nutrient management approach (combining inorganic NPK and organic poultry manure) has the most favorable yield. While inorganic NPK promoted rapid vine elongation, poultry manure was more effective at increasing the number of leaves and branches, contributing to a larger photosynthetic

capacity. This combined effect directly improved tuber yields. For the Orange-fleshed variety, the combined application of 225kg NPK/ha and 1.5t PM/ha produced the highest tuber weight and was regarded as the optimal treatment. In the case of the Cream-fleshed variety, 300kg NPK/ha alone produced a high tuber weight; the combined treatment of 75kg NPK/ha and 3.5t PM/ha was exceptionally effective, yielding a high number of marketable tubers. In order to maximize yield and improve yield quality, there is a need for a balanced application of organic and inorganic fertilizers rather than using just a single source.

References

Bhuyan, M. H. M. B., Islam, M. N., Hossain, M. A., & Al Mamun, M. A. (2022). *Nutritional and health benefits of sweet potato (Ipomoea batatas L.): A review.* Journal of Food Biochemistry, 46(2), e14043. https://doi.org/10.1111/jfbc.14043

CRI. (2002). *Sweet potato production guide.* Crops Research Institute, Ghana.

FAOSTAT. (2021). *Sweet potato production data.* Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/faostat

Food and Agriculture Organization (FAO). (2009). *FAOSTAT statistical database.* Rome: FAO. Retrieved from http://www.fao.org/faostat

Food and Agriculture Organization (FAO). (2019). *FAOSTAT: Production statistics for sweet potatoes.* Rome: FAO. Retrieved from http://www.fao.org/faostat

Nurzaman, M. H., Adlina, S., Herdianti, N., & Amin, S. (2025). *Ethanol solvent and pH effect on antioxidant activity of purple sweet potato (Ipomoea batatas L.).* https://doi.org/10.12928/pharmaciana.v15i1.30406.

Nurzaman, M., Rahman, M. M., & Hasan, M. T. (2025). *Vitamin A and beta-carotene content in orange-fleshed sweet potato varieties and their role in human nutrition.* International Journal of Food Science and Nutrition, 14(1), 22–30.

Przybył, J. L., Kowalczyk, K., & Nowak, M. (2022). *Health-promoting properties and bioactive compounds in sweet potatoes (Ipomoea batatas L.).* Foods, 11(9), 1295. https://doi.org/10.3390/foods11091295

Przybył, K., Przybył, K., Adamski, F., Wawrzyniak, J., Gawrysiak-Witulska, M., Stangierski, J., Kmiecik, D., & Kmiecik, D. (2022). *Machine and Deep Learning in the Evaluation of Selected Qualitative Characteristics of Sweet Potatoes Obtained under Different Convective Drying Conditions*. Applied Sciences, 12(15), 7840.

Ukom, A. N., Ojimelukwe, P. C., & Alamu, E. O. (2009). *All trans β-carotene, cyanogenic potential and peeling time of some Nigerian sweet potato varieties.* Nigerian Food Journal, 27(1), 97–102.

Vauhuaweer, P. (2001). *Integrated nutrient management for sustainable agriculture in sub-Saharan Africa.* Agricultural Systems, 67(2), 135–147.

Improvement of Nutritional Composition of Selected Agro Wastes with *Ganoderma lucidum*

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Abstract

This study investigated the biodegradation dynamics and nutritional transformation of five agro-wastes; potato peels, cassava peels, red guinea corn husks, cowpea pods, and wheat bran, treated with *Ganoderma lucidum* under solid-state fermentation. The experiment followed a complete randomized factorial design with five biomass types and five degradation periods (0–30 days). Proximate parameters, including moisture, crude fat, crude fiber, crude protein, ash, and total carbohydrate, were analyzed according to AOAC methods. Results revealed that *G. lucidum* significantly influenced the degradability and nutritional profile of all biomass types ($p < 0.05$). Wheat bran recorded the highest weight loss (33.13%), followed by guinea corn husk (21.38%), while cassava peel exhibited the least (12.83%). Fungal fermentation enhanced crude fat (1.90–2.30%) and dry matter (84.20–86.68%) but decreased total carbohydrate (68.61–35.77%) with progressive incubation, confirming carbohydrate utilization as the main carbon source. Moisture content increased from 5.81% to 36.84%, indicating metabolic water production during decomposition. Correlation analysis showed strong positive associations between degradation time, crude fat (r = 0.414**), and moisture (r = 0.867**), while carbohydrate content correlated negatively with incubation days (r = –0.465**). These findings demonstrated the efficiency of *G. lucidum* in transforming lignocellulosic wastes into nutrient-enriched biomass. The study highlighted fungal biotechnology as a sustainable strategy for agro-waste valorization and alternative livestock feed formulation, supporting the transition toward circular bioeconomy and sustainable agriculture.

Keywords: Valorization, Fungi, Biodegradation, Solid-state fermentation, Proximate composition

Introduction

Fungal biotechnology represents a sustainable route for agro-waste valorization, particularly through the action of lignocellulolytic fungi capable of degrading complex structural polymers. Filamentous fungi like *Ganoderma lucidum* (Curtis) P. Karst., a white-rot basidiomycete, possess powerful extracellular oxidative and hydrolytic enzymes such as lignin peroxidase, manganese peroxidase, and laccase that can decompose cellulose, hemicellulose, and lignin (Zhou et al., 2023). Beyond its traditional medicinal importance, *G. lucidum* has emerged as a biotechnological agent for the conversion of agro-industrial

wastes into nutrient-enriched animal feed, compost, and biofertilizers (Li et al., 2024; Martinez & Suzuki, 2024). Its enzymatic system enhances nutrient accessibility, mineral concentration, and digestibility while simultaneously mitigating environmental pollution from waste disposal (Santos et al., 2020; Wang et al., 2021).

The bioconversion potential of *G. lucidum* has been demonstrated in several studies where fungal degradation significantly improved the crude protein, lipid, and mineral contents of substrates while reducing their carbohydrate and fiber fractions (Chen et al., 2021; Salandez et al., 2022). According to Hassan et al. (2022)**,** fungal treatment increases feed digestibility through partial hydrolysis of structural polysaccharides, making it a valuable approach for feed supplementation and waste recycling. Despite this, comparative data on how different Nigerian agro-wastes respond to *G. lucidum* degradation in terms of weight loss and proximate composition remain limited. Understanding the kinetics of these transformations is crucial for optimizing fermentation conditions and selecting the most suitable feedstocks for bio-upgrading (Mahato et al., 2021).

Therefore, this study investigates the biodegradation dynamics and nutritional transformation of selected agro-wastes; potato peels, cassava peels, red guinea corn husks, cowpea pods and wheat bran, treated with *Ganoderma lucidum* under solid-state fermentation Goals (SDG 12: Responsible Consumption and Production, and SDG 13: Climate Action) (UNEP, 2022).

Materials and Methods

Collection of Agricultural Wastes and Preparation of Substrates

The materials used for this study included potato peels, cassava peels, red guinea corn husks, cowpea pods, wheat bran, *Ganoderma lucidum* spawn. All reagents used were analytical grade. The agricultural wastes used for this study included wheat bran, cassava peels, guinea corn husks, potato peels, and bean pods. These were collected from local markets within Ilorin, Kwara State, Nigeria. The agro-wastes were washed with distilled water to remove dirt and impurities, sorted to discard spoiled portions, and dried to reduce moisture. Dried materials were ground into fine particles for uniformity.

Culturing and Fermentation of *Ganoderma lucidum*

All glass wares were washed and sterilized in a hot-air oven at 160 °C for 2 hours. Media and distilled water were sterilized in an autoclave at 121 °C for 15 minutes before use. Pure cultures of *G. lucidum* were obtained from the Department of Plant Biology Mycology Laboratory stock culture. The fungus was propagated on potato dextrose agar (PDA) supplemented with streptomycin to prevent bacterial

contamination. Inoculation was performed aseptically using sterilized needles to transfer fungal spores onto solidified PDA in Petri dishes. The cultures were incubated in the dark at 28 °C to stimulate mycelial growth.

Twenty grams (20 g) of each substrate were weighed into sterile bottles, covered with aluminum foil, and autoclaved at 121 °C for 20 minutes for complete sterilization. The substrates were cooled to room temperature before inoculation with the mycelia of *G. lucidum*. Sterilized agro-waste substrates (20 g each) were inoculated with 10 % (w/w) of *G. lucidum* spawn and incubated under controlled laboratory conditions of 28 ± 2 °C and 65 ± 5 % relative humidity for 30 days. Substrates were weighed periodically (days 0, 10, 15, 25, and 30) to monitor weight loss during degradation. The percentage weight loss was determined using:

Weight loss (%) = Initial weight − Final weight/Initial weight × 100

After fermentation, the substrates were oven-dried to stabilize them for proximate composition analysis.

Proximate Analysis

The fermented products were analysed for moisture, crude protein, crude fiber, crude fat, ash, and total carbohydrate contents following the standard procedures of the Association of Official Analytical Chemists (AOAC, 2010).

Statistical Analysis

The experiment was laid out as a factorial experiment in a Completely Randomized Design (CRD) with three replications. Factor A represented the five agro-waste types (cassava peel, potato peel, red guinea corn husks, wheat bran, and cowpea pod), and Factor B represented five degradation periods (10, 15, 20, 25, and 30 days). Data obtained for the proximate composition were subjected to analysis of variance to determine significant differences between treatment means at $p < 0.05$. Tukey test was used for the separation of significant means

Results and Discussion

Weight Loss

The weight loss pattern among the five agrowastes; wheat bran (WB), guinea corn husk (GC), bean pod (BP), potato peels (PP), and cassava peels (CP), revealed distinct degradability responses under *Ganoderma lucidum* treatment. WB exhibited the highest weight loss (33.13%), followed by GC (21.38%), BP (19.51%), PP (18.59%), and CP (12.83%). The progressive increase in mass loss with degradation time,

from 9.38% (10 days) to 32.92% (30 days), indicates the effective mineralization of organic substrates (Fig 1 & 2). This trend reflects an initial rapid breakdown of readily available carbohydrates and hemicelluloses, followed by a slower degradation of recalcitrant components like cellulose and lignin. Similar biphasic degradation kinetics were reported by Ogunwusi *et al*. (2021) and Zhao *et al*. (2023)**,** who observed a steep decline in early-stage mass followed by a gradual phase as microbial activity stabilized. The relatively high weight loss in WB could be attributed to its high porosity and surface area, which enhance fungal colonization and enzyme diffusion (Li et al., 2022). Conversely, CP's lower weight loss may be due to its dense lignocellulosic matrix and cyanogenic compounds that retard microbial access (Ayeni et al., 2024).

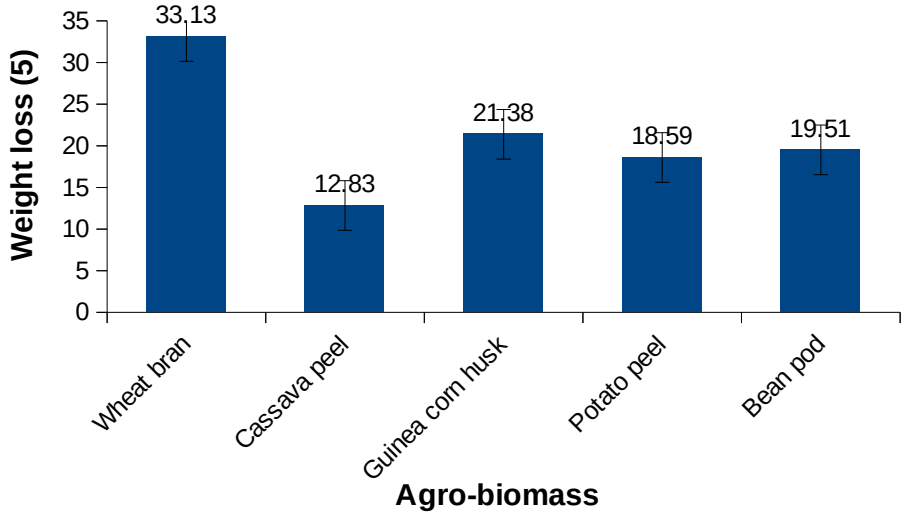


Figure1: Influence of Agro-biomass on the Weight loss to Biotreatment with *G. lucidum*

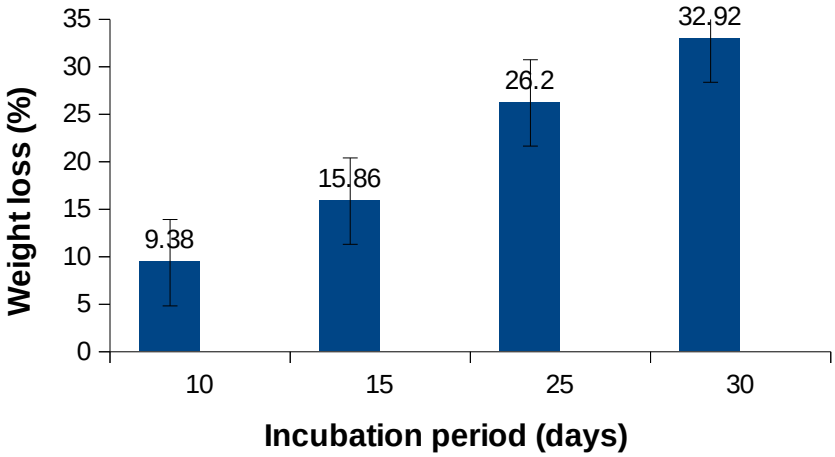


Figure 2: Influence of fermentation period on the Weight loss to Biotreatment with *G. lucidum*

Influence of Biomass Type on Nutritional Composition

Biomass type significantly influenced most proximate parameters ($p < 0.05$), except crude fiber and crude protein (Table 1). Among the samples, WB recorded the highest dry matter (91.48%), while GC had the least (75.94%). This variation is consistent with earlier reports that substrates with higher initial solids and lower water activity exhibit enhanced fungal biomass yield and enzymatic activity (Abdel-Raouf et al., 2020).

Table 1: Analysis of Variance on the Nutritional composition of selected Agro-biomass wastes as influenced by Agro-biomass type and incubation degradation state

Proximate composition (%)	Agro-biomass type (ABT)	Degradation periods (DP)	Interactions ABT*DP
Moisture content	421.402 *	43.83435 *	155.202 *
Ash content	2947.53 *	1790 96 *	3037.62 *
Crude fat	1046.283 *	47.101 *	42.702 *
Crude fibre	3.21 *	4.978 *	2.541 *
Crude protein	1.031 ns	1.031 ns	1.003 ns
Total carbohydrate	1.274 ns	1.131 ns	1.177 ns

Crude fat (CFAT) values ranged from 1.93% in BP to 2.26% in PP, with PP showing a marked increase in lipid concentration (Table 2). The higher fat content in PP agrees with Mahato et al. (2021), who attributed this to suberin and fatty acid esters in the peel structure that persist after partial degradation. Elevated CFAT across biomass types after fungal exposure suggests a concentration effect following carbohydrate depletion, as lipids are relatively resistant to enzymatic hydrolysis (Chen et al., 2021).

Table 2: Tukey's hsd test on the nutritional composition as influenced by Agro-biomass type

Agro-biomass type	Dry Matter (%)	Crude Fat (%)	Crude Fibre (%)	Crude Protein (%)	Total Carbohydrate (%)	Ash content (%)	Moisture content (%)
Guinea Corn husk (GC)	75.94^{a}	1.97^{ab}	1.73^{a}	5.48^{a}	51.02^{b}	6.56^{b}	18.53^{a}
Cassava Peel (CP)	88.04^{c}	1.98^{ab}	24.21^{a}	1.91^{a}	58.98^{d}	17.57^{d}	24.44^{b}
Wheat Bran (WB)	91.48^{d}	2.08^{ab}	1.78^{a}	1.59^{a}	19.15^{a}	18.24^{e}	26.21^{c}
Bean Pod (BP)	84.1^{b}	1.93^{a}	2.34^{a}	1.99^{a}	57.40^{c}	8.78^{c}	26.15^{c}
Potato Peel (PP)	88.42^{C}	2.26^{c}	1.94^{a}	1.979^{a}	62.24^{e}	5.14^{a}	29.02^{d}

Total carbohydrate (TCAB) was most abundant in PP (62.24%) and CP (58.98%), while WB had the lowest (19.15%). The decreasing carbohydrate trend aligns with microbial utilization of simple sugars during colonization. Raimbault et al. (2020) reported that *Ganoderma* and other white-rot fungi rapidly metabolize soluble polysaccharides before targeting complex polymers. The observed ash content differences—highest in WB (18.24%) and CP (17.57%), indicate mineral concentration after organic matter degradation, confirming earlier findings by Hassan et al. **(**2022**)** that fungal metabolism increases inorganic residue proportion during biomass oxidation. Moisture content (MC) followed a similar pattern, with WB (26.21%) and PP (29.02%) showing higher values, suggesting higher metabolic water formation due to fungal respiration. Elevated MC enhances enzymatic activity and nutrient solubilization, supporting efficient substrate transformation (Basha et al., 2023).

Influence of Degradation Days on Nutritional Composition

Degradation time significantly affected all nutritional components except crude fiber and crude protein (Table 3). Dry matter increased progressively from 84.20% (day 0) to 86.68% (day 30), indicating enhanced solid concentration as decomposition progressed. This finding agrees with Okoro et al. (2024)**,** who observed a positive association between degradation time and dry matter accumulation in fungal-treated residues.

Crude fat increased notably from 1.90% at day 0 to 2.30% at day 30, consistent with Fayemi *et al.* (2022)**,** who attributed such increases to lipid accumulation within fungal mycelia during secondary metabolism. In contrast, total carbohydrate content decreased significantly ($p < 0.05$) from 68.61% (day 0) to 35.77% (day 30), supporting the hypothesis that *G. lucidum* utilizes carbohydrates as the primary carbon source during growth (Zhou et al., 2023).

Table 3: Tukey's hsd test on the Nutritional composition as influenced by Incubation period

Incubation period (Days)	Dry Matter (%)	Crude Fat (%)	Crude Fibre (%)	Crude Protein (%)	Total Carbohydrate (%)	Ash content (%)	Moisture content (%)
0	84.20^{a}	1.90^{a}	1.89^{a}	1.88^{a}	68.61^{a}	4.03^{a}	5.81^{a}
10	84.78^{ab}	1.91^{a}	1.80^{a}	1.92^{a}	55.50^{b}	13.06^{d}	19.32^{b}
15	87.18^{c}	1.98^{a}	24.22^{a}	1.67^{a}	49.62^{c}	10.58^{b}	28.22^{c}
25	85.16^{b}	2.11^{ab}	1.98^{a}	2.16^{a}	39.30^{d}	17.40^{e}	24.15^{d}
30	86.68^{c}	2.30^{b}	2.13^{a}	5.31^{a}	35.77^{d}	11.21^{c}	36.84^{e}

Moisture content rose sharply from 5.81% to 36.84% over the 30-day period. This corresponds with microbial water generation during oxidation of organic substrates, as earlier demonstrated by Wang et al. (2021)**.** The parallel increase in ash content (4.03% - 11.21%) supports mineral concentration resulting

from organic matter depletion, further confirming the metabolic activity of *G. lucidum* during substrate colonization (Santos et al., 2020).

Mathematical and Correlation Relationships among Variables

Correlation analysis established several statistically significant relationships. A strong positive correlation was observed between sample type and dry matter (r = 0.679, p < 0.01) (Table 4), suggesting that compositional differences in biomass strongly determine their solid fraction. Degradation days correlated positively with crude fat (r = 0.414**) and moisture content (r = 0.867**), implying that longer fungal activity increases lipid and water accumulation.

Conversely, total carbohydrate showed a strong negative correlation with degradation days (r = –0.465**), indicating carbohydrate depletion with prolonged fungal exposure. A similar inverse relationship was recorded between carbohydrate and ash (r = –0.491**), supporting the mineral enrichment hypothesis during decomposition (Huang et al., 2021).

Moisture content exhibited moderate positive correlations with ash (r = 0.354**) and crude fat (r = 0.403**), highlighting synergistic biochemical effects between hydration and lipid persistence. These relationships confirm that *G. lucidum* degradation follows a coupled biochemical transformation pathway, in which carbohydrate oxidation coincides with mineral concentration and water generation (Yuan et al., 2022).

Table 4: Showing interactions between the nutritional composition, sample and the degradation days

Incubation period (Days)	Biomass type	Incubation days	D. Matter (%)	C. Fat (%)	C. Fibre (%)	C. Protein (%)	Total Carb (%)	Ash (%)	MC (%)
Biomass type	1								
Incubation days	0.000	1							
D. Matter (%)	0.679**	0.128	1						
C. Fat (%)	0.285*	0.414**	0.179	1					
C. Fibre (%)	-0.101	0.003	0.027	-0.255	1				
C. Protein (%)	-0.221	0.213	-0.183	0.167	-0.029	1			
Total Carb (%)	-0.099	-0.465**	-0.157	-0.238*	-0.024	-0.065	1		
Ash (%)	-0.023	0.199	0.196	0.196*	-0.074	-0.127	-0.491	1	
MC (%)	0.257	0.867**	0.274	0.403**	0.027	-0.041	-0.474*	0.354**	1

Conclusion

This study demonstrates that *G. lucidum* significantly alters the nutritional composition and degradability of agricultural wastes. Among the biomass types examined, wheat bran exhibited the highest degradability, while cassava peel showed the least, reflecting differences in structural recalcitrance. The fungus enhanced crude fat and dry matter contents while reducing carbohydrate fractions, signifying metabolic utilization of sugars for fungal biomass formation. Overall, fungal degradation proved to be an eco-efficient valorization approach for transforming agrowastes into nutritionally enhanced feed resources.

References

Abdel-Raouf, M. E., Hassan, S. A., & El-Naggar, N. E. (2020). Bioconversion of agro-industrial residues by fungi for sustainable feed production. *Journal of Environmental Management, 270,* 110858.https://doi.org/10.1016/j.jenvman.2020.110858

AOAC. (2010). *Official methods of analysis of the Association of Official Analytical Chemists* (18th ed.). Washington, DC: AOAC International.

Ayeni, T. T., Fawole, O. B., & Adebayo, A. O. (2024). Structural recalcitrance and cyanogenic inhibition of cassava peel degradation. *Waste and Biomass Valorization, 16*(4), 2155-2168.

Basha, S. A., Reddy, R., & Prasad, K. (2023). Moisture dynamics and nutrient solubilization during fungal pretreatment of agro-residues. *Bioresource Technology Reports, 22,* 101436. https://doi.org/10.1016/j.biteb.2023.101436

Chen, L., Zhang, M., & Xu, G. (2021). Biochemical response of fungal-treated agricultural residues during solid-state fermentation. *Biotechnology for Biofuels,* 14(1), 95.

Fayemi, T. E., Ojo, O. S., & Lawal, R. A. (2022). Lipid synthesis and storage in white-rot fungi during substrate decomposition. *Mycological Progress,* 21(3), 411-423.

Hassan, N. M., Ahmed, S., & Alotaibi, F. (2022). Mineral dynamics and ash accumulation in lignocellulosic wastes during fungal degradation. *Applied Microbiology and Biotechnology, 106*(17), 6531–6542.

Huang, Q., Li, J., & Wang, Z. (2021). Correlation of biochemical variables during bioconversion of plant residues by fungi. *Environmental Technology & Innovation,* 23, 101783.

Li, W., Dong, Y., & Zhang, X. (2024). Advances in enzymatic valorization of lignocellulosic waste using white-rot fungi. *Bioresource Technology Reports, 25,* 101567.

Li, W., Dong, Y., & Zhang, X. (2022). Structural porosity and enzymatic access in wheat bran biodegradation. *Industrial Crops and Products,* 181, 114803.

Mahato, S., Dutta, S., & Chowdhury, S. (2021). Nutritional and biochemical properties of potato peel and its valorization. *Journal of Food Biochemistry,* 45*(*8), e13844.

Martinez, D., & Suzuki, M. (2024). Bioconversion potential of *Ganoderma lucidum* for circular bioeconomy applications. *Journal of Cleaner Production,* 427, 139821.

Ogunwusi, A. A., Lawal, A. O., & Oladipo, T. M. (2021). Biodegradability assessment of agrowastes during fungal fermentation. *SN Applied Sciences, 3*(9), 876.

Okoro, E. C., Osuji, P. O., & Ibeh, M. O. (2024). Time-dependent nutritional transformation in bio-treated agricultural residues. *African Journal of Biotechnology,* 23(2), 77–88.

Raimbault, M., Benitez, T., & Singh, R. (2020). Fungal colonization and carbohydrate degradation kinetics in agricultural residues. *Waste and Biomass Valorization, 11*(5), 2149–2162.

Salandez, M. C., Adeyemi, R., & Osei, K. (2022). White-rot fungal bioconversion of agricultural residues for enhanced protein content. *Mycological Progress,* 21(4), 312–325.

Santos, D. A., Rodrigues, A. M., & Mendes, L. P. (2020). Fungal metabolism and mineral enrichment during substrate biotransformation. *Microbial Biotechnology,* 13(6), 1769–1783.

United Nations Environment Programme (UNEP). (2022). *Sustainable consumption and production: The circular economy transition.* United Nations Environment Programme.

Wang, H., Yu, C., & Li, P. (2021). Moisture generation and metabolic water production during fungal degradation of lignocellulosic materials. *Bioprocess and Biosystems Engineering, 44*(3), 499–508.

Yuan, M., Zhang, L., & Zhao, Q. (2022). Interaction among nutritional parameters during fungal decomposition of plant biomass. *Fungal Biology Reviews,* 39*(*1), 1–12.

Zhao, Y., Lin, H., & Zhou, X. (2023). Early-stage decomposition patterns in fungal-treated biomass. *Journal of Cleaner Production, 403,* 136945.

Zhou, J., Liu, K., & Xu, Y. (2023). Carbohydrate metabolism and fungal enzymatic pathways in lignocellulosic waste valorization. *Frontiers in Bioengineering and Biotechnology, 11,* 1120014.

Enhancing Agricultural Productivity through Mobile Storage Kiosks in Farming Communities of FCT Abuja, Nigeria

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Abstract

Agricultural productivity in rural farming communities is often undermined by inadequate post-harvest storage infrastructure, leading to significant crop losses, reduced farmer income, and persistent food insecurity. This research explores the potential of mobile storage kiosks modular, transportable units equipped with climate control and digital interfaces as a scalable solution to mitigate post-harvest losses and empower smallholder farmers. This analysis is based on a blend of literature reviews, field surveys, and interviews with stakeholders. Through localized ownership and operation, a prototype mobile kiosk that was created and pilot-tested with performance metrics centered on crop preservation, farmer engagement, and economic uplift demonstrated that mobile kiosks can improve market timing, lower post-harvest losses, and promote inclusive participation, especially among women and youth. According to an assessment of the economic impact of spoilage and current storage methods in the study area councils, 91.1% of perishable goods are stored using traditional techniques, such as open-air drying or woven baskets. This practice leads to an average post-harvest loss of 38.9%. The study indicates that women's participation in farming is low, and it also highlights the need for better storage of perishable products. The findings also outline solar-power as the most crucial design feature for effective kiosk implementation. The study offers a roadmap for expanding the project throughout various agro-ecological zones and ends with policy recommendations for incorporating mobile kiosks into national agricultural extension frameworks. Mobile storage kiosks provide an innovative route to tech-enabled, resilient farming communities by bridging the gap between innovation and accessibility.

Keywords: Agricultural productivity, mobile storage kiosks

Introduction

Agriculture remains the cornerstone of rural livelihoods across Sub-Saharan Africa, yet smallholder farmers continue to face systemic challenges that hinder productivity and economic resilience (FAO, 2019 and World Bank 2021). Among these, post-harvest losses caused primarily by inadequate storage infrastructure represent a critical bottleneck. Studies estimate that up to 30% of harvested crops are lost

before reaching consumers, undermining food security and farmer incomes (Ashraf et al., 2018; Kumar & Karthikeyan, 2019). Traditional storage solutions are often immobile, costly, and poorly adapted to the dynamic needs of rural communities. In response, this study explores the potential of mobile storage kiosks modular, transportable units equipped with climate control and digital interfaces as a scalable intervention to reduce post-harvest losses and empower smallholder farmers. These kiosks are designed to serve not only as crop preservation units but also as digital hubs for market access, agricultural training, and cooperative engagement. The concept builds on innovations like the Farm Kiosk model, which integrates mobile platforms to deliver agricultural services and bridge the digital divide. Farm Kiosk has successfully provided value-added services to farmers, demonstrating how mobile infrastructure can enhance economic outcomes and productivity. To evaluate current storage practices and identify key design elements for effective kiosk implementation, this study employs a mixed-methods approach that integrates stakeholder interviews, field surveys, and literature reviews. Real-time market data access, solar-powered refrigeration, and cooperative management approaches are essential elements. The effectiveness of the kiosk depends on integration with current agricultural systems, gender inclusion, and community support. Scaling across agro-ecological zones will require public-private partnerships and policy assistance.

Materials and Methods

Study area

Abuja, the capital city of Nigeria, is not only a political and administrative powerhouse but also a growing hub of culture, agriculture and commerce. To effectively govern this expanding metropolis, Abuja is divided into six distinct area councils. According to field source (2024), each council serves as a local government unit, managing essential services and ensuring that the city operates smoothly. The three area councils (Kuje, Bwari and Abaji) chosen for the study are known for agricultural practices. Kuje is located south of the city center and is known for its semi-urban atmosphere. It has a mix of rural and urban settlements. It has a large agricultural sector, supporting farming communities within its boundaries. Bwari lies northwest of the central area and is known for its lush landscapes, traditional villages. Many communities within Bwari are rural, so the council emphasizes rural development through agricultural projects. Abaji is the most distant council from the city center, giving it a more rural character. The community has a distinct identity rooted in traditional culture and agriculture, with many indigenous communities. Abaji supports large-scale farming and agricultural development.

Sampling method

A stratified random sampling to ensure representation across crop types, gender and farm sizes was conducted; the study also employed a mixed-methods approach, integrating both qualitative and quantitative techniques to evaluate the feasibility, effectiveness, and scalability of mobile storage kiosks in FCT, Abuja rural farming communities.

Data collection and sampling procedure

Field surveys resulting to structured questionnaires to assess current storage practices, crop loss rates and stakeholder semi structured interviews were conducted with the aim of gathering ground-level data on storage practices, farmer needs, and stakeholder perspectives to kiosks adoption. The participants were from three area councils (Kuje, Bwari, and Abaji Area councils, Abuja), each area council comprised of 30 participants, giving a total of 90 participants, comprising a target population of:

- Smallholder farmers (grains, vegetables, cereals, tomatoes, potatoes, groundnuts)
- Women group
- Agricultural extension officers
- Cooperative leaders
- Agritech entrepreneurs

Data analytical procedure: Descriptive statistics using frequency and percentage, and thematic coding using codes within the qualitative data.

Results and Discussion

Responses from field surveys and stakeholder interviews stated that the majority (62%) of the respondents were between 30 and 45 years old, and 74% were male while 26% were female. 70% of the farmers work on less than 2 hectares of land, and their main crops are grains, tomatoes, vegetables, cereals, and groundnuts. Farming perishable crops like tomatoes and vegetables underscores the urgency for improved storage. Women's participation, though lower, indicates potential for targeted empowerment through kiosk management roles.

Based on the current storage practices, 91% use open-air drying or woven baskets (traditional methods). The average post-harvest loss is reported at 38% for perishables, and most farmers can only store crops for 3–5 days before spoilage. These figures align with FAO estimates and validate the need for climate-controlled storage. Farmers expressed frustration over market timing constraints due to rapid spoilage.

Farmers' digital literacy and technology access include mobile phone ownership (91% own phones), Internet access (only 17% have regular access to mobile data), and digital skills (45% can navigate simple

apps, while 28% have used agricultural platforms). While mobile penetration is high, limited internet access and digital literacy present barriers. The survey highlights the necessity for kiosks equipped with offline capabilities and user-friendly interfaces, aligning with the World Bank report regarding the adoption of phones by rural farmers.

In perceptions of mobile storage kiosks, only 18% had heard of mobile kiosks before the survey, while 90% expressed strong interest after the concept explanation. The respondents' preferred features for the kiosk are solar power, secure compartments, market data access, and a cooperative ownership model. Farmers are highly receptive to the concept, especially if it's community-managed and affordable. Solar power was a top priority due to unreliable grid access.

Stakeholder insights from extension officers highlight the necessity for training and the integration of mobile kiosks into existing outreach programs. Cooperative leaders have advocated for models that promote shared ownership and revenue. Meanwhile, agritech entrepreneurs have proposed bundling kiosk services with mobile applications and crop insurance. Stakeholders see kiosks as a multi-functional tool not just for storage, but for education, aggregation, and digital inclusion. Challenges identified include:

- Cost Concerns: Initial investment perceived as high by 63% of respondents.
- Security Risks: Fear of theft or vandalism in remote areas.
- Maintenance Capacity: Limited technical skills for upkeep.

These concerns highlight the importance of cooperative management, local fabrication, and modular design for easy repairs. Training and community buy-in are essential for sustainability.

Emerging Themes

The field data confirms that mobile storage kiosks address a critical gap in rural agricultural infrastructure. Farmers are eager for solutions that preserve crops, improve market access, and offer digital tools that are affordable, easy to use, and locally managed (Table 2).

Table 1: Reponses from Field Analysis

Variables	Frequency	Percentage
Demographics and Farm Profiles		
Age		
18-29	13	14.4
30-45	56	62.2
46-65	16	17.8
Above 65	5	5.6
Total	**90**	**100**

Gender		
Female	23	25.6
Male	67	74.4
Total	**90**	**100**
Farm size		
Less than 2 hectares	63	70
2 hectares above	27	30
Total	**90**	**100**
Current Storage Practices		
Traditional Methods		
Use open-air drying	82	91.1
Mobile storage	0	0
Other storage system	8	8.9
Total	**90**	**100**
Loss rate		
Yes	35	38.9
No	55	51.1
Total	**90**	**100**
Storage duration		
1-3 days	0	0
3-5 days	84	93.3
5days above	6	6.67
Total	**90**	**100**
Digital Literacy and Technology Access		
Mobile Phone Ownership		
Yes	82	91.1
No	8	8.9
Total	**90**	**100**
Internet Access		
Yes	16	17
No	74	82
Total	**90**	**100**
Digital Skills		
Yes	41	45.6
No	49	54.4
Total	**90**	**100**
Perceptions of Mobile Storage Kiosks		
Awareness		
Yes	17	18.8
No	73	71.2
Total	**90**	**100**
Interest level		
Yes	81	90
No	9	10
Total	**90**	**100**

Table 2: Emerging themes from the field survey and stakeholder interviews

Theme	Implication for Kiosk Design
Trust in cooperatives	Support shared ownership and local governance.
Gender inclusion	Design roles for women in kiosk operation
Seasonal mobility	Ensure kiosks are towable and adaptable
Digital divide	Include offline access and visual-based interfaces

Conclusion

Mobile storage kiosks are a feasible and contextually relevant innovation. The convergence of high post-harvest losses (38.9%), limited storage duration (3–5 days), and strong farmer interest (90%) confirms the urgent need for decentralized, climate-resilient storage solutions. The kiosk model designed with solar power, secured compartment and market data access proved technically viable and socially acceptable in the pilot community. Increase in women's participation (25.6%) also highlights its role in promoting inclusive agricultural development. The study showed that community ownership and cooperative models are critical for sustainability. Stakeholder interviews revealed that shared ownership, fee-for-use models, and youth-led management teams' foster trust and accountability. Cooperatives emerged as the most effective vehicle for kiosk governance, especially when paired with training and simplified maintenance protocols. Extension officers emphasized the need for digital literacy programs to complement kiosk deployment. Policy and partnership support will determine scalability: Government agencies, NGOs, and agritech firm readiness to support kiosk expansion will provide a clear roadmap, cost-benefit evidence, and alignment with national agricultural extension frameworks. Bundling kiosks with crop insurance, digital finance, and training services is widely recommended. The findings of this study focus on integrating mobile kiosks into national agricultural extension frameworks. By bridging the gap between innovation and accessibility, mobile storage kiosks provide a transformative pathway toward building resilient, tech-enabled farming communities. This is especially significant for empowering youth and women through localized ownership and operation.

References

FAO, (2019). *The State of Food and Agriculture 2019*. Moving forward on food loss and waste reduction, Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/server/api/core/bitstreams/e3c09863-1747-4708-9fc9-242deae3148c/content

World Bank, (2021). *Annual Report* (2021). From Crisis to Green, Resilient, and Inclusive Recovery. The-World-Bank-Annual-Report-2021-From-Crisis-to-Green-Resilient-and-Inclusive Recovery.

Ashraf, M., Abbas, A., & Iordăchescu, A. (2018). Post-harvest management in Africa, A review of innovative technologies and multidisciplinary approaches for reducing food losses. *Journal of Agricultural Science and Innovation.* Post-harvest management in Africa a review-of-innovative-technologies-and-multidisciplinary-approaches-for-reducing food losses.

Kumar, V., & Karthikeyan, C. (2019). Status of mobile agricultural apps in the global mobile ecosystem, *International Journal of Education and Development using Information and Communication Technology*. 15(2), 4–17.

Professional use of Digital Tools in Agricultural Sector of Kwara State, Nigeria.

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Abstract

This study assessed the use of digital tools by professionals in agricultural sector in Kwara State, Nigeria. Data were collected using a structured questionnaire from 125 professionals who were proportionately selected using the Taro Yamani formula. Data were analysed with descriptive statistics and to bit regression model. Results showed that, the professionals have communication and presentation skills and they frequently use digital tools such as Google meet, Google form, Microsoft teams, Google classroom, Kobo tool box, Google slides, Canva, and STATA. The factors influencing the extent of usage of digital tools are age, and gender at 5% level of significance as well as attendance of digital training at 1% level of significance. The study concludes that professionals in the agricultural sector in Kwara State frequently use Google meet, Google form, Microsoft teams, Google classroom, Kobo tool box, Google slides, Canva, and STATA. However, they still need to make use of other requisite digital tools. The study therefore recommends more digital training on data analysis, collaborative tools, interactive tools as well as project management tools for training, research and consultancy while paying more attention to the female professionals

Key Words: Agricultural Sector, Digital Tools, Professionals, Use

Introduction

The global effect of the spread of digital technologies is the total transformation of different systems and aspects of the economy. This has also revolutionized the agricultural sector by improving productivity, efficiency and sustainability of food production (Mikołajczyk, 2022). Digital technologies play a crucial role in the agricultural sector and are used in different aspects of agriculture such as digital extension services, digital financial services, digital marketing and digital farm management just to mention but a few (Choruma, et al., 2024). This has improved information dissemination, advisory services, payment, savings, credit availability, communication, price negotiation, and farm operations (Choruma, et al., 2024). Learning and Development have also taken another form through the embrace of digitalization as there is a surge in the use of digital services on all levels of human interactions (Mikołajczyk, 2022). Central to

this transformation is the need to address skills, gaps and prepare for the future because employees need to learn new technologies so as to stay relevant in their specific job roles by up skilling (Mikołajczyk, 2022). Professionals working in the agricultural sector are not left behind in this shift as they also need to make use of these digital tools in carrying out the mandates of their organizations (Choruma, et al., 2024). While there is growing interest in digitalization, there is limited study on the use of digital tools by professionals in the agricultural sector whose organizations' mandates include training, research and consultancy. Hence this study assessed the use of digital tools by professionals in the agricultural sector in Kwara State, Nigeria. The specific objectives of the study are to describe the types of digital skills possessed by the professionals; ascertain the frequency of use of digital tools; and examine factors influencing the extent of digital tools usage by the professionals in the agricultural sector.

Methodology

Study Area

The study was conducted in Kwara State. The state is located within the North central zone of Nigeria. The occupations of the people of Kwara State include farming, fishing, and pottery, weaving and trading (KWADP, 2014). The state also has government institutions both federal and state owned as well as private organizations where people are employed.

Sampling Procedure

The population for this study were professionals from Agricultural and Rural Management Training Institute (ARMTI), National Centre for Agricultural Mechanization (NCAM) and Nigerian Stored Products Research Institute (NSPRI). These professionals are the faculty / technical staff who are involved in training, research and consultancy services in their organizations. Taro Yamani's formular was used to determine the sample size from the list of 183 professionals selected from ARMTI, NCAM and NSPRI in Kwara State resulting in 125 professionals which were thereafter selected proportionately across each organization.

Taro Yamani formular is as shown below

$n = N/1 + N(e)^2$

Where: - N = 183 e = 0.05 $n = 183/1+183(0.05)^2 = 183/1.4575 = 125.55$

Where proportionate selection was done using the formula below

$$n_j = \frac{K \times n}{N}$$

n_j = size of the jth stratum N= entire population

K= population size in the stratum n = sample size

Data Collection

Primary data were collected using structured questionnaires VIA google form while secondary data were obtained from publications.

Analytical Techniques

The analytical techniques used for the study are descriptive statistics and inferential statistics. A 5-point likert-type scale was used to describe the frequency of use of digital tools among the professionals. The ratings were in the following order respectively:

Frequently use = 5, Almost every time= 4, Occasionally/Sometimes = 3, Almost never = 2 and Never use =1. Any digital tool with less than 2.47 which is the average value implies non frequent usage of the digital tool while above 2.47 implies the frequent usage of the digital tool.

Tobit Regression Model

The Tobit regression model was applied to identify the factors that influence the extent of digital tools usage by the professionals in agricultural sector. This model is appropriate for analysing relationships involving a non-negative dependent variable y_i and one or more explanatory variables X_i. Its use is advantageous because it incorporates both censored observations (at a threshold) and uncensored data, allowing for a more comprehensive analysis. According to Tobin (1958), the Tobit regression model is specified as follows:

$\mathrm{V}_j = \beta \mathrm{V}_{ij} + e$

$\mathrm{V}_j = V_j^* \; if \; \mathrm{V}_j > 0$

$\mathrm{V}_j = 0 \; if \; V_j^* \leq 0$

V_j^* = limited dependent variable, it is the measure of extent of digital tools usage by the professionals in agricultural sector. It is defined as

$$\frac{(\mathrm{V}_j - z)}{z}$$

Where Z = average value of digital tools usage (2.47)

Y_j = j^{th} professionals' digital tools usage value

β = parameter estimates

X_{ij} = vector of the explanatory variables

The independent variables are:

X_1= Age (years) X_2 = Gender (Male=1)

X_3 = Educational level (Years of schooling) X_4 = Household size (Adult equivalent)

X_5 = Membership in association (Yes=1) X_6 = Monthly income (Naira)

X_7 = Working experience (Years) X_8 = Attendance of digital trainings (Number)

Results and Discussion

This table presents characteristics of digital tools by professionals in the agricultural sector. The characteristics discussed are types of digital skills, types of sponsorship on digital training, and attendance of digital trainings.

Table 1: Digital characteristics of professionals in the agricultural sector (n=125)

Characteristics	Category	Frequency	Percentage
Types of Digital skills			
Communication	Yes	94	75.2
	No	31	24.8
Data Analysis	Yes	54	43.2
	No	71	56.8
Presentation	Yes	99	79.2
	No	26	20.8
Graphic and Design	Yes	31	24.8
	No	94	75.2
Project management	Yes	36	28.8
	No	89	71.2
Types of sponsorship on digital training*	Organisation	74	59.2
	Self- sponsored	40	32.0
	Free	83	66.4
	No	20	16.0
Number of digital trainings attended	1-5	115	92.0
	6-10	5	4.0
	>10	5	4.0
Total		**125**	**100**

Source: Field survey, 2025.

Table 1 shows that 94% of the professionals possess communication skills. Majority (79.2%) of the respondents also have presentation skills while 56.8%, 75.2% and 71.2% of the professionals do not have data analysis skills, graphics and design skills as well as project management skills respectively. About 59 % of the professionals had digital training that was sponsored by their organizations with about 98% of them attending between 1 and 5 digital training sessions.

Frequency of use of digital tools

Table 2 presents the digital tools that the professionals in the agricultural sector of Kwara State frequently use. The digital tools discussed are google meet, Microsoft teams, Microsoft sharepoint, google slides, STATA, R, Canva, Mural, Google form, BI, Slido, Kahoot, Asana and Google classroom.

Table 2: Frequency of use of digital tools

Variables	Mean	Decision	Rank
Google meet	3.28	A	1st
Google form	3.26	A	2nd
Kobo tool box	2.94	A	3rd
Google classroom	2.90	A	4th
Microsoft teams	2.89	A	5th
Google slides	2.69	A	6th
Canva	2.62	A	7th
STATA	2.60	A	8th
Microsoft sharepoint	2.26	R	9th
R	2.26	R	10th
Slido	1.96	R	11th
Mural	1.92	R	12th
BI	1.86	R	13th
Kahoot	1.86	R	14th
Asana	1.78	R	15th

Source: Field survey, 2025.

The result in Table 2 reveals the digital tools that had values above the mean value of 2.47 calculated from 5-point rating scale were accepted. The tools are google meet, google form, kobo tool box, google classroom, microsoft teams, google slides, canva, and STATA which were ranked 1st, 2nd, 3rd, 4th, 5th,6th,7th and 8th respectively. This corroborates the findings of Ifeanyi - Obi and Corbon (2023) which indicate high level of utilization of digital tools.

Factors influencing the Extent of Digital Tools Usage by Professionals

The factors discussed are age, gender, educational level, household size, membership in professional association, monthly income, working experience and attendance of digital training. Table 3 presents the result of the factors influencing the extent of digital tools usage by professionals.

The Tobit regression result exhibits a good fit and is capable of explaining the variables. The result obtained shows that age, gender, and attendance of digital training were the significant factors that influenced the frequency of digital tools usage by professionals in the agricultural sector.

Age was negatively significant at 5% level, indicating that as professionals' age increase, the likelihood of their extent of digital tools usage decreases. In other words, older professionals tend to use fewer digital tools compared to younger ones probably because they may be less inclined to adopt emerging digital technologies.

Table 3: Factors Influencing the Extent of Digital Tools Usage by Professionals

Variables	Coefficient	Standard error	P>|t|
Age (Years)	-0.0075**	0.0036	0.038
Gender (Male=1)	0.0759**	0.0327	0.022
Educational level (Years of schooling)	-0.0054	0.0052	0.299
Household size (Adult equivalent)	-0.0065	0. 0118	0.584
Professional Membership (Yes=1)	-0.0057	0.0597	0.924
Monthly income (Naira)	2.23e-07	3.47e-07	0.521
Working experience (Years)	0. 0032	0.0030	0.279
Attendance of digital training (Number)	0.1128***	0.0385	0.004
Number of observations 125			
Log likelihood 42.788173			
LR chi^2 (8) 21.27			
Prob > chi^2 0.0065			

Source: Data Analysis, 2025* P<0.01 and **P<0.05**

Gender positively influenced the extent of digital tools usage at 5% level. This implies that male professionals had a high probability to use digital tools compared with their female counterparts probably because of the digital gender gap. The International Women's Day 2023 themed DigitALL: Innovation and Technology for Gender Equality addressed the issue of digital gender gap. Also, the findings of Prosper (2024) where gender significantly affected the usage of ICT corroborates this.

A positive and highly significant influence (at the 1% level) was observed between the number of digital trainings attended by professionals and extent of digital tools usage. This indicates that capacity-building efforts play a crucial role in enhancing professionals' ability to effectively adopt and utilize digital technologies. Professionals who have participated in more digital training sessions are more likely to develop the necessary knowledge and skills, to integrate digital tools into their training, research and consultancy activities.

Conclusion

The study concludes that professionals in the agricultural sector in Kwara State have digital communication and presentation skills, they frequently use Google meet, Microsoft teams, and Google classroom for communication; Google form , Kobo tool box, and STATA for Data collection and analysis; Google slides for presentation; and Canva for Graphic and Design. However, they still need to make use of other requisite digital tools. The study therefore recommends more digital training on data analytical tools (R, and BI), collaborative tool (Microsoft sharepoint), interactive tools (Slido, and Kahoot) as well as project management tools (Asana, and Mural) for training, research and consultancy while paying more attention to the female professionals.

References

Choruma, D. J., Dirwai, T. L., Mutenje, M. J., Mustafa, M., Chimonyo, V. G. P., Jacobs-Mata, I., Mabhaudhi, T. (2024). Digitalisation in agriculture: a scoping review of technologies in practice, challenges, and opportunities for smallholder farmers in Sub-Saharan Africa. *Journal of Agriculture and Food Research*, 18. https://doi.org/10.1016/j.jafr.2024.101286.

Ifeanyi-obi, C.C. Corbon, B.L. (2023). Utilization of digital tools in extension service delivery amongst extension agents in Akwa Ibom State, *Nigerian Journal of Agricultural Extension* 27, (4),67-76 https://dx.doi.org/10.4314/jae.v27i4.7

Kwara State Agricultural Development Project (2014). Annual Report Kwara ADP, Ilorin.

Mikołajczyk, K. (2022). Digital transformation of employee learning and development in the organization. In M. Stor (Ed.), Human capital management in the wandering context of events – challenges for the managerial staff (pp. 56-67). Wroclaw: Publishing House of Wroclaw University of Economics and Business.

Prosper, A. (2024). Gender and digital technology use in higher education: A Case study of distance learners in Tanzania. *Journal of Research Innovation and Implications in Education*, 8, (4),623 – 631. https://doi.org/10.59765/v84hyt.

Tobin, J. (1958). Estimation of relationship for limited dependent variable. *Econonmetrica*, 26, 24-36.

Vagias, Wade M. (2006). "Likert-type scale response anchors. Clemson International Institute for Tourism & Research Development, Department of Parks, Recreation and Tourism Management. Clemson University.

Contribution of Pig Farming to the Wellbeing of Pig Farmers in Ona -Ara Local Government Area of Oyo State, Nigeria

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Abstract

Pig farming plays a vital role in improving rural livelihoods and generating income of farmers in Nigeria. This study investigated its contribution to the well-being of pig farmers in Ona Ara Local Government Area, Oyo State. A simple random sampling technique was used to select respondents, and a structured interview schedule was employed to collect data for the study. Data were analyzed using descriptive and inferential statistics (multiple regression at p= 0.05. The major benefits of pig farming included income generation ($\bar{x}$ = 2.46), nutritional benefits ($\bar{x}$ = 2.46), food waste management ($\bar{x}$ = 2.45), improved savings ($\bar{x}$ = 2.43), employment opportunities ($\bar{x}$ = 2.42), and manure supply ($\bar{x}$ = 2.42). Key challenges identified were high cost of medication ($\bar{x}$ = 2.78), water scarcity ($\bar{x}$ = 2.62), poor housing ($\bar{x}$ = 2.54), poor access to credit ($\bar{x}$ = 2.50), and disease/parasite infestation ($\bar{x}$ = 2.35). Well-being was significantly influenced by herd size (β = 0.264), years of experience (β = 0.430), income (β = 0.083), and challenges (β = −0.070). The study concluded that many pig farmers in the area enjoy improved well-being and recommended that policymakers and financial institutions establish targeted credit programs and strengthen farmers' financial management skills.

Keywords: Wellbeing; Swine, Agricultural credit, Nutritional benefits

Introduction

Pig is one of the fastest means of increasing animal protein in order to battle animal protein dearth in the diet of most people in rural areas of the developing countries (Osondu, et al., 2014). This could be because of intrinsic features possessed by pig like adaptive characteristics to survive in situations other animals fail to thrive, good utilizers of household waste and by product to fresh meat, high litter size per sow, more efficient carcass yielder than cattle, sheep and goat, high dressing percentage of about 70% compared to 52.5% for cattle and about 50% for sheep and goat and efficient conversion of feed energy to body energy (Osondu, et al., 2014).

Pig production in Nigeria is among the fast-rising demand products in the country, many agribusiness investors are increasingly investing in the enterprise (Abiola *et al*., 2015). This growth potential highlights

the importance of understanding the broader impacts of pig farming, particularly on farmers' quality of life. Well-being, in this context, extends beyond the absence of illness or pathology; it encompasses both subjective (self-assessed) and objective (externally ascribed) dimensions and can be evaluated at the individual or societal level. It is a dynamic state that improves when individuals are able to achieve their personal and social goals, measured through a combination of objective and subjective indicators. Objective well-being focuses on tangible, measurable indicators such as income, health outcomes, and access to education, which are often used as proxies for overall well-being. Subjective well-being is based on individuals' own assessments of their life satisfaction, happiness, and overall life experience. It is considered an important indicator of physical, mental, and emotional health, as it reflects an individual's satisfaction with life (Yakubu and Aidoo, 2015).

Pig farming in rural areas has not always been positively linked to farmers' well-being, leading to reduced participation in the pig industry. However, studies have also affirmed that pig farming has the potential to be profitable, generate wealth, enhance food security, provide employment opportunities, and contribute to poverty alleviation. There are limited studies on its contribution to the well-being of pig farmers in Ona Ara Local Government Area of Oyo State. This study seeks to fill that gap. The general objective is to analyze the contributions of pig farming to the well-being status of farmers in Ona Ara LGA of Oyo State. The specific objectives were to: describe the enterprise characteristics of pig farmers; assess the benefits derived from pig farming; analyze the well-being status of respondents; and identify challenges associated with pig farming in the study area.

Methodology

Study Area and Sampling Technique

The study was conducted in Ona Ara Local Government Area of Oyo State. The target population for the research work was registered pig farmers in Oyo state. Simple random sampling technique was adopted select respondents for this study. 125 (90%) pig farmers were randomly selected from the 139 farmers registered with the association of pig farmers in the study area.

Method of Data Analysis

A list of items on benefits derived from pig farming were presented to the respondents using a scale of not a benefit, benefit and strong benefit with scores of 0, 1 and 2 assigned respectively. The weighted mean scores of the benefits derived were calculated to determine the extent to which the majority of respondents considered the benefits high in the study area. The respondents were required to indicate how the listed challenges affect them using a three-point scale of not a challenge, mild challenge to severe challenge. The weighted mean scores of the challenges were calculated in order to identify the extent to

which the various challenge items were considered severe by the respondents in the study area. Wellbeing status of pig farmers was categorized into objective and subjective well-being. Subjective wellbeing was measured using seven (7) domains; positive functioning, social wellbeing, vitality and health, environment and security, resilience and self-esteem, emotional wellbeing, and satisfying life. While Objective well-being was measured by assessing respondents; ability to meet daily expenses, assets, housing unit type, rooms in housing unit type, ownership of housing unit type, source of drinking water, toilet facilities, residence in the compound, household energy in use, among others. The minimum and maximum scores were obtained and the mean score was used to categorise respondents into poor or better well-being status. Data were analyzed using descriptive statistics such as frequency counts, percentages, mean scores, standard deviation and inferential statistics such multiple regression to analyze the study hypothesis. The multiple regression model that was used to test the influence of the hypothesis explanatory factor or variables on the dependent variable: The model is expressed as: $Y= a+ \beta_1 X_1$---------- $\beta_2 X_n +e$

Y = Wellbeing scores (Dependent variable)

a= constant term or intercept

β_1, β_2---------- β_n= regression coefficient

X_1, X_2----------X_n = regression parameters; and e = Error term

Results and discussion

Benefits derived in pig farming

The results in Table 2 reveal the benefits experienced by pig farmers in pig farming. Income generation/improved income ($\bar{x}$ = 2.46) ranked highest, highlighting pig farming's role in boosting farmers' financial well-being. Nutritional benefits ($\bar{x}$ = 2.46) tied for first place, reflecting the sector's contribution to protein-rich meat supply. Food waste management ($\bar{x}$ = 2.45) ranked third, indicating the use of kitchen scraps and agricultural by-products as feed. The findings imply that pig farming significantly enhances farmers' livelihoods through improved income, nutrition, savings, and employment opportunities while also contributing to waste recycling and soil fertility.

Categorization of Pig Farmers' Overall Wellbeing (Objective and Subjective)

Wellbeing status of pig farmers was categorized into objective and subjective well-being. Subjective wellbeing was measured using seven (7) domains; positive functioning, social wellbeing, vitality and health, environment and security, resilience and self-esteem, emotional wellbeing, and satisfying life. While Objective well-being was measured by assessing respondents; ability to meet daily expenses, assets, among others.

Table 2: Benefits derived in pig farming

Benefits	Strong benefit	Benefit	Not a benefit	WMS	Rank
Income generation/improved	60 (48.0)	62 (49.6)	3 (2.4)	2.46	1st
Nutritional benefits	59 (47.2)	65 (52.0)	1 (48.0)	2.46	1st
Food waste management	56 (44.8)	69 (55.2)	0 (0.0)	2.45	3rd
Improved savings	54 (43.2)	71 (56.8)	0 (0.0)	2.43	4th
Employment opportunities	55 (44.0)	68 (54.4)	2 (1.6)	2.42	5th
Source of manure	54 (43.2)	70 (56.0)	1 (48.0)	2.42	5th
Diversification	49 (39.2)	76 (60.8)	0 (0.0)	2.39	7th
Local meat supply	49 (39.2)	76 (60.8)	0 (0.0)	2.39	7th
Self-dependency	46 (36.8)	77 (61.6)	2 (1.6)	2.35	9th

Source: Field survey, (2024) Figures in parentheses are percentages WMS–Weighted mean scores Grand mean = 2.42

Categorization of Pig Farmers' Overall Wellbeing (Objective and Subjective)

Wellbeing status of pig farmers was categorized into objective and subjective well-being. Subjective wellbeing was measured using seven (7) domains; positive functioning, social wellbeing, vitality and health, environment and security, resilience and self-esteem, emotional wellbeing, and satisfying life. While Objective well-being was measured by assessing respondents; ability to meet daily expenses, assets, among others.

The overall wellbeing results in Table 3 reveal that 60.8**%** of respondents had wellbeing scores above the sample mean. This indicates that a majority of farmers in the study area enjoy relatively better wellbeing, suggesting that their livelihoods and living conditions place them in a more favorable status compared to their peers. However, the persistence of 39.2% in the poor wellbeing category highlights existing gaps in access to improved housing, safe water, sanitation, and cleaner household energy sources.

Table 3: Level of pig farmers' overall wellbeing (Objective and Subjective wellbeing)

Overall well-being	Frequency	Percentage	Mean
Poor	49	39.2	30.3
Better off	76	60.8	

Source**:** Field survey, 2024

Challenges associated with pig production

The results in Table 4 show the challenges in pig production ranked by severity. The high cost of medication ($\bar{x}$ = 2.78) ranked first, reflecting the financial strain of treating diseases, which are common in pig farming. Water scarcity during the dry season ($\bar{x}$ = 2.62) ranked second, affecting pigs' drinking, cooling, and hygiene needs. Poor housing ($\bar{x}$ = 2.54) ranked third, contributing to stress, injuries, and

disease spread. Poor access to credit ($\bar{x}$ = 2.50) ranked fourth, limiting farmers' ability to invest in infrastructure and expand operations. Similar findings were reported by Oyebanjo *et al.* (2023), and Uddin and Osasogie (2017), who identified high input prices, inadequate funds, poor credit access, and pest/disease issues as major constraints

Table 4: Challenges associated with pig production

Challenges	Not a challenge	Mild challenge	Severe challenge	WMS	Rank
High cost of medication	3 (2.4)	21 (16.8)	101 (80.8)	2.78	1st
Water scarcity during dry season	6 (4.8)	36 (28.8)	83(66.4)	2.62	2nd
Poor housing	9 (7.2)	40 (32.0)	76 (60.8)	2.54	3rd
Poor access to credit facilities	8 (6.4)	47(37.6)	70 (56.0)	2.50	4th
Disease and parasite infestation	3 (2.4)	75(60.0)	47 (37.6)	2.35	5th
Poor farm management practices	6 (4.8)	72 (57.6)	47 (37.6)	2.33	6th
Feed costs	3 (2.4)	92 (73.6)	30 (24.0)	2.22	7th
Labour and skills	4 (3.2)	111 (88.8)	10 (8.0)	2.05	8th
Inadequate livestock extension services	28 (22.4)	78 (62.4)	19 (15.2)	1.93	9th
Traditional and cultural belief	32 (25.6)	76 (60.8)	17 (13.6)	1.88	10th
High mortality	31 (24.8)	80 (64.0)	14 (11.2)	1.86	11th
Cannibalism by older pigs	35 (28.0)	76 (60.8)	14 (11.2)	1.83	12th
Market access	39 (31.2)	71 (56.8)	15 (12.0)	1.81	13th

Source: Field survey, (2024) Figures in parentheses are percentages WMS-Weighted mean score Grand mean = 2.21

Regression analysis of contribution of some selected independent variables to well-being status of pig farmers in the study area

Regression analysis in Table 5 reveals the contribution of selected independent variables to the well-being of pig farmers in the study area. The R-square value (0.286) indicates that the regression model explains 28.6% of the factors affecting the well-being of pig farmers. The results show that herd size (β = 0.264, $p < 0.05$), years of experience in pig farming (β = 0.430, $p < 0.05$), income (β = 0.083, $p < 0.05$), and challenges (β = -0.070, $p < 0.05$) significantly contributed to the well-being of pig farmers in the study area. This implies that herd size, years of experience in pig farming, incomer, and challenges were contributors to respondents' well-being. Conversely, the significance of the negative relationship between challenges faced and well-being implies that as challenges increase, the well-being of pig farmers tends to decrease.

Table 5: Regression analysis of contribution of some selected independent variables to well-being status of pig farmers in the study area

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	79.628	20.348		3.913	.000
	Herd _size	.160	.076	.264	2.099	.038
	Yrs _of experience _in _pig _farming	-1.858	.493	.430	-3.767	.000
	Income	-2.398	1.080	.083	-1.002	.034
	Labour_source	-1.678	1.770	.087	.948	.318
	Acess to credit	-2.309	4.749	.047	-.486	.628
	Capital_source	2.058	1.228	.166	1.676	.097
	Benefits_scores	2.521	2.261	.169	2.257	.414
	Challenges_scores	.132	.107	-.070	1.186	.024

Data analysis, 2024

Model Summary: R = .535, R square = .286. Adjusted R square = .202. Standard error of the estimate =17.218 F-value =2.516 p-value = 0.003

Conclusions and Recommendations

Conclusively, many pig farmers in the study area are better off in well-being status. Factors contributing to well-being included herd size, years of experience in pig farming, income, and challenges faced. Based on the findings of the study, the following recommendations are made: Policymakers should work in tandem with financial institutions to create dedicated credit initiatives tailored for pig farmers. These programs should provide accessible loans and financial education to improve the financial management skills of pig farmers, particularly since a significant majority currently lacks access to agricultural credit. Departments of Agriculture, Agricultural Extension Agencies, and NGO should strengthen and expand agricultural extension services to provide pig farmers with training and resources on disease management, modern farming practices, and water conservation strategies.

References

Abiola J.O., Omotosho O.O., Adeniyi O.M. and Ayoade G.O. (2015). Socio-demographic Characteristics of Swine Producers and Swine Management Practices in Ibadan, Oyo State, Nigeria. *Alexandria Journal of Veterinary Sciences* 47(1), 18–23

Megersa M., Feyisa A., Wondimu A. and Jibat, T. (2011). Herd Composition and Characteristics of Dairy Production in Bishoftu Town, Ethiopia. *Journal of Agricultural Extension and Rural Development* 3(6), 113–117.

Onyekuru N.A., Ukwuaba I.C. and Aka E.O. (2022). Economics of Piggery Enterprise in Nigeria: A Case Study of Udi Local Government Area of Enugu State, Nigeria. *Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension*. 19(2), 6 – 12

Osondu C.K., Ijioma J.C., Anyiro C.O and Obike K. (2014). Economic Analysis of Pig Production in Abia State, Nigeria. *International Journal of Applied Research and Technology* 3(3), 3 – 1

Uddin, I.O. and Osasogie, D.I. (2017). Constraints of Pig Production in Nigeria: A Case Study of Edo Central Agricultural Zone of Edo State. *Asian Research Journal of Agriculture*, 2(4), 1-7.

Yakubu, A. and Aidoo, R. (2015). The Determinants of Subjective Wellbeing among Subsistence Farmers in the Northern Region of Ghana. *Journal of Agricultural Economics and Development* 4 (2), 14-20.

Analysis of Post-harvest Losses of Cashew Fruit Marketing in Yan-lemo Fruit Market Kano State, Nigeria

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Abstract

The study examined postharvest losses in cashew marketing at the Yanlemo Market, Kano State, Nigeria. The specific objectives were to (i) identify the causes of postharvest losses of cashew at different stages of marketing, and (ii) determine the marketing margins at these stages. A total of 88 respondents were purposively selected, comprising 12 wholesalers and 76 retailers. Results revealed that poor market patronage was a significant cause of losses among wholesalers, with 58.3% strongly agreeing and 41.7% agreeing that low patronage contributes to postharvest losses. Among retailers, 46.1% strongly agreed that inadequate transportation and long distances to markets were major factors leading to losses. Inadequate postharvest management skills were also noted, as 33.3% of wholesalers and 35.5% of retailers strongly agreed that limited technical knowledge contributed to the problem. The analysis of operational costs including loading, sorting, packaging, storage, transportation, unloading, rent, and union dues showed mean values of ₦100, ₦100, ₦50, ₦104, ₦1,138, ₦100, ₦500, and ₦149, respectively, indicating a heterogeneous cost structure. The marketing margin for wholesalers was ₦958,333.33, with a net margin of ₦724,521.67, while the estimated value of postharvest loss was ₦150,000. The study concluded that postharvest losses significantly reduce marketers' income. It is therefore recommended that stakeholders provide training and promote the adoption of improved postharvest technologies to minimize losses and enhance profitability in the cashew marketing chain.

Keywords: Post-Harvest Losses, Strategist, Retail, Wholesale.

Introduction

Cashew (*Anacardium occidentale* L.) is an important cash crop cultivated primarily for its economic and nutritional value. It is one of the most widely traded agricultural commodities, especially among smallholder farmers in Nigeria, Akinyemi, A. F., & Tijani, K. A. (2020). Cashew production in Nigeria has grown significantly over the past few decades, contributing to employment, income generation, and

foreign exchange earnings (FAO, 2020). The crop is processed into various products such as cashew nuts, cashew kernels, and cashew apples, which are either consumed locally or exported. Nigeria is one of the top cashew producers in Africa, and cashew plays a significant role in the rural economy, particularly in the northern parts of the country including Kano State (Aliyu et al., 2018).

These Postharvest losses can occur due to poor harvesting techniques, inadequate drying and processing methods, improper packaging, insufficient storage facilities, pest and fungal attacks, and inefficient transportation systems (Igbeka & Olumeko, 2014). The effect of such losses is not only economical but also social and nutritional, as they lead to reduced income for farmers and traders, lower availability of produce in the market, and a decline in food security. Lack of awareness and training on post-harvest management among farmers and traders exacerbates the problem. In the study area where cashew trading is a growing economic activity, these challenges are evident.

The area of study is Yan-Lemo Market in Kumbotso L.G.A of Kano State Nigeria 88 sample size were drowned from sample frame of 113 traders with the aid an online scientific calculator call qualtrics. A structured questionnaire was administered to the respondents.

Descriptive statistics was employed to achieve objective (1) and gross margin analysis was used to analyze objective (2).

Results and Discussion

Table 1 presents the major causes of postharvest losses in cashew marketing among wholesalers and retailers in Yanlemo Market, Kano State. The results indicate variations in the perceived causes of losses across different marketing stages. Poor market patronage was identified as a major factor contributing to postharvest losses. Among wholesalers, 58.3% strongly agreed and 41.7% agreed that poor patronage resulted in significant unsold stock and quality deterioration. Similarly, 46.1% of retailers strongly agreed, and 26.3% agreed, highlighting that slow sales turnover leads to prolonged storage and subsequent spoilage of cashew nuts. This finding underscores the effect of fluctuating market demand and limited consumer access on product wastage.

Inadequate transportation facilities also emerged as a key contributor to postharvest losses. About 41.7% of wholesalers and 64.5% of retailers strongly agreed that insufficient and unreliable transport systems hindered the timely movement of cashew from farms to markets. Long delays during transit, poor vehicle conditions, and high transportation costs likely contribute to the physical damage and reduced quality of nuts before reaching consumers. For bad road conditions, fewer respondents attributed losses directly to

this factor. Only 25% of wholesalers and 14.5% of retailers agreed that poor road networks were a major problem.

Table 1: Causes of post-harvest losses during marketing

Variable Causes of post-harvest lost	CASHEW Wholesale		Retail	
Poor market patronage	Frequency	%	Frequency	%
Strongly Agreed	7	58.3	35	46.1
Agreed	5	41.7	20	26.3
Neutral	-	-	8	10.5
Strongly Disagreed	-	-	4	5.3
Disagreed	-	-	9	11.8
Total	12	100.0	76	100.0
Inadequate Tp Facility				
Strongly Agreed	5	41.7	49	64.5
Agreed	2	16.7	15	19.7
Neutral	1	8.3	2	2.6
Strongly Disagreed	3	25.0	9	11.8
Disagreed	1	8.3	1	1.3
Total	12	100.0	76	100.0
Bad road				
Agreed	3	25.0	11	14.5
Neutral	1	8.3	6	7.9
Strongly Disagreed	2	16.7	12	15.8
Disagreed	-		4	5.3
Total	12	100.0	76	100.0
Inadequate storage				
Strongly Agreed	7	58.3	33	43.4
Strongly Agreed	6	50.0	43	56.6
Agreed	2	16.7	28	36.8
Neutral	1	8.3	10	13.2
Strongly Disagreed	1	8.3	3	3.9
Disagreed	1	8.3	2	2.6
Total	12	100.0	76	100.0

Source: Field Survey, 2025

Nonetheless, bad roads may exacerbate transportation challenges by increasing travel time and exposure to harsh conditions, which indirectly lead to quality deterioration. Inadequate storage facilities were another prominent cause of loss. A significant proportion of wholesalers (58.3%) and retailers (43.4%) strongly agreed that poor storage conditions led to product spoilage, pest infestation, and loss of weight and quality. Limited access to proper storage infrastructure such as moisture-proof and pest-resistant

facilities likely amplifies these challenges, particularly in peak harvest seasons when supply exceeds market demand.

It was revealed from the result in Table 2, that poor market patronage for cashew at the wholesale level shows 58.3% of respondents strongly agreed and 41.7% agreed that low patronage contributes to losses, indicating a significant concern. In retail, these figures decrease, with 46.1% strongly agreeing at wholesale and 41.7% strongly agreed that inadequate transport is one of the major factors causing post-harvest losses. This could result from low demand, or spoilage of produce before it can be sold. The main causes were mechanical and physical damages and over-ripening (Morales-Sillero *et al,* 2023).

Road conditions also significantly affect post-harvest losses for cashew 50% of wholesalers strongly agreed and 56.6% strongly agreed at retail that bad roads are a challenge. The Inadequate storage facilities also represent yet another critical challenge. Wholesalers of cashew showed 43.4% strong agreement and 36.8% agreed regarding the impact of inadequate storage on losses, signaling a significant concern. Retailers were similarly aligned, with 43.4% strongly agreeing and 36.8% agreeing. The result clearly indicates cashew traders encounter substantial challenges related to market patronage, transportation logistics, road infrastructure, and storage conditions (Paredes, 2020).

Table 2: Summaries of Cost and Return of 1box (17kg) of Cashew qt Retail

Variable cost	Min	Max	Mean(₦)	Std
Uploading	100	100	100.00	.000
Transportation	1000	1300	1138.16	121.070
Unloading	100	100	100.00	.000
Sorting	50	100	99.34	5.735
Packaging	50	50	50.00	.000
Storage	100	200	104.61	20.294
Union dues	500	500	500.00	.000
Tax	100	200	148.68	50.315
Total Operating cost			2240.79	
Purchasing price	9000	15000	11934.21	1975.419
Total marketing cost			14175	
Selling price	22000	24000	23157.89	712.790
Marketing margin			11223.76	
Net marketing margin			8982.89	
Total value of PHLs			2700	

Source: field survey 2025

Table 2 examining the operational costs incurred during the distribution of, cashew, the mean values of; uploading, sorting, packaging, storage, transportation and unloading, rent, union dues, were ₦100, ₦100,

₦50, ₦104, ₦1138., ₦100, ₦500, ₦149 respectively this suggest a more heterogeneous cost structure. While the total operating costs total for cashew stand at ₦2240. This implies good fortune for the traders, as in the study of Adenso-Díaz *et al.* (2017) who emphasized the importance of maintaining lower operational costs for enhancing profit margins in perishable goods. The purchasing prices of cashew were ₦11,934, with cashew marketing margin of ₦11,223.76. The net marketing margins is ₦8,982.76. The value of post-harvest lost is ₦2,700.

Table 3: Summaries of Cost and Return of 100 box of Cashew at Wholesale

Variable cost	Min	Max	Mean	Std
Uploading	4000	6000	4833.33	717.741
Transportation	200000	250000	222500.00	24167.973
Unloading	3000	4000	3333.33	492.366
Sorting	400	500	466.67	49.237
Packaging	300	1000	583.33	210.3
Storage	1000	2000	1166.67	389.249
Union dues	400	500	458.33	51.493
Tax	400	500	475.00	45.227
Total Operating cost			236013.66	
Purchasing price	3000000	3200000	3091666.67	79296.146
Total marketing cost			3325478.33	
Selling price	3900000	4200000	4050000.00	144599.761
Marketing margin			958333.33	
Net marketing margin			724521.67	
Total value of PHLs			150000	

Source: field survey 2025

The result in table 3 shows that cashew marketers had mean values of; uploading, sorting, packaging, storage, transportation and unloading, tax and union dues were ₦4833.33, ₦466.67, ₦583.33, ₦1166.67, ₦ 222500.00, ₦3333.33, ₦458.33 and₦475.00 respectively this suggests a more heterogeneous cost structure. While the total operating costs for Cashew stand at ₦236013.66. The purchasing prices cashew is priced at ₦3,091,666.67, the marketing margins further underscore this reality, as cashew marketing margin of ₦958333.33. The net marketing margins is ₦724521.67. The value of post-harvest lost is ₦150000. The result of this study implies that with reduction of PHLs will increase the income of the traders and also provide fruits with less cost to consumers.

Conclusion and Recommendations

The results demonstrate that post-harvest losses are substantial and occur at various stages of the supply chain. The study also identifies the need for effective strategies to reduce post-harvest losses, including

improving transportation facilities, using jute bags for packaging, spreading under shade for storage, training on new management skills, and adopting new management techniques.

Based on the findings of this study, the following recommendations are made for policy actions to reduce the post-harvest losses, thereby increasing the standard of living of the cashew and cashew marketing supply chain actors in Kano State; it is recommended that there should be an improvement in transportation facilities to reduce post-harvest losses during transportation.

References

Akinyemi, A. F., & Tijani, K. A. (2020). Analysis of post-harvest losses in cashew nut processing and marketing in Nigeria. *International Journal of Agricultural Research and Development*, 13(1), 45–54.

Aliyu, L., Mohammed, I., & Yahaya, A. (2018). Trends in cashew production in northern Nigeria. *Journal of Horticultural Science*, 2(3), 56–61.

FAO. (2020). *Reducing post-harvest losses in developing countries: A sustainable approach*. Food and Agriculture Organization of the United Nations.

Igbeka, J. C., & Olumeko, T. O. (2014). Post-harvest technology and storage of agricultural products. *Nigerian Journal of Agriculture*, 9(2), 70–78.

Olayemi, O. J., Adebayo, S. A., & Ojo, M. A. (2019). Economic effects of post-harvest losses on farmers' income. *Agricultural Economics Review*, 11(2), 17–26.

Omodara, M. A., Akangbe, J. A., & Lawal, B. M. (2021). Assessment of post-harvest losses and preservation methods among cashew farmers in Nigeria. *Journal of Post-Harvest Technology*, 9(3), 101–109.

Osei-Agyemang, L. (2022). Reducing post-harvest losses through improved storage facilities: A case study of tree crops. *Journal of Agribusiness and Rural Development*, 10(1), 45

Value Chain Mapping and Distribution of Value Added Among Actors in the Cultured Fish Sector in Southwestern Nigeria

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Abstract

This study examined value chain mapping and the distribution of value added among actors in the catfish value chain in Southwestern Nigeria. With the aid of a questionnaire and interview schedule, a multi-stage sampling procedure was employed to select 360 participants, comprising 52 input suppliers, 85 producers, 83 processors, 86 marketers, and 54 consumers. Data were analyzed using descriptive statistics, value chain mapping, net income analysis, value-added share models, and Analysis of Variance (ANOVA). Findings revealed that the primary actors in the chain were input suppliers, producers, processors, marketers, and consumers, while research, financial services, and legislative activities were acquired through support actors. The total value added within the system was estimated at ₦10,180/kg, with respective value-added shares of 6.8%, 19.4%, 34.5%, and 39.2% for input suppliers, producers, processors, and marketers. These differences were statistically significant at the 5% level. This outcome indicates that marketers derive the greatest benefits from their activities, while producers receive relatively limited returns despite their central role in sustaining the chain. The study recommends interventions that will enhance producers' capacity to capture greater value through improved bargaining power, cooperative organization, contract farming schemes, and direct market linkages. Such measures would not only improve producers' livelihoods but also foster inclusiveness, resilience, and sustainability in Nigeria's aquaculture sector.

Keywords: Actors, Catfish, Value Chain Map, Value-Added Share

Introduction

The fisheries sub-sector in Nigeria plays a vital role in the national economy, providing opportunities for improved nutrition, income generation, and job creation, thereby contributing to wealth creation and food security at both household and national levels. Fish remains the most affordable and widely consumed source of animal protein in Nigeria, accounting for over 40% of total protein intake (Agoro et. al., 2025). The expansion of aquaculture in Nigeria has become increasingly important in addressing the persistent gap between the nation's rising demand for fish and the limited domestic supply. According to the Food and Agriculture Organization (FAO, 2020), fish farming is now widely recognized as a viable strategy for reducing Nigeria's heavy dependence on imports and for meeting national consumption

requirements. Nevertheless, small-scale fish farmers continue to face significant challenges, particularly in value addition, processing, and market access, which constrain their ability to enhance incomes and improve livelihoods. Weak market linkages, inadequate cold-chain and processing infrastructure, and limited access to credit and market information further exacerbate these constraints.

Despite substantial investments by the Nigerian government through initiatives such as the Agricultural Transformation Agenda, the National Aquaculture Strategy, and more recent interventions like the FISH4ACP catfish Programme, alongside support from NGOs and development partners, the experiences of small-scale actors in Nigeria's fish value chains remain poorly researched, and their contribution to economic growth is undermined. This has made their performance continue to weaken with persistent structural challenges such as low productivity, high input costs, inadequate value addition, weak market linkages, and limited access to credit and technology. Although both the government and donors recognize these challenges, there is still a scarcity of systematic academic research that explores the lived experiences of small-scale farmers in Nigeria's fish value chains. This neglect is deeply troubling, as Nigeria continues to rely heavily on fish imports despite its immense aquaculture potential and repeated cycles of policy reform. Confronting this research gap is not only timely but also imperative, with far-reaching consequences for national food security, poverty alleviation, and the long-term sustainability of the fisheries sector (Agoro et al., 2025). This study, therefore, investigates the structure of Nigeria's small-scale cultured fisheries value chains to identify their composition, opportunities for growth, and the critical challenges that must be addressed to enhance their contribution to national fish supply, food security, and rural livelihoods.

Methodology

A multi-stage sampling technique, comprising purposive, proportionate, and random sampling procedures, was adopted for the selection of respondents in the study. Primary data were collected using a questionnaire, alongside personal observations and key informant interviews, from the selected sample respondents in each state's purposively selected local government areas. From Lagos State: (Epe and Ibeju-Lekki LGAs), Ogun State: (Ijebu-Ode and Ota LGAs), and Oyo State (Ikere and Moba). The sampling frame of 360 catfish actors consists of the list of catfish input suppliers, producers, processors (smoked catfish), marketers, and consumers was sought through the catfish actors' associations in the selected areas. The last stage involved a proportionate sampling of actors across the selected villages based on the number of actors collected from the various associations' sample frames. Random sampling techniques were employed to select actors across all the villages with the aid of Krejcie and Morgan's sample collection methods for easy determination of sample sizes. The total sample size of 360 actors comprises

52 input suppliers, 85 catfish producers, 83 catfish processors, 86 catfish marketers, and 54 consumers (obtained by using stratification) for the study. Data were analyzed using the value chain map and value share model. ANOVA was used to test the significant differences in the actors' value share. According to Coulibaly et. al (2010), the value added is the amount of value that each actor in the chain adds. It is the difference between the price the actor sells the value-added product and the price he pays for the raw material purchased from the preceding actor, i.e $VA_i = P_1 - P_{-1}$ .....(1)

Where: VAi = value added by each chain actor

i = input suppliers, producers, processors, and marketers; P_1 = price actor offered to sell valued product to the subsequent actor; P_{-1} = price of product purchased from the preceding actor.

Therefore,

$VA_{input\ supplier} = P_{fingerling} - P_{breedingstock}$ .....(2); $VA_{producer} = P_{harvested\ fish} - P_{fingerling}$ .....(3)

$VA_{processor} = P_{proccesed\ fish} - P_{harvested\ fish}$ .....(4); $VA_{marketer} = P_{marketer\ fish} - P_{processed\ fish}$ .....(5)

Hence, value share is the percentage share of an actor in the total value added in the value chain system.

i.e $\%VA_i = \frac{VA_i}{\sum_{i=1}^{n} VA_i}$.....(6)

All products that passed through the value chain were measured in kg to allow for easy comparison of the activity of the chain actors. The Analysis of Variance (ANOVA) was performed using Scheffe test to compare the Analysis of Variance (ANOVA) multiple means. The ANOVA model is specified following Igwenagu et. al., 2020. $F = \frac{MSSB}{MSSW} = \frac{SSB/(k-1)}{SSW/(n-k)}$..... (7)

TSS (total sum of squares) = SSW + SSB

$SSW = \sum_{i=1}^{nj}[\sum_{j=1}^{n}(\overline{X_{ij}} - \overline{X_j})^2]$ ..... (8); $SSB = \sum_{i=1}^{n}(\overline{X_j} - \bar{X})^2$..... .... (9)—Where,

$\overline{Xij}$ = ith value added of the chain actor j; $\overline{Xj}$ = Mean value-added responding actors j

$\bar{X}$ = Grand mean value added of all actors; SSB = Sum of squared deviations between the scores

SSW = Sum of squared deviations within the scores; n_j = Sample size of chain actors j

n = Sample size of chain actors in all categories; K = Number of actors' categories

k-1 = Degrees of freedom for SSB (numerator); n-k = Degrees of freedom for SSW (denominator)

F = Value by which the statistical significance of the mean differences was judged

Results and Discussion

Socio-economic Characteristics of the Respondents

As shown in Table 1, respondents were predominantly middle-aged. The modal ages among input suppliers, producers, and consumers clustered around the late-40s (46–49 years), whereas processors and marketers skewed younger (30–37 years). This age profile mirrors recent evidence that upstream primary

production is aging, while downstream agri-food activities (processing, trade, and marketing) increasingly attract younger entrants (FAO, 2025). In contrast, the relatively smaller household sizes among processors and marketers may indicate reduced household labor contributions, potentially necessitating hired labor, but also less consumption pressure on household income, allowing for greater flexibility in reinvesting profits. The average years of experience varied across the cultured fish value chain in 2025. Table 1 shows that the average years of formal education among actors in the cultured fish value chain ranged from 11.9 to 12.4 years, which corresponds to the completion of senior secondary school. This level of educational attainment suggests that most actors possess a moderate literacy foundation, sufficient for understanding basic production, marketing, and record-keeping practices. The sex distribution among cultured fish value-chain actors, coded as 1 = male and 0 = female, reveals a marked male predominance.

Table 1: Profile of socioeconomic characteristics of cultured fish Actors

	Input Suppliers (52)	Producer (85)	Processors (83)	Marketers (86)	Consumers (54)
Age	46.5	46.6	36.5	30.2	48.9
Hhsz	6.5	6.4	5.0	4.0	6.1
Expce	23.2	22.2	19.5	17.7	26.8
Educ	11.9	11.9	12.0	12.4	12.0
Sex	11.9	11.9	12.0	12.4	12.0
	M=88.5; F= 11.5	M=76.5; F=23.5	M=33.7; F=66.3	M=55.8; F=44.2	M=64.7; F=35.3

Source: Field survey, 2025

Value Chain Mapping and Functional Roles of Catfish Actors

The Value chain map of catfish in the southwest zone was illustrated in Figure 1. This shows the map of the overall catfish value chain, the segments, their inter dependencies, and linkages in the study area.

Input Suppliers: the input dealers within the catfish aquaculture value chain primarily provide brood stock, formulated feeds, and production equipment to farmers (Fig. 1). Beyond supplying materials, they often played advisory roles, particularly in guiding farmers on appropriate stocking densities and feed management practices, including feed quality and quantity.

Producers**:** Catfish farmers constitute the most critical actors in the aquaculture value chain, comprising both hatchery operators and out-grower farmers (Fig. 1). A significant proportion (52%) employed artificial ponds or fibre cages for catfish production. In comparison, the majority operated on a small-scale basis (68%). Production cycles typically spanned six to eight months, during which catfish, under optimal management, attained an average market weight of 0.8 to 1 kilogram, consistent with earlier findings (Olalekan et al., 2023).

Processors: Most processors (66.3%) were female, with an average age of 36.5 years, underscoring the gendered dimension of value addition in aquaculture. Smoked catfish dominated production, engaging 73% of processors due to strong consumer preference and high market demand. Processing was largely small-scale, with 87% handling between 10 kg and 20 kg of fish daily. The sector is characterized by low entry barriers, as minimal start-up capital is required, which accounts for its rapid expansion and growing participation (Olalekan et al., 2023).

Marketers: Marketing formed a vital link in the catfish value chain, ensuring the distribution of both processed and fresh fish to consumers (Fig. 1). About 55.8% of marketers were male, showing a slight gender imbalance in favor of men. The marketing portfolio consisted mainly of whole smoked catfish (75%), followed by fresh fish (38%) and fillets (10%), reflecting strong consumer preference for smoked products. Distribution channels included roadside stands (48%), open markets (58%), supermarkets (20%), restaurants and hotels (14%), and office supplies (26%). Most marketers (78%) operated at the retail level, illustrating the low capital requirement and accessibility of small-scale trading within the aquaculture sector.

Consumers: The study revealed that catfish consumption was concentrated in urban centers, where 70% of consumers resided (Fig. 1). Household income data indicated that about 66.7% of consumers earned between ₦30,000 and ₦80,000 per month, while 33.3% earned between ₦120,000 and ₦450,000. Households with an average monthly income of ₦50,833 and a mean size of seven members fell into the lower-income, larger-family group, where affordability of fish was a major concern. In contrast, households earning ₦239,722 with an average of five members were relatively better off. At an average retail price of ₦8,500 per kilogram depending on fish size, delivery, and vendor promotions catfish was not easily affordable to all households. Consumption data showed that 25% of households purchased 1 kg of catfish weekly, while only 15.3% maintained this rate consistently.

Support Actors: Collaborations between farmers and support actors in the catfish value chain can be broadly categorized into four domains: financial services, technical advisory support, information and knowledge dissemination, and legislative frameworks (Fig.1). Fish farmers through microfinance institutions have access to production credit, soft loans for feed and fingerlings purchase, micro-savings schemes, and insurance packages to mitigate risks from climate shocks or disease outbreaks.

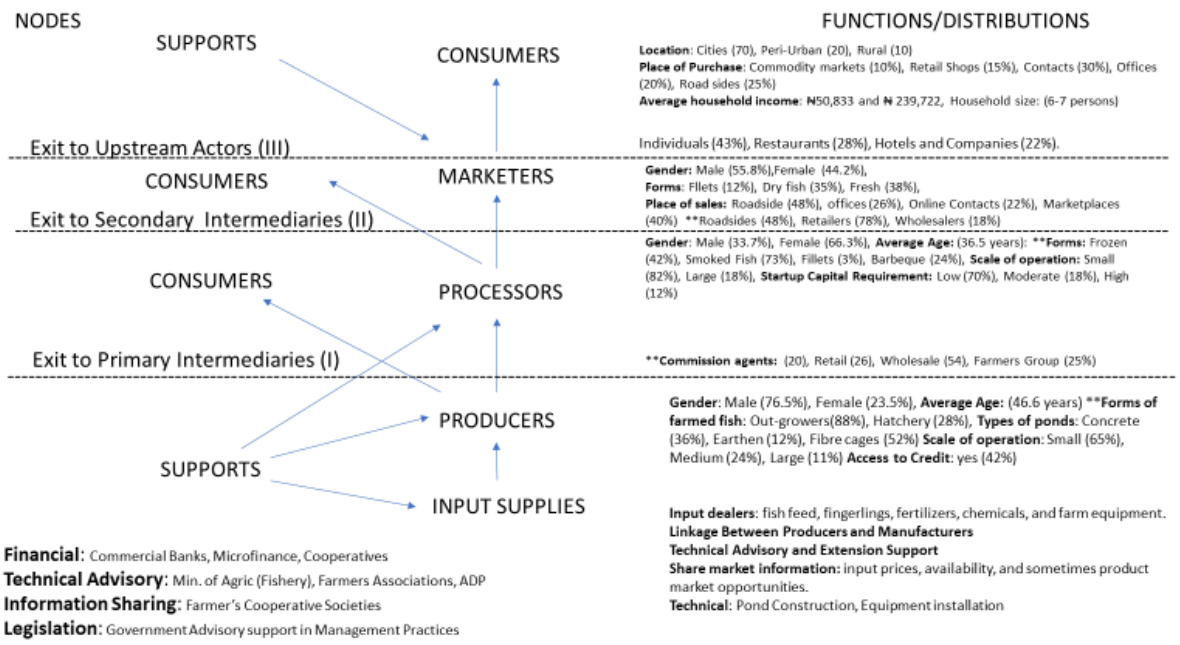


Figure 1: Catfish value chain Map in Southwestern Nigeria.

Source: Field survey, 2025; **Multiple Responses.

Estimate of the actors' value-added share in the catfish value chain

The value-added results for actors within the catfish value chain input suppliers, producers, processors, and marketers are summarized in Table 2.

For input suppliers, value addition was measured as the price differential between the cost of brooded fingerlings and their selling price to producers. Fingerlings were purchased at ₦2,112.50/kg and sold at ₦2,812.50/kg, giving a margin of ₦700/kg. With a total supply of 34,850.42 kg, the aggregate value added amounted to ₦24,395,294.00. Among producers, value addition was determined by the margin between input and output prices. Producers bought fingerlings from suppliers at ₦2,900/kg and sold mature catfish to processors at ₦4,800/kg, resulting in ₦1,900/kg value added. Based on 1,681.23 kg sold, total value added reached ₦3,194,337.00. For processors, value addition came from the difference between the selling price of smoked catfish (₦8,400/kg) and the purchase price of fresh catfish (₦4,850/kg), yielding ₦3,550/kg. With total sales of 1,261.85 kg, processors generated ₦4,479,567.50 in value added.

Marketers realized value addition through the price gap between sales to consumers (₦12,580/kg) and purchases from processors (₦8,550/kg), a difference of ₦4,030/kg. From 702.81 kg of sales, this amounted to ₦2,832,324.30 in total value added. Overall, the catfish value chain recorded a cumulative value addition of ₦10,180/kg, distributed as follows: 6.8% for input suppliers, 19.4% for producers, 34.5% for processors, and 39.2% for marketers. This distribution indicates a progressive increase in value-added

shares along the chain, with marketers contributing the highest due to their role in creating place, time, and possession utilities. The hypothesis test assessing differences in value added among actors was analyzed using ANOVA (Tables 3 and 4). The F-calculated value (318.32) exceeded the F-tabulated value (2.60) at the 5% significance level (df = 3, 302). Hence, the null hypothesis of no significant difference was rejected, confirming that value addition differed significantly among the catfish value chain actors in Southwest Nigeria.

Table 2: Estimate of the actors' value-added share in catfish value chain

	Input Supplier			**Producer**	
Items	**Qty**	**Value (₦)**	**Items**	**Qty**	**Value (₦)**
Fingerling brooded *(Pfp)	36,210.68 (2112.5)	76,495,061.50	Fingerling stocked*(Pfs)	1,843.00 (2,900)	5,344,700
Fingerling sold*(Pfs)	34,850.42 (2812.5)	98,016,806.24	Catfish sold (Pcs)	1681.23 (4,800)	8,069,904
Value added (Vai)= Pfs-Pfp		700.00	Value added (Vap)= Pcs-Pfs		1,900.00
Total value added	34,850.42 (700)	24,395,294.00	Total value added	1681.23 (1,900)	3,194,337
Value added share (Vs)=Va/CVA		6.8%	Value added share (Vsp)=Va/CVA		19.4%
	Processor			**Marketer**	
Items	**Qty**	**Value (₦)**	**Items**	**Qty**	**Value (₦)**
Harvested Fish (Phf)	1,625 (4,850)	7,881,250.00	*Catfish bought (Pfs)	823.74 (8,550)	7,042,977.0
Qty Marketed (Ppf)	1261.85 (8,400)	10,599,540.00	Catfish sold (Pcs)	702.81 (12,580)	8,841,349.8
Value Added (Vapr)=Phf-Ppf		3,550.00	Value added (Vam)=Pfs–Pcs		4,030.00
Total value added	1,261.85 (3,550)	4,479,567.50	Total value added	702.81 (4,030)	2,832,324.30
Value added share (Vspr)=Va/CVA		34.5%	Value added share (Vsm)=Va/CVA		39.2%

Source: Field Survey, (2025) *Catfish bought represents average quantity of wholesale and retail Marketers; CVA= ∑ (Vai + Vap + Vapr + Vam) = ₦10, 180/Kg; 1 fingerling = 6.25g;

All measurements are done on the unit of price per kg; Figures in parentheses are the unit prices of the respective items.

To identify the sources of the observed differences, a multiple comparison post-hoc test (Scheffé test) was employed. Before this, Bartlett's test of equality of error variances yielded a chi-square value of 390.4404 ($p < 0.000$), confirming that the assumption of homogeneity of variance was not violated, as shown in Table 3. Table 4 presents the results of the post-hoc test, labeled multiple comparisons, which highlight the statistical significance of differences between groups. The mean difference analysis revealed

significant variations among the catfish value chain actors. Specifically, the mean difference between marketers and processors was ₦479.651 ($p < 0.000$), indicating that marketers' net value addition was significantly higher than that of processors at the 5% significance level. Similarly, producers' net value addition was found to be significantly higher than that of input suppliers, with a mean difference of ₦1,650 ($p < 0.000$), also significant at the 5% level. The post-hoc analysis revealed marked disparities in value addition across the catfish value chain.

Table 3: Analysis of variance

Source	SS	Df	MS	F	Prob > F
Between groups	473865203	3	157955068	318.32	0.0000
Within groups	149857919	302	496218.273		
Total	623723121	305	2044993.84		

Source: Computed from ANOVA; Bartlett's equal-variances test: $chi^2(3) = 390.4404$ Prob>$chi^2 = 0.000$

Table 4: Comparison of Value Added by Actors (Scheffe)

Actors	Input suppliers	Producers	Processors
Producers	1199.98 (0.000) **		
Processors	2849.98 (0.000) **	1650 (0.000) **	
Marketers	3329.63 (0.000) **	2129.65 (0.000) **	479.651(0.000) **

Source: Computed from ANOVA; Figures in parentheses are the P-values; **= Significant @5%
Breusch–Pagan/Cook–Weisberg test for heteroskedasticity $chi^2(1) = 0.000$; Prob > $chi^2 = 0.9989$

Marketers' net value added was significantly higher than that of input suppliers by ₦3,329.63 ($p < 0.000$) and higher than producers by ₦2,129.65 ($p < 0.000$). Likewise, producers' net value added exceeded that of input suppliers by ₦1,199.98 ($p < 0.000$), while processors recorded significantly higher net value added than input suppliers by ₦2,849.98 ($p < 0.000$). These findings confirm that net value added differs significantly across all nodes of the chain, with marketers capturing the highest share. This unequal distribution underscores the need for interventions to reduce structural imbalances in value appropriation. Strengthening the bargaining power of producers and processors through cooperatives, contract farming arrangements, and improved access to reliable markets could help enhance their share of value added. (Adeyeye et. al., 2022). Furthermore, policies that promote innovation in processing, access to finance, and investment in infrastructure, particularly cold chain systems and efficient logistics, would improve efficiency and competitiveness across the chain (FAO, 2020). A more equitable distribution of value among actors not only enhances rural livelihoods but also stimulates aquaculture investment and supports inclusive growth in Nigeria's fisheries sector (Trieekens, 2011).

Conclusion and Recommendations

Within the catfish value chain, each actor contributes to the cumulative value addition as fingerlings progress from the input supplies to the consumption nodes. Significant disparities exist in value added among the actors in Southwest Nigeria. The distribution of value-added shares reveals a progressive increase along the chain, with input suppliers contributing the least and marketers capturing the highest share. Notably, producers who constitute the most fundamental primary actors recorded disproportionately low value-added shares, while marketers appropriated the largest portion. This imbalance calls for interventions that enhance producers' capacity to capture greater value, such as through improved bargaining power, cooperative organization, contract farming schemes, and direct market linkages, as well as encouraging them to be secondary actors, such as getting involved in processing their produce to maximize profits in their venture. Furthermore, policies that strengthen processing infrastructure, facilitate access to finance, and promote consumer-oriented product development could help align value addition with consumer preferences, while ensuring more equitable benefit distribution across the chain. Such measures would not only improve producers' livelihoods but also foster inclusiveness, resilience, food security, and sustainability in Nigeria's aquaculture sector.

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References

Adam, R. I., Njogu, L. G., Okoth Ouko, K., Rajaratnam, S., Adeleke, L., Ogunya, L. and Fregene, B. (2025). Unveiling gender dynamics and disparities in the aquaculture value chain: Evidence from Ogun and Delta States, Nigeria. *Aquaculture International*, 33(5), 343. https://doi.org/10.1007/s10499-025-01966-1.

Adeyeye, S. A. O., Oyedele, D. J., & Olusola, O. O. (2022). Traditional fish smoking methods and their public health implications: Evidence from Nigeria. *Food Control, 134,* 108726. https://doi.org/10.1016/j.foodcont.2021.108726.

Agoro Taiwo O; Ofunama Preye; Oguntade S.T(2025). Artisanal Fishing in Coastal Communities: Socioeconomic Profiling and Fishing Practices in Southern Ijaw Local Government Area (SILGA),

Bayelsa State. *International Journal of Innovative Science and Research Technology* 10(5): 4503-4508. https://doi.org/10.38124/ijisrt/25may812

Food and Agriculture Organization of the United Nations (FAO). (2022). *The State of World Fisheries and Aquaculture 2022: Towards Blue Transformation.* Rome: FAO. https://doi.org/10.4060/cc0461en.

Igwenagu M. O., Ohajianya D. O., Nwaiwu I. U. O., Gbolagun, A. O and Ehirim, N. C 2020.

Journal of Agriculture and Food Sciences Volume 18, Number 2, October 2020, pp . 120-134

Kassali, R., Komolafe, S. E., & Omonona, B. T. (2022). Market structure and pricing dynamics of aquaculture inputs in Nigeria. *Sustainability, 14*(19), 12034. https://doi.org/10.3390/su141912034

Olukunle, O. (2023). *Profitability Analysis of Small-Scale Fishery Enterprise in Nigeria. Journal of Agricultural Science*, *Canadian Center of Science and Education.* Federal Ministry of Agriculture and Rural Development. (2020) Report

Impact of Peeling on the Micronutrient and Proximate Composition of Potato (*Solanum tuberosum*) for Biofortification

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Abstract

The major global health challenge of micronutrient deficiencies, particularly zinc (Zn) and iron (Fe), can be addressed by the biofortification of staple crops such as potatoes. This study assessed the concentrations of Zn and Fe in three commercial potato varieties (Nicola, Marabel, Jelly) while evaluating the impact of peeling on zinc (Zn) and iron (Fe) retention to identify optimal varieties for future biofortification breeding programs. Tubers were processed and analyzed using Atomic Absorption Spectrophotometry (AAS) for mineral content. The AOAC standard methods was used to determine the proximate composition. Statistical analysis was performed using ANOVA. Significant ($p < 0.05$) differences were observed among varieties and processing method. The unpeeled Nicola variety exhibited the highest Zn (21.63 ppm) and Fe (47.30 ppm) concentrations, exceeding those of the other varieties. Unpeeled potatoes consistently retained greater amounts of Zn, Fe, crude protein, crude fiber, and ash. The Jelly variety demonstrated the highest crude protein and ash content. These findings indicate that the Nicola variety is a strong candidate for Zn and Fe biofortification.

Keywords: Potato, Biofortification, Micronutrients, Proximate Composition, Variety.

Introduction

The potato (*Solanum tuberosum L.*) is the third most important food crop globally after rice and wheat, providing nutrition to over one billion individuals (Singh et al., 2020). Its significance is attributed to high yield potential and substantial nutritional value, including essential carbohydrates, high-quality protein, dietary fiber, vitamins, and minerals (Kharumnuid et al., 2021). However, the potential of potatoes to address micronutrient deficiencies remains underutilized.

Micronutrients particularly zinc (Zn) and iron (Fe), are essential for human health due to their roles in immune function, cognitive development, and metabolic processes (Maggini et al., 2018). Deficiencies in these minerals, often referred to as "hidden hunger," affect over two billion people worldwide and have severe consequences, especially in developing countries (Kumar et al., 2023). Biofortification, which increases the nutrient content of food crops through traditional breeding or agronomic practices, has emerged as a sustainable and cost-effective strategy to address these deficiencies (Azeem et al., 2025).

Potatoes are suitable candidates for biofortification because of their widespread consumption(Singh et al., 2022).

There is a significant knowledge gap about the genetic differences in Zn and Fe levels among commonly grown potato varieties(Seid et al., 2023). Moreover, a common practice like peeling can greatly change the nutritional profile, since the skin is known to hold many minerals and fiber (Camire et al., 2009). Measuring these losses is key for breeding programs and public health nutrition. Choosing varieties with naturally high mineral density in the flesh or those where the skin adds significantly can speed up biofortification efforts.

This study aimed to assess Zn and Fe concentrations in three commercially available potato varieties (Nicola, Marabel, and Jelly), evaluate the impact of peeling on the retention of these micronutrients and key proximate components, and identify optimal varieties for future biofortification breeding programs.

Materials and Methods

Plant Materials and Experimental Design

Tubers of three potato varieties (Nicola, Marabel, and Jelly) were harvested at maturity under uniform agronomic conditions. These varieties were selected based on commercial availability and local farmer preference. Each variety was subjected to two treatments: unpeeled (skin intact) and peeled (skin removed with a stainless-steel knife).

Sample Preparation

The tubers were washed thoroughly to eliminate soil and debris. For each treatment, the potatoes were cut into uniform pieces and dried in a forced-air oven at 60°C until they reached a constant weight. The dried samples were ground into a fine, uniform powder using a laboratory mill and stored in airtight containers prior to analysis.

Micronutrient Analysis

The content of zinc and iron was measured using an Atomic Absorption Spectrophotometer (AAS). This was done following a wet digestion method. Briefly, 0.5 g of the powdered sample was digested with a 5:1 (v/v) mix of concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$). The digest was heated until it formed a clear solution, cooled, and diluted to a known volume with deionized water. Standard solutions for Zn and Fe were used to calibrate the machine, and concentrations in the samples were recorded in parts per million (ppm).

Proximate Composition Analysis

The proximate composition was analyzed using standard methods from the Association of Official Analytical Chemists (AOAC 1990).

Moisture Content: Determined by drying a 5 g fresh sample in the oven at 105°C until it reached constant weight.

Crude Protein: Measured using the Kjeldahl method (N × 6.25), which estimates protein content by determining total nitrogen in the sample.

Crude Fiber: Evaluated with sequential digestion with acid and alkali.

Lipids: Measured through Soxhlet extraction, a technique that uses repeated washing of the sample with a solvent (petroleum ether) to extract fats.

Ash Content: Measured by burning a 2 g sample in a furnace at 550°C for 6 hours.

Nitrogen-Free Extract (NFE): Calculated as follows: NFE (%) = 100% - (Moisture % + Crude Protein % + Crude Fiber % + Lipids % + Ash %).

Statistical Analysis

All analyses were done in triplicate. Data were shown as mean ± standard deviation. Analysis of variance (ANOVA) was performed, with means separated using the Duncan Multiple Range Test ($p < 0.05$).

Results and Discussion

The Zn and Fe levels of the three potato varieties, both peeled and unpeeled, are shown in Table 1.

Table 1: Micronutrient composition (ppm, dry weight basis) of potato varieties

Variety	Treatment	Zinc	Iron
Nicola	Unpeeled	$21.63^{a} \pm 0.00$	$47.30^{a} \pm 5.97$
	Peeled	$19.36^{b} \pm 1.17$	$42.77^{b} \pm 3.91$
Marabel	Unpeeled	$17.67^{c} \pm 0.13$	$29.10^{d} \pm 2.58$
	Peeled	$13.08^{d} \pm 0.48$	$19.87^{e} \pm 2.39$
Jelly	Unpeeled	$17.83^{c} \pm 0.10$	$35.13^{c} \pm 2.54$
	Peeled	$13.89^{d} \pm 0.01$	$27.48^{d} \pm 0.30$

Means in the same column with different superscripts are significantly different ($p < 0.05$).

The results showed highly significant ($p < 0.05$) differences among varieties and between preparation methods. The unpeeled Nicola variety consistently had the highest amounts of both Zn (21.63 ppm) and Fe (47.30 ppm), which were significantly greater than all other variety-treatment combinations. Even

when peeled, Nicola still had higher Zn and Fe levels than the unpeeled forms of the other varieties, suggesting a genetically superior ability for mineral accumulation in its tuber flesh.

For all varieties, unpeeled potatoes had significantly higher Zn and Fe content compared to their peeled versions. This aligns with previous studies that identify the skin and outer layers of the potato as important for mineral deposition (Vaitkevičienė, 2019). The loss of these nutrients during peeling represents an important nutritional trade-off in food preparation.

The proximate composition of the potato varieties is shown in Table 2.

Table 2: Proximate composition (%) of potato varieties fresh weight basis

Variety	Moisture	Crude Protein	Crude Fiber	Lipids	Ash	NFE
Nicola (Peeled)	82.17± 0.11	5.26± 0.03	0.09± 0.01	0.04± 0.44	0.85± 0.00	11.59± 0.12
Nicola (Unpeeled)	79.37± 0.02	4.82± 0.11	0.18± 0.09	0.03± 0.15	0.90± 0.00	14.7± 0.10
Jelly (Peeled)	80.32± 0.04	5.69± 0.05	0.11± 1.00	0.03± 0.13	0.95± 1.00	12.9± 0.04
Jelly (Unpeeled)	81.14± 0.13	6.57± 0.11	0.15± 0.17	0.07± 0.16	1.00± 0.11	11.08± 0.02
Marabel (Peeled)	79.44± 0.01	4.82± 0.14	0.10± 0.11	0.05± 0.10	0.75± 0.03	14.84± 0.01
Marabel (Unpeeled)	81.62± 0.05	4.38± 0.00	0.14± 0.00	0.06± 0.04	1.00± 0.01	12.81± 0.20

Values are mean ± standard deviation.

The moisture content was high and typical for fresh potatoes, ranging from 79.37% to 82.17%.

The crude protein content varied significantly, with the Jelly variety showing the highest values (up to 6.57% in unpeeled tubers). Similar to the micronutrients, the unpeeled potatoes consistently had higher crude protein, crude fiber, and ash content compared to the peeled samples. The higher ash content in unpeeled tubers is directly related to the increased mineral (Zn, Fe) content. The Jelly variety's high ash and protein content make it a valuable genetic resource for improving these traits.

The crude fiber was significantly higher in unpeeled samples, confirming that the skin is a major source of dietary fiber. The lipid content was low across all samples, as expected for potatoes (Alvani et al., 2011). The Nitrogen-Free Extract (NFE), which mainly represents digestible carbohydrates, was higher in peeled potatoes, reflecting the concentration of the starchy flesh after removing fiber and other components.

Conclusion

This study showed significant varietal differences in the micronutrient and proximate composition of potatoes. The Nicola variety was identified as a candidate for zinc and iron biofortification due to its high mineral content. The Jelly variety also showed potential for its high protein and ash content. The significant decrease in Zn, Fe, protein, fiber, and ash after peeling showed the vital role of potato skin in its overall nutritional value. Consumption of potatoes with the skins on, could be a simple and effective method to boost dietary mineral and fiber intake. Nicola variety should be prioritized as a parent in breeding programs aiming to create new, high-mineral potato types.

References

Alvani, K., Qi, X., Tester, R. F., & Snape, C. E. (2011). Physico-chemical properties of potato starches. *Food chemistry*, *125*(3), 958-965.

AOAC. (1990). Official methods of analysis. In: Aoac Washington, DC.

Azeem, A., Khan, S., Zia Ul Haq, M., Shafiq, S., Aslam, M. T., Munir, S., & Sikandar Zaman, M. (2025). Biofortification strategies for enhancing crop nutritional value: a review of methods, challenges, and future directions. *Discover Plants*, *2*(1), 185.

Camire, M. E., Kubow, S., & Donnelly, D. J. (2009). Potatoes and human health. *Critical reviews in* food *science and nutrition*, *49*(10), 823-840.

Kharumnuid, P., Pandey, N., Devarani, L., Chauhan, J. K., Singh, R., Das, B., & Marbaniang, E. K. (2021). Potato production for nutritional security and doubling farmers' income. *Journal of Pharmacognosy and Phytochemistry*, *10*(1), 193-197.

Kumar, A., Kerketta, A., Dewali, S., Sharma, N., Kumari Panda, A., & Singh Bisht, S. (2023). Tackling hidden hunger: understanding micronutrient deficiency and effective mitigation strategies. In *Emerging solutions in sustainable food and nutrition security* (pp. 305-319). Springer.

Maggini, S., Pierre, A., & Calder, P. C. (2018). Immune function and micronutrient requirements change over the life course. *Nutrients*, *10*(10), 1531.

Livelihood Diversification for Poverty Reduction among Oil Palm Farmers in Okitipupa Local Government Area of Ondo State, Nigeria.

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Abstract

Livelihood diversification in Nigeria is the practice of engaging in a variety of income generating activities to improve household welfare and income, enhance food security and reduce risk. This study investigated livelihood diversification for poverty reduction among oil palm farmers in Okitipupa Local Government Area of Ondo State in Nigeria. The analysis of data elicited from 120 respondents, using both inferential and descriptive statistics, focused on socio-demographic characteristics, income and occupational patterns, engagement in livelihood activities, perceptions of diversification and the constraints faced by respondents. The socio-demographic results revealed that respondents had a mean age of 45 years, majority being Males (56.0%) and married (64.2%). Education levels were relatively high, as 43.4% attained secondary or tertiary education. The mean monthly income was ₦221,291.67. Livelihood engagement showed that oil palm farming was the dominant occupation (36.7%), though trading (19.2%), civil service (22.5%), and artisan work (10.8%) also contributed to household income. Perception analysis revealed that respondents strongly agreed that diversification improves household income ($\bar{x}$ = 4.87) and enhances capacity to meet basic needs ($\bar{x}$ = 4.57). Constraints to diversification was dominated by limited access to credit ($\bar{x}$ = 3.83). The regression analysis revealed a high explanatory power (R^2 = 0.89) that indicated variation in livelihood diversification as explained by the socio-economic characteristics. Oil Palm farmers are encouraged to practice mixed cropping system, be trained and empowered to engage in entrepreneurship activities to enhance economic resilience and reduce risk associated with having single source of income.

Keywords: Livelihood, Poverty, Diversification, Entrepreneurship activities

Introduction

Livelihood diversification refers to the expansion of income sources beyond primary agricultural production, enabling rural households to mitigate financial risks and stabilize their living standards. In Ondo State, where oil palm cultivation plays a crucial role in household economies, farmers often engage in multiple income-generating activities to navigate economic shocks and achieve sustainable growth (Olutumise et. al., 2019). The necessity of livelihood diversification for rural farmers cannot be

overemphasized. Economic instability, policy shifts, and climate unpredictability pose considerable risks to smallholder farmers, who frequently encounter barriers such as limited access to land, financial resources, and extension services (Mkpado and Omowole 2020). Understanding these dynamics will provide valuable insights for policymakers, extension officers, and development practitioners seeking to empower rural farmers through sustainable agricultural and non-agricultural livelihood strategies. This study investigated livelihood diversification for poverty reduction among oil palm farmers in Okitipupa Local Government Area of Ondo State. The analysis focused on socio-demographic characteristics, income and occupational patterns, engagement in livelihood activities, perceptions of diversification, and the constraints faced by respondents.

Materials and Methods

The study was carried out in Okitipupa Local Government Area of Ondo State, Nigeria. The climate in the area is humid and tropical. These climatic conditions made it highly suitable for agriculture, particularly the cultivation of oil palm along with other crops such as cassava, maize, yams, cocoa, plantain, pineapple, and vegetables. A multi- stage sampling procedure was used to select 120 samples from the population oil palm producers in Okitipupa Local Government area of Ondo State. Primary data were collected using a structured questionnaire and face to face interview to capture relevant information based on the research objectives. Descriptive and inferential statistics were employed in the data analysis. Descriptive statistics, including frequency counts, percentages, means, likert scale and standard deviations, were used to summarize the socioeconomic characteristics of respondents, the types of livelihood activities they engage in, and the challenges they face. The effect of livelihood diversification on the poverty levels of rural farmers was analyzed using the likert scale to measure the strength and direction of the relationship between livelihood diversification and perceived poverty reduction. The effects of Livelihood diversification on poverty level were analyzed using a logistic regression Model.

Results and Discussions

The socio-demographic results revealed that respondents had a mean age of 45 years. The predominance of middle-aged respondents aligns with the findings of Chinalurum et. al. (2024) who reported a mean age of 51 years among farming households in Nigeria. Males (56.0%) slightly outnumbered females (44.0%), reflecting the gendered nature of access to farm resources. Women, although fewer in number, play significant roles in processing, marketing, and small-scale trading of palm products, which are essential components of livelihood diversification and household welfare. This agrees with the findings of Daudu et. al. (2025), who found that men are more engaged in resource-intensive farming practices, while

women's involvement is often shaped by household responsibilities and socio-cultural barriers. Most respondents were married (64.2%), indicating the role of family structures in livelihood support. This corroborates the report of Olutumise et. al. (2021) that most rural households in Ondo State were married and that marital status influenced diversification and food security. Education levels were relatively high, as 43.4% attained secondary or tertiary education, implying good literacy and decision-making capacity. The mean monthly income was ₦221,291.67, placing most farmers in the lower to middle-income category. Studies such as Agwu and Oteh (2014) highlight that income inequalities remain widespread among farmers in Nigeria, with many households struggling to convert agricultural earnings into sustained improvements in welfare and food security.

Livelihood engagement showed that oil palm farming was the dominant occupation (36.7%), though trading (19.2%), civil service (22.5%), and artisan work (10.8%) also contributed to household income. In addition, respondents diversified into other crop farming (28.3%), livestock rearing (28.3%), trading (20.8%), and fishing (6.7%).

Perception analysis on the effects of livelihood diversification on livelihood reduction revealed that respondents strongly agreed that diversification improves household income ($\bar{x}$ = 4.87), enhances capacity to meet basic needs ($\bar{x}$ = 4.57), reduces vulnerability to shocks ($\bar{x}$ = 4.53), and supports financial security ($\bar{x}$ = 4.38). Engagement in sustainable practices was also high, particularly investment in multiple income activities ($\bar{x}$ = 3.81), cooperative membership ($\bar{x}$ = 3.74), skill acquisition ($\bar{x}$ = 3.67), and saving earnings ($\bar{x}$ = 3.67). However, adoption of new technologies was relatively low ($\bar{x}$ = 3.17). These findings are consistent with evidence from Nigeria and other developing contexts. Gwandi et al. (2024) found that diversified farming households in Adamawa State were less vulnerable to income shocks and better able to cope with financial stress, thereby lowering their poverty incidence.

Constraints to diversification were dominated by limited access to credit ($\bar{x}$ = 3.83), high cost of inputs ($\bar{x}$ = 3.54), lack of government support ($\bar{x}$ = 3.40), and poor infrastructure ($\bar{x}$ = 3.40). Other moderate constraints included land access ($\bar{x}$ = 3.29), post-harvest losses ($\bar{x}$ = 3.19), and price volatility ($\bar{x}$ = 2.99). Water scarcity ($\bar{x}$ = 2.19) and limited access to information ($\bar{x}$ = 2.16) were considered less serious. Balana (2022) emphasized that credit inaccessibility remains a key barrier to improving agricultural productivity and livelihood diversification, as many farmers cannot meet collateral requirements of formal institutions The regression analysis in table 4 revealed a model with high explanatory power (R^2 = 0.89). The choice of livelihood diversification was explained by 89% variation of the socio-economic variables. The results indicated that among the various socio-economic characteristics examined, only the age of the farmer

was statistically significant determinant to livelihood diversification. This finding suggests that older farmers are more likely to engage in multiple income-generating activities compared to their younger counterparts, while other socio-economic variables did not exhibit a significant influence on the choice of diversification strategies in the study area. This supports the findings of Adepoju and Obayelu (2013), who noted that age and experience often increase the likelihood of engaging in multiple livelihood activities as a way of reducing risks.

Conclusions and Recommendations

Livelihood diversification is a critical pathway for poverty reduction among oil palm farmers in Okitipupa LGA. Respondents were largely middle-aged, educated, and moderately income-secured, which positioned them well to engage in multiple livelihood activities. Diversification significantly contributed to improved income, resilience to shocks, ability to meet basic needs, and enhanced long-term financial stability.

However, several systemic barriers hinder the full benefits of diversification. Limited access to credit, high input costs, weak infrastructure, and inadequate government support remains persistent constraints. The regression results also highlight that age plays an important role in determining informal credit access, potentially excluding younger farmers who lack established networks. Without targeted interventions, households will continue to depend heavily on informal mechanisms and remain vulnerable to poverty, income shocks, and market risks. The study recommends that farmer cooperative formations should be encouraged to harness production resources jointly at minimum costs. Financial institutions and government should expand access to credit for oil palm farmers by strengthening rural cooperatives, providing low-interest agricultural loans, and promoting group-based lending with support from NGOs to reduce barriers.

References

Adepoju, A., and Obayelu, A. (2013). The role of rural women in economic diversification in Nigeria. Journal of Rural Studies, 8(1), 45-57.

Agwu, N. M., and Oteh, O. U. (2014). Analysis of income inequalities and food security among farmers in Abia State, South Eastern Nigeria. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 14(3), 9–16.

Balana B.B., Aghadi C. N. and Ogunniyi A. I. (2022). Improving livelihoods through postharvest loss management: evidence from Nigeria. The international society for plant pathology, Vol.14 (1), pages 249-265.

Chinalurum, C. A., Ojoko, E. A., and Junaidu, M. (2024). Determinants of livelihood diversification among farming households in Nigeria. Journal of Agripreneurship and Sustainable Development, 7(2).

Daudu, A. K., Aderinoye-Abdulwahab, S. A., Karakara, A. A., Kareem, O. W., and Orkoh, E. (2025). Gender differentials and distributional effect of climate-smart agriculture practices on farm production and welfare in Nigeria. Discover Food, 5, 236.

Gwandi, O., Adewuyi, A. K., and Dia, Y. Z. (2024). Evaluation of livelihood diversification strategies as a panacea to poverty reduction among rural farming households in Adamawa State, Nigeria. International Journal of Agriculture and Environmental Research, 10(2), 230–250.

Gwandi, O., and Adewuyi, K. A. (2022). An empirical assessment of farmers' livelihood security in the North-Eastern region of Nigeria. Journal of Agricultural Extension and Rural Development, 14(6), 251–260.

Mkpado Mathias and Omowole Adebisi. (2020). Structural constraints on women's participation in agribusiness. African Journal of Economic Policy, 18(3), 201-217.

Olutumise, A. I., Abiodun, T. C., and Ekundayo, B. P. (2021). Diversification of livelihood and food security nexus among rural households in Ondo State, Nigeria. Journal of Rural Economics and Development, 23(1), 23–32.

Omoghie, E. S., Adeleye, A. S., Ojedokun, C. A., Bamigboye, A. O., and Simpson, V. B. (2022). Evaluating off-farm income-generating activities among agroforestry farmers in Sakponba Forest Reserve Area, Edo State, Nigeria. Nigerian Agricultural Journal, 53(2), 105–112.

Comparative Evaluation of Mineral Composition of Fresh and Dried Mango Chips using Cabinet and Solar Dryers

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Abstract
Mango (*Mangifera indica L.*) is a highly nutritious tropical and climacteric fruit, characterized by rapid ripening and high perishability under ambient conditions, resulting in significant postharvest losses. This study evaluated the mineral composition of fresh mango and mango chips dried using two different technologies: the NSPRI multi-crop cabinet dryer (MCD) and the NSPRI parabolic shaped solar dryer (PSSD). Fresh ripe mango fruits were procured from Oje Market, Ibadan, Nigeria (7.3879° N, 3.8964° E), peeled, sliced into 5 mm chips, and dried to safe moisture levels. Mineral analyses of potassium (K), magnesium (Mg), calcium (Ca), iron (Fe), and copper (Cu) were carried out following AOAC (2019) methods using atomic absorption spectrophotometry. Results indicated that drying significantly increased mineral concentrations compared to fresh mango. Potassium, calcium, and most other mineral contents increased after drying, with higher concentrations generally observed in the Parabolic Shaped Solar Dryer (PSSD) than in the Multi-Crop Dryer (MCD). Potassium, magnesium, and calcium increased from 1140, 870, and 620 mg/kg in fresh mango to 1270, 1380, and 1100 mg/kg in the MCD samples, and 1220, 860 and 1070 mg/kg in the MCD and PSSD samples, respectively. Similarly, iron and copper rose from 12.65 mg/kg and 1.60 mg/kg (fresh) to 15.79 mg/kg and 3.70 mg/kg (MCD) and 22.45 mg/kg and 5.32 mg/kg (PSSD). Although, magnesium content was slightly higher in the MCD, the PSSD generally demonstrated better mineral retention, indicating its potential for preserving nutrient quality during solar drying. Findings from this study showed that dehydration of mango fruit using PSSD is more efficient than MCD in terms of mineral concentrations, thus, should be recommended for users. Its adoption can reduce postharvest losses, enhance food quality, and promote value addition,

Keywords: Mango, Mineral retention, Convective drying, Solar drying, Postharvest technology, Food quality.

Introduction

Mango (*Mangifera indica* L.) is highly valued tropical fruit, widely cultivated and consumed in Nigeria and many parts of sub-Saharan Africa, due to its desirable taste and rich nutritional profile. Mango pulp contains essential minerals such as potassium, magnesium, calcium, iron, and copper, along with vitamins and bioactive compounds that contribute to human health (Maldonado-Celis et al., 2019). However, one of the major challenges in mango production is its short postharvest shelf life under ambient tropical conditions, which leads to substantial losses in quality and quantity (Ampah et al., 2022).

Drying is a key postharvest preservation strategy employed to reduce moisture content, thereby inhibiting microbial growth and enzyme activity to prolong storage life. In addition to extending shelf life, drying often concentrates nutrients on a dry matter basis, making dried fruit more nutrient-dense (Yahia, et al., 2023). The choice of drying technique is critical, because different methods (cabinet drying, solar drying) can affect the retention, degradation, or redistribution of mineral nutrients and other quality attributes (Maldonado-Celis et al., 2019). For instance, improved solar drying methods have been shown to better preserve mineral composition compared to open-sun drying (Mohammed et al., 2020), while hot-air drying may lead to losses or alterations in mineral and micronutrient contents (Petikirige et al., 2022).

Despite the importance of minerals for nutritional quality, relatively few studies have explicitly compared multiple drying methods in mango to assess how they influence mineral retention or concentration. This knowledge gap is especially relevant for smallholder agro-processors in tropical regions, where low-cost drying technologies must balance efficiency and quality. Therefore, this study aims to evaluate and compare the mineral composition of fresh mango and mango dried using a cabinet dryer (NSPRI multi-crop dryer) and a solar dryer (NSPRI parabolic shaped solar dryer), focusing on key minerals: K, Mg, Ca, Fe, and Cu.

Materials and Methods

Sample Collection and Preparation

Fresh, ripe mango (*Mangifera indica* L.) fruits of uniform maturity and free from defects were procured from Oje Market, Ibadan, Oyo State, Nigeria (7.3879° N, 3.8964° E). The fruits were washed with clean water, peeled, and manually sliced into uniform chips of approximately 5 mm thickness to ensure consistency during drying. A portion of the fresh sample (unprocessed) was retained as control.

Drying Methods

Multi-Crop Cabinet Dryer (MCD)

Drying was carried out using the NSPRI multi-crop cabinet dryer (Figure 1a) in NSPRI Ibadan Zonal Office, with dimension of 1300 × 1200 × 600 mm (height × length × width). Mango slices were uniformly arranged on perforated trays and dried at a controlled temperature ranging from 50 – 60 ℃ until a final moisture content of approximately 8% was attained. The drying process was monitored for 11 h in the MCD.

Parabolic Shaped Solar Dryer (PSSD)

Drying was also conducted using the NSPRI-designed Parabolic Shaped Solar Dryer (Figure 1b), which has dimensions of 6.5 × 4.2 × 2.4 m^3 and an effective drying area of 17.85 m^2. Mango slices were spread evenly on mesh trays and dried under natural solar radiation until constant weight was achieved. The drying duration ranged from 2-3 days depending on prevailing weather conditions. For this study, solar drying was conducted for a total duration of 12 hours under prevailing weather conditions. The dried products are shown in Figure 2a and 2b.



Figure 1a: NSPRI parabolic shaped solar dryer



b: NSPRI multi-crop dryer



Figure 2a



Figure 2b

Dried mango chips from both drying systems and fresh samples were milled into fine powder, packaged in airtight containers, and analyzed for mineral composition following AOAC (2010) standard procedures. Potassium (K), magnesium (Mg), and calcium (Ca) were determined by flame photometry, while iron (Fe) and copper (Cu) were quantified using Atomic Absorption Spectrophotometer (AAS; Buck Scientific 210 VGP, USA) after wet digestion with nitric-perchloric acid.

Potassium (K): Fresh mango contained 1140 ± 20 mg/kg, while dried samples recorded higher levels of 1270 ± 10 mg/kg (MCD) and 1380 ± 10 mg/kg (PSSD). Potassium is the most abundant mineral in mango and plays an essential role in nerve function and fluid balance. The observed increase is consistent with earlier findings that drying enhances mineral concentration on a dry weight basis (Maldonado-Celis et al., 2019).

Magnesium (Mg): The magnesium content increased from 870 ± 20 mg/kg in fresh mango to 1100 ± 20 mg/kg and 1220 ± 10 mg/kg in MCD and PSSD, respectively. Magnesium is vital for enzymatic reactions and energy metabolism. Similar increases in Mg after drying have been reported in dried fruits such as banana and pawpaw (Mohammed et al., 2020).

Calcium (Ca): Calcium concentration rose from 620 ± 20 mg/kg (fresh) to 860 ± 10 mg/kg (MCD) and 0.107 ± 0.001% (PSSD). Calcium fortification through drying is beneficial since mango chips can contribute significantly to dietary calcium intake, particularly in communities with limited dairy consumption (Maldonado-Celis et al., 2019).

Iron (Fe): A marked increase was observed in Fe levels, from 12.65 ± 0.15 mg/kg in fresh mango to 15.79 ± 0.10 mg/kg in MCD and 22.45 ± 0.15 mg/kg in PSSD. The higher concentration in PSSD may be attributed to slower drying under solar conditions, which could allow for better retention of micronutrients. These results align with studies by Petikirige et al. (2022), who reported that solar drying often better preserves iron in fruits compared to hot-air drying.

Copper (Cu): Copper increased from 1.60 ± 0.10 mg/kg in fresh mango to 3.70 ± 0.10 mg/kg (MCD) and 5.32 ± 0.10 mg/kg (PSSD). Copper is an essential trace element required for iron metabolism and antioxidant defense. Its concentration was highest in solar-dried samples, confirming the nutritional advantage of PSSD over MCD.

Overall, the results demonstrate that both drying methods increased the concentration of minerals in mango chips compared to fresh samples. However, the PSSD consistently yielded higher values across all minerals measured. This could be attributed to the larger effective drying area and the gentle drying conditions, which reduce thermal degradation of nutrients (Maldonado-Celis, 2019). From a nutritional

and technological perspective, solar drying not only enhances nutrient retention but also offers a cost-effective and environmentally sustainable preservation method suitable for smallholder agro-processors in Nigeria.

Table 1. Mineral Contents of Mango Fruit dried using NSPRI-PSSD and NSPRI-Multi-crop Dryers

Treatment	K (mg/kg)	Mg (mg/kg)	Ca (mg/kg)	Fe (mg/kg)	Cu (mg/kg)
Fresh	1140 ± 20^{c}	870 ± 20^{c}	620 ± 20^{c}	12.65 ± 0.15^{c}	1.60 ± 0.10^{c}
MCD	1270 ± 10^{b}	1100 ± 20^{b}	860 ± 10^{b}	15.79 ± 0.20^{b}	3.70 ± 0.10^{b}
PSSD	1380 ± 10^{a}	1220 ± 10^{a}	1070 ± 10^{a}	22.45 ± 0.15^{a}	5.32 ± 0.10^{a}

Means with different superscripts in the same column are significantly different ($p < 0.05$)

Conclusion

This study evaluated the mineral composition of fresh mango and mango chips dried using a multi-crop cabinet dryer (MCD) and a parabolic shaped solar dryer (PSSD). Results revealed that drying significantly increased the concentrations of potassium, magnesium, calcium, iron, and copper compared to fresh mango. Between the two drying systems, the parabolic shaped solar dryer consistently produced higher mineral values than the cabinet dryer, demonstrating its effectiveness in nutrient retention.

The findings underscore the potential of solar drying as a sustainable, low-cost, and energy-efficient technology for fruit preservation in Nigeria and other tropical regions. Beyond extending shelf life, solar-dried mango chips can contribute substantially to dietary mineral intake, offering nutritional and economic benefits.

Recommendations

1. Smallholder farmers and processors, particularly women who are actively engaged in fruit processing, should be encouraged to adopt solar drying technology for value addition and reduction of postharvest losses.
2. Policy makers and development agencies should support the dissemination and scaling up of parabolic solar dryers, considering their affordability, environmental sustainability, and nutritional benefits.
3. Further research should explore the combined effect of solar drying with pre-treatments (e.g., blanching, osmotic dehydration) on mineral and vitamin retention, as well as sensory quality of mango chips.
4. Capacity-building programs through NiWARD and related platforms should emphasize gender-inclusive technology transfer, ensuring women researchers and processors play a central role in advancing solar drying innovations.

References

Ampah, J., Dzisi, K. A., Addo, A., & Bart-Plange, A. (2022). Drying Kinetics and Chemical Properties of Mango. *International Journal of Food Science*, 11;2022:6243228. https://doi.org/10.1155/2022/6243228

AOAC (2019). Official Methods of Analysis of AOAC International, 21st Edition. AOAC International, Rockville, MD, USA. ISBN: 978-0-935584-90-2.

Maldonado-Celis, M. E., Yahia, E. M., Bedoya, R., Landázuri, P., Loango, N., Aguillón, J., Restrepo, B., & Guerrero Ospina, J. C. (2019). Chemical Composition of Mango (*Mangifera indica* L.) Fruit: Nutritional and Phytochemical Compounds. *Frontiers in plant science*, 10, 1073. https://doi.org/10.3389/fpls.2019.01073

Mohammed, S., Edna, M., & Siraj, K. (2020). The effect of traditional and improved solar drying methods on the sensory quality and nutritional composition of fruits: A case of mangoes and pineapples. *Heliyon*.17;6(6): e04163. https://doi.org/10.1016/j.heliyon.2020.e04163

Petikirige, J., Karim, A., & Millar, G. (2022). Effect of drying techniques on quality and sensory properties of tropical fruits. *International Journal of Food Science and Technology*, 2022, 57, 6963–6979. https://doi.org/10.1111/ijfs.16043

Yahia, E. M., de-Jesús, J. Ornelas-Paz, J. K. Brecht, García-Solís, P., & Maria Elena Maldonado Celis. (2023). The contribution of mango fruit (Mangifera indica L.) to human nutrition and health, *Arabian Journal of Chemistry*, Volume 16, Issue 7, 2023, https://doi.org/10.1016/j.arabjc.2023.104860

Effect of Mango Peel Inclusion on the Nutritional and Sensory Qualities of Biscuits

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Abstract

The study evaluated the effect of mango peel inclusion on the nutritional and sensory qualities of produced biscuits. Mango peels were washed, milled into paste, incorporated into wheat flour for biscuit production at varying levels: 0, 5, 10, 15 and 20 % and labelled WMP1, WMP2, WMP3, WMP4 and WMP5 respectively. The proximate composition, phenolic content and sensory properties of the biscuit samples were determined using standard methods. Crude protein, crude fibre and ash contents ranged from 9.47-10.25 %, 0.12 - 1.16 % and 0.96 - 2.06 % respectively. Phenolic composition ranged from 24.55- 40.87 mg/100g. Overall acceptability scores ranged from 6.3-7.3. WMP4 with 15 % mango peel inclusion had the highest taste score (7.8). Acceptable enriched fibre biscuit could be produced by incorporating mango peel to wheat flour up to 20 % level.

Key words: Biscuits, Food waste, Mango peel, Nutritional and sensory qualities

Introduction

Biscuits are popular snacks primarily made of flour, fat, sugar and water, in addition to milk and salt, with other ingredients for taste, nutritional quality or shelf-life extension (Pratap-Singh et al., 2022). Biscuit is one of the most important and widely consumed cereal-based staple foods worldwide (Agu et al., 2023). Their popularity stems from their affordability, variety and ability to supply instant energy (Ogo et al., 2021). Different types of biscuits include sweet, semi-sweet, cracker, cookies and specialty biscuits. Conventional biscuits are low in protein and other macronutrients but contain high level of carbohydrates, with a relatively high glycemic index, which can predispose one to obesity, diabetes and biliary-tract cancer (Mudau et al., 2021).

In recent times, there's been a notable rise in the desire to improve the functional and nutritional composition of food products and this is predicated on the growing consumer demand for healthier dietary options. As a staple food, there is need to enrich biscuit with phytochemical and fibre dense raw material like fruits, vegetables, legumes, etc. in other to meet consumer expectations. The inclusion of fruit peels into biscuits has received little research attention. Peels from many fruits are usually discarded as waste after the pulp is consumed. Fruits peels have been reported to be rich in health promoting phytochemicals that possess excellent antioxidant activities.

Mango is one of the most consumed fruits worldwide, and it is still mostly appreciated in the fresh form (Okino-Delgado et al., 2020). The processing of mango into juice, drinks, jams and jellies generates a huge amount of peel, constituting about 15-20 % of the fruit, contributing to environmental pollution issue due to the challenge of its disposal. The byproducts of mango processing such as the peels and kernels have been shown to be rich in bioactive compounds including carotenoids, polyphenols, and dietary fibers (Owino and Ambuko, 2021). Mango peels have high potential to be reused as a source of functional ingredients and natural preservatives. They contain high amounts of nutrients and phytochemicals such as fiber, ascorbic acid, tocopherols, phenolic compounds and carotenoids (Marçal and Pintado, 2021; Kučuk et al., 2024). The valorization of mango peels in biscuit production would not only reduce the bio-waste discarded to the environment but will serve as a new source of income to mango processing industries and an affordable raw material in the biscuit industry. It was based on the foregoing that this study was carried out to investigate the effect of mango peel incorporation on some quality characteristics of produced biscuits.

Materials and Methods

Procurement of materials

Wheat flour, 'kerosene' mango, baking powder, sugar, margarine and powdered milk were purchased from Ogige Market in Nsukka Local Government Area, Enugu State.

Preparation of mango peel paste

The ripe 'kerosene'mango fruits were washed in water and the peels separated from the pulp. The mango peels were milled using a blender.

Production of Biscuits

Biscuits were produced according to the method described by Peter Ikechukwu et al (2017).

Mango peel pastes fortified flours at various levels of 0, 5, 10, 15, and 20%. Biscuit was prepared using the traditional creaming method. The fat and sugar were mixed in a bowl with a hand mixer until the mixture was fluffy. Eggs and milk were added. Baking powder, flour, water and salt were introduced into the mixture to form a soft dough. The dough was removed from the bowl and kneaded on a flat surface to obtain a uniform mix. The kneaded dough was rolled out into sheets using a rolling pin and cut into the desired shape using a cutter. The cut mass was transferred to a greased baking tray. Baking was carried out at 180°C for 30 min.

Determination of proximate composition of the biscuit samples

All proximate composition parameters were determined using the AOAC (2010) method. Moisture content was determined using the hot oven method to evaporate the moisture until constant weight was reached. Crude protein content was determined by the Kjeldahl method. The Soxhlet extraction method using petroleum ether as solvent was used to determine crude fat content. Ash content was determined by incineration in a muffle furnace at 550^{o}C. The crude fibre was determined by first hydrolyzing with of 1.25 % sulphuric acids (H_2SO_4) and then with 1.25 % of NaOH. The Carbohydrate content of the sample was determined by difference.

Determination of phenolic content

Total phenolic content was analyzed according to colorimetric method of Folin-Ciocalteu with some modifications as described by Chlopicka *et al.* (2012). The absorbance was read at 765 nm using a UV–Vis spectrophotometer. The standard calibration curve was plotted using gallic acid.

Sensory evaluation

Sensory evaluation was conducted using 20 semi trained panelists made up of students of Department of Food Science and Technology, University of Nigeria, Nsukka. Nine-point hedonic scales were used. 9-like extremely,8-like very much,7-like moderately,6-like slightly,5-neither like nor dislike, 4-dislike slightly, 3-dislike moderately,2-dislike very much,1-dislike extremely.

Experimental Design and Data Analysis

The experiment was laid out in a Completely Randomized Design. The means and standard deviations of the data were calculated from duplicate determination of each parameter. One Way Analysis of Variance (ANOVA) in SPSS version 25 was used to analyze the data. Mean separation was done using Duncan's Multiple Range Test. Significance was accepted at $p<0.05$.

Results and Discussion

The result of the proximate composition of the biscuit samples is shown in Table 1. The moisture, protein and ash contents of the mango peel (MP) incorporated samples were significantly lower than the control. The protein content ranged from 9.47 to 10.75% and ash contents ranged from and 0.96 to 2.06 % for WMP5 and WMP1 respectively. The lower moisture content of the experimental samples implies higher shelf life. The reduced protein content of the MP biscuits is due to lower protein and ash content of the MP and these have negative nutritional significance considering the high prevalence of protein energy and micronutrient deficiencies in the developing countries like Nigeria. The ash content of a food product

is related to its mineral composition. The crude fat ranged from 10.75 to 14.11 % and crude fibre ranged from 0.12 to 1.16 %. Both crude fat and fibre increased with MP addition. These shows that fat would contribute to its aroma and flavor. Mango peel is rich in both soluble and insoluble dietary fiber, which contributes to its fibrous texture (Aslam et al., 2014). Ajila et al. (2008) also recorded the similar pattern in fiber content of biscuits with increasing level of supplementation with mango peel. Fiber helps in digestion of carbohydrate, blood sugar levels regulation and cholesterol levels reduction (Chen et al., 2019).

The phenol content of the samples ranged from 24.55 to 40.87 mg/100g, where sample WMP1 had the least value while sample WMP5 had the highest phenolic content. There was significant difference ($p<0.05$) in the phenolic content of the biscuit samples. This increase in phenolic content with addition of mango peel could be as a result of high phenol compound of the mango peel. Bertagnoli et al. (2014) reported that incorporating large amounts of guava peel powder into cookies resulted in a significant increase in phenolic compounds. Phenolic compounds are excellent antioxidants possessing numerous health benefits. Hence, MP could be a good functional ingredient in biscuit production.

Table 1: Proximate composition (%) and Phenolic content of biscuit samples.

Sample	Moisture	Crude Protein	Crude Fat	Crude Fiber	Ash	Carbohydrate	Phenol(mg/100g)
WMP1	8.79^{a}±0.23	10.25^{a}±0.02	10.75^{e}±0.23	0.12^{e}±0.02	2.06^{a}±0.01	68.04^{d}±0.01	24.55^{e}±0.00
WMP2	6.62^{b}±0.11	10.20^{a}±0.02	12.82^{d}±0.05	0.23^{d}±0.02	1.84^{b}±0.06	68.32^{c}±0.13	28.27^{d}±0.13
WMP3	5.32^{c}±0.08	10.03^{b}±0.03	13.33^{c}±0.03	0.39^{c}±0.01	1.46^{c}±0.03	69.47^{a}±0.07	34.27^{c}±0.25
WMP4	5.11^{c}±0.07	9.88^{c}±0.08	13.66^{b}±0.01	0.53^{b}±0.03	1.20^{d}±0.01	69.63^{a}±0.11	32.51^{b}±0.08
WMP5	5.44^{c}±0.04	9.47^{d}±0.01	14.11^{a}±0.08	1.16^{a}±0.04	0.96^{e}±0.02	68.88^{b}±0.04	40.87^{a}±0.06

Sample means on the same column with different superscripts are significantly ($p<0.05$) different. WMP1: (100% wheat, control), WMP2: (95% wheat, 5% mango peel paste), WMP3:(90% wheat, 10% mango peel paste), WMP4: (85% wheat, 15% mango peel paste), WMP5 (80% wheat, 20% mango peel paste).

Sensory scores of biscuit samples

The sensory scores of the biscuit samples is presented in Table 2. The flavour scores of the samples ranged from 6.20 to 7.40, with sample WMP1 having the lowest score and sample WMP4 having the highest score for aroma. There was no significant ($p > 0.05$) difference among the samples. The scores for taste of the samples ranged from 6.30 to 7.30. There was however no significant ($p > 0.05$) difference among the samples. The sensory score for colour of the biscuit ranged from 4.50 to 8.30. The lowest score for colour was observed in sample WMP5 and the sample with the highest score was WMP1. The lower colour scores for the MP samples could be attributed to their darker appearance due to addition of MP.

The after-taste scores of the samples ranged from 6.10 to 7.60. The lowest score for after-taste was recorded for sample WMP5 and the highest score was from sample WMP4. Sensory score for mouth feels of the biscuit incorporated with mango peel ranged from 5.80 to 7.30. The overall acceptability of biscuit incorporated with mango peel ranged from 6.30 to 7.80. Sample WMP5 had the lowest score for overall acceptability while WMP4 had the highest acceptability. It is noteworthy that addition of MP resulted in either same or higher overall acceptability than the control sample. It was noted that MP imparted a fruity flavor to the biscuits which was appreciated by the panelists.

Table 2: Sensory scores of biscuit samples

Sample	Flavour	Taste	Colour	Aftertaste	Mouth Feel	Overall Acceptability
WMP1	$6.20^{a}\pm1.40$	$6.60^{a}\pm1.26$	$8.30^{a}\pm0.95$	$6.90^{b}\pm1.23$	$5.80^{c}\pm1.99$	$6.90^{ab}\pm0.99$
WMP2	$6.90^{a}\pm2.02$	$6.30^{a}\pm1.95$	$7.50^{ab}\pm0.85$	$6.80^{b}\pm1.69$	$6.50^{b}\pm1.08$	$7.20^{ab}\pm1.14$
WMP3	$7.00^{a}\pm1.12$	$6.40^{a}\pm0.97$	$6.10^{c}\pm1.37$	$6.90^{b}\pm1.10$	$5.80^{c}\pm1.62$	$6.80^{b}\pm0.92$
WMP4	$7.40^{a}\pm1.35$	$7.30^{a}\pm1.42$	$6.80^{bc}\pm0.79$	$7.60^{a}\pm1.35$	$7.30^{a}\pm1.49$	$7.80^{a}\pm1.03$
WMP5	$6.60^{a}\pm2.07$	$6.90^{a}\pm1.20$	$4.50^{d}\pm1.27$	$6.10^{c}\pm1.52$	$5.80^{c}\pm1.87$	$6.30^{b}\pm0.67$

Sample means on the same column with different superscripts are significantly ($p<0.05$) different. WMP1: (100% wheat, control), WMP2: (95% wheat,5% mango peel paste), WMP3:(90% wheat, 10% mango peel paste), WMP4: (85% wheat, 15% mango peel paste), WMP5 (80% wheat, 20% mango peel paste).

Conclusion

The addition of mango peel into biscuits resulted in samples with higher crude fibre and phenolic contents but lower protein and ash contents. MP incorporation did not significantly alter the flavor scores of the samples. Overall acceptability scores showed that the MP samples were well appreciated. The sample containing 15% MP had the highest overall acceptability scores. Biscuits with higher fibre and phenolic content could therefore be produced by incorporating MP into wheat flour for biscuits production even at 20% level.

References

Agu, H. O., Ihionu, J. C., & Mba, J. C. (2023). Sensory and physicochemical properties of biscuit produced from blends of whole wheat, soy okara, and tiger nut residue flours. *Heliyon, 9*(4):2247.

Ajila, C.M., K. Leelavathi & U.J.S.P. Rao., (2008). Improvement of dietary fiber content and antioxidant properties in soft dough biscuits with the incorporation of mango peel powder. *Journal of Cereal Science*, *48*: 319-326

AOAC (2010). Official methods of analysis, 25th ed. Washington, DC: Association of Official Analytical Chemist

Aslam, H. K. W., Raheem, M. I. U., Ramzan, R., Shakeel, A., Shoaib, M., & Sakandar, H. A., (2014). Utilization of mango waste material (peel, kernel) to enhance dietary fiber content and antioxidant properties of biscuit. *Journal of Global Innovations in Agricultural and Social Sciences, 2*(2), 76-81.

Bertagnolli, S.M.M., Silveira, M.L.R., Fogaca, A.O., Umann, L. & Penna, N.G., (2014). Bioactive compounds and acceptance of cookies made with guava peel flour. *Journal of Food Science and Technology, 34*(2): 303-308.

Chen Y, Zhao L, He T, Ou Z, & Hu.Z, (2019). Effects of mango peel powder on starch digestion and quality characteristics of bread. *International Journal of Biological Macromolecules 140*: 647- 652.

Chlopicka, J., Pasko, P., Gorinstein, S., Jedryas, A. & Zagrodzki, P. (2012). Total phenolic and total flavonoid content, antioxidant activity and sensory evaluation of pseudocereal breads. *LWT-Food Science and Technology, 46*(2): 548-555.

Kučuk, N., Primožič, M., Kotnik, P., Knez, Z. & Leitgeb, M.(2024). Mango Peels as an Industrial By-Product: A Sustainable Source of Compounds with Antioxidant, Enzymatic, and Antimicrobial Activity. *Foods, 13*(4):553.

Marçal, S. & Pintado M. (2021). Mango Peels as Food Ingredient/Additive: Nutritional Value, Processing, Safety and Applications. *Trends Food Sci. Technol., 114*:472–489.

Mudau M., Ramashia, S. E., Mashau M. E. & Silungwe H. (2021). Physicochemical characteristics of bread partially substituted with finger millet (*Eleusine corocana*) flour. Brazilian. *Journal of Food Technology, 24*:1-14.

Ogo, A. O., Ajekwe, D. J., Enenche, D. E. & Obochi, G. O. (2021). Quality evaluation of novel biscuits made from wheat supplemented with watermelon rinds and orange pomace flour blends. *Food and Nutrition Sciences, 12*:332-341.

Okino-Delgado, C. H., Prado, D. Z., Pereira, M. S., Camargo, D. A., Koike, M. A. & Fleuri, L. F. (2020). Enzymatic bioremediation: current status, challenges of obtaining process, and applications. *In C. M. Galanakis (Ed.), Valorization of fruit processing by-products* (pp. 167-181). Academic Press.

Owino, W. O. & Ambuko, J. L. (2021). Mango fruit processing: options for small-scale processors in developing countries. *Agriculture, 11*(11): 1105.

Peter-Ikechukwu, A., Okafor, D. C., Kabuo, N. O., Ibeabuchi, J. C Odimegwu, E. N., Alagbaoso, S. O., Njdeka, N. E. & Mbah, R. N. (2017). Production and Evaluation of Cookies from Whole Wheat and Date Palm Fruit Pulp as Sugar Substitute. *International Journal of Advancement in Engineering Technology, Management and Applied Science, 4*(4): 1-31.

Livelihood Activities and Household Food Security: A case Study of Idanre Local Government Area of Ondo State, Nigeria

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Abstract

This study examines the livelihood activities and household food security in Idanre Local Government Area of Ondo State, Nigeria. To achieve this, a multi-stage sampling technique was used to select 132 respondents, and data were collected through a structured questionnaire. Descriptive statistics in form of frequency and percentage tables were employed. The results revealed that the respondents were predominantly middle-aged with a mean age of 45.52years. Males constituted 62.1% of the sample, indicating a male-dominated livelihood structure, while 58.3% of respondents were married. Educational attainment was relatively high, with 37.9% having tertiary education. Household sizes were moderate (4–6 members), and the mean monthly income was ₦150,432.35. Livelihood activities were highly diversified, with farming (38.6%) and trading (28.0%) dominating; artisan (20.2%) and private salaried jobs (9.0%), while just 4.2% of the respondents were civil servants. Food security analysis revealed that 65.15% of households were food secure. The study concludes that livelihood diversification is critical to sustaining household food security, but challenges persist. And thus, recommend that government and community programs should promote family welfare planning and provide better education and vocational skills training to have various livelihood activities. The household heads should be encouraged to involve in more income diversification activities such as non-farm and off-farm activities in order to improve their livelihood and hence their food security status. These measures would reduce vulnerability, strengthen rural resilience, and contribute to achieving the Sustainable Development Goal of zero hunger.

Keywords: Agricultural Activities, Food Security, Household, Income, Livelihood

Introduction

Agriculture remains the cornerstone of rural livelihoods in Nigeria, providing food, income, and employment for millions of households. Despite rapid urbanization and growth in other sectors, rural areas continue to depend heavily on farming as their main source of survival. In the absence of sufficient non-farm opportunities, agriculture serves as the primary means of subsistence and a key driver of rural economies. However, smallholder farming in Nigeria is still characterized by low productivity, heavy

reliance on rainfall, and weak market linkages, which expose rural households to frequent shocks and food insecurity (Oyetunde-Usman and Olagunju, 2019). The sustainable livelihood approach emphasizes not just income, but also the ability of households to access and manage resources, cope with shocks, and maintain well-being without destroying the natural environment. In Nigeria, this framework has become particularly relevant as farming households increasingly adopt livelihood diversification strategies to survive economic and environmental pressures. Empirical studies confirm that diversification into off-farm and non-farm activities such as trading, food processing, and wage employment significantly improves resilience and household food access (Sule *et al.*, 2019; Ojoko *et al.*, 2025).

Food security, which is central to rural welfare, is multidimensional, encompassing availability, access, utilization, and stability. In practice, rural Nigerian households face challenges in almost all the dimensions. While crops may be available during harvest, poor storage facilities and post-harvest losses reduce food availability in the lean season. Access is constrained by high transport costs, poor roads, and volatile prices, while utilization is weakened by low dietary diversity and limited nutrition knowledge. Stability is threatened by climate shocks, economic downturns, and conflicts, particularly farmer–herder crises that disrupt production and displace households (Akinyemi and Olaniyan, 2019; Okeke *et al.*, 2020). Recent evidence shows that these factors reinforce cycles of poverty and vulnerability, making food insecurity a persistent problem in farming communities. In Ondo State, particularly in Idanre Local Government Area, farming households depend heavily on rain-fed agriculture and operate on small plots with limited access to credit, inputs, and modern technologies. This situation exposes them to persistent risks such as poor yields, postharvest losses, and seasonal hunger, all of which undermine household food security (Oyetunde-Usman and Olagunju, 2019; Ogunniyi *et al.*, 2021).

Livelihood diversification has been widely promoted as a strategy to improve resilience and reduce vulnerability. Households that combine farming with off-farm or non-farm activities are often better positioned to withstand income shocks and improve food access. However, access to diversification opportunities is unequal. Factors such as gender inequality, insecure land tenure, limited education, and lack of start-up capital prevent many farmers especially women and youth from benefiting from these opportunities. Studies confirm that women in rural areas remain constrained by cultural and institutional barriers that restrict access to resources, even though they play a crucial role in food provisioning (Olaniyan *et al.*, 2024; Belonwu *et al.*, 2024).

Several policy initiatives, such as agricultural financing schemes, have been introduced to strengthen smallholder farming in Nigeria. However, implementation challenges such as poor targeting, bureaucratic hurdles, limited awareness, weak infrastructure such as unreliable electricity, inadequate storage

facilities, and deteriorating rural roads further hinder productivity and market access, limiting farmers' ability to improve their livelihoods sustainably (Ogunniyi *et al.*, 2021). Given these realities, sustainable livelihoods and food security in rural Nigeria cannot be achieved by production-focused approaches alone. Instead, there is a need for holistic strategies that account for household-level decision-making, gendered access to resources, and resilience against shocks. Studies affirm that households with diversified and inclusive livelihood strategies are better positioned to achieve long-term stability and improved welfare (Ojoko *et al.*, 2025; Olaniyan *et al.*, 2024). It is on this premise that the study is anchored, by focusing on Idanre Local Government Area of Ondo State, Nigeria. The objectives were to examine the socio-economic characteristics of households, identify their livelihood activities, and determine their food security status in the study area. This study provides localized evidence that can guide development planning, assist policymakers, and support interventions aimed at reducing rural poverty and achieving sustainable food security.

Methodology

Sampling Techniques and Data Analysis

The study was carried out in Idanre Local Government Area of Ondo State, Nigeria. Idanre Local Government is located in Ondo State, Southwestern Nigeria, between latitudes 6°40'N and 7°6'N and longitudes 5°5'E and 5°12'E. A multi-stage sampling technique was employed in selecting respondents for the study. In the first stage, five rural communities within Idanre Local Government Area were purposively selected based on their high involvement in agricultural activities. These communities include Alade, Atosin, Odode, Gbalegi, and Owena. The second stage involved random selection of 30 respondents from each of the community selection, making a total of 150 respondents. Out of the 150-questionnaire administered, 132 were adequately filled and retrieved. Primary data was collected from the respondents through the use of a well-structured questionnaire that were based on the objectives of the study.

Data collected were analyzed using descriptive statistical methods. Descriptive statistics were used to describe the socio-economic characteristics and food security status of the respondents.

Results and Discussion

Socio-economic Characteristics of Respondents in the Study Area

Table 1: The Table showing Socio-economic Characteristics of Respondents in the Study Area

Characteristics		%		%		%		%		%	Mean
Age Distrib (yrs)	<30	6.8	31-45	45.5	46-60	39.4	61-75	8.3	>75	0.0	45.52
Gender	Male	62.1	Female	37.9							
Marital Status	Single	25.0	Married	58.3	Widow	9.8	Divorced	2.3	Separated	4.5	
Household size	1-3	42.4	4-6	50.0	>6	7.6					
Education Status	A	11.4	X	1.5	Y	31.1	D	18.2	K	37.9	
Monthly Income (₦)	<100,000	28.2	100,001 - 200,000	34.0	200,001- 300,000	18.4	300,001- 400,000	11.1	>400,000	8.3	₦150,432
Livelihood Activities	Farming	38.6	Trading	28.0	Artisan	20.2	Private salaried job	9.0	Civil Service	4.2	
Food Security	Food Secured	65.2	Food Insecured	34.8							

Source: Field survey, 2025
Key: A=No Formal Education, X=Adult Education, Y= Primary Education, D= Secondary Education, K=Tertiary Education

The results in Table 1 above revealed that most respondents were between 31–45 years (45.5%), only 6.8% were below 30 years, while 8.3% fell within the 61–75 years bracket. The mean age of the respondents was 45.52 years, indicating that the respondents are largely middle-aged and in their economically productive years. This finding supports that of Gani *et al*., (2019) and Oladapo et al., (2025) which showed that rural livelihood activities in Nigeria are dominated by middle-aged individuals who possess both the physical capacity and household responsibility to sustain productive work. The results show that majority of respondents were male (62.1%), while female respondents accounted for 37.9%. This indicates that livelihood activities in the study area are largely male-dominated. The predominance of men suggests that they are the primary actors in household income generation, reflecting cultural patterns where men engage more in farming and other productive activities. The results also show that majority of the respondents were married (58.3%), while 25.0% were single. This distribution indicates that livelihood activities are largely sustained by married individuals who often have greater household

responsibilities and dependents. These findings are consistent with Ezeh *et al*. (2023), who observed that married farmers dominate agricultural and livelihood activities in Nigeria due to family responsibilities, and are more likely to diversify income sources to meet household needs. The results in Table 1 above further reveal that a large proportion of respondents (88.6%) had some form of formal education, while only 11.4% had no formal education. This indicates that most households in the study area had access to education, which is an important factor for livelihood diversification and adoption of improved practices.

The results in Table 1 above also indicate that half of the respondents (50.0%) had medium-sized households (4–6 members), followed by 42.4% with small households (1–3 members). Only 7.6% reported large households (above 6 members). Smaller households may face labor shortages but enjoy lower dependency burdens, while larger households, though fewer, may provide more labor but also experience higher consumption pressures. This agrees with Afolabi (2022), who noted that household size in rural Nigeria commonly ranges between 4–6 persons, which influence welfare outcomes and resource allocation.

Furthermore, the results indicate that most respondents earned between ₦100,001- ₦200,000 (34.0%), and 28.25% earnings below ₦100,000, while a smaller proportion of 8.3% earned ₦400,000 and above. The mean monthly income of ₦150,432.35 shows that higher-income households exerts a strong influence on the overall average, despite the majority of respondents earning less. This pattern reflects the uneven distribution of income often observed in rural Nigeria. And in line with Mukaila et al., (2021) who reported that household income levels are significantly shaped by access to productive resources and non-farm opportunities, with large gaps between low and high earners. The results in Table 1 above show that 38.65% of the respondents are fully engage in agriculture, followed by trading (28.0%), and artisan (20.0%), while civil service was just 4.2%. This implies that farming is the main occupation and largest employer in Nigeria. Olajide and Ogundele (2022) reported that diversification of livelihood activities increases income levels and reduces vulnerability to food insecurity.

These studies suggest that households relying on diverse income sources besides farming, particularly trading and private employment like artisan. They are more likely to maintain stable access to food, highlighting the importance of livelihood diversification for achieving food security. Lastly, the results in Table 1 above show that 65.15% of the respondents were food secure while 34.84% of the household heads were food insecure. This indicates that a majority of the sampled households were able to meet their food needs, while a significant proportion still face challenges in accessing adequate food. This finding is consistent with the report of Adepoju and Adejare (2013), who noted that although some rural

households in Nigeria were food secure during the harvesting season, a considerable number remained vulnerable to food insecurity due to seasonal fluctuations and limited access to stable income.

Conclusion and Recommendation

Based on the findings of this study, it can be concluded that livelihood activities are significant determinant of household food security in the study area. The strong positive relationship found between total household income and livelihood activities confirms that diversification and sustained engagement in profitable economic activities are crucial for ensuring stable access to food. While the majority of households are currently food secure, the significant negative impact of household size highlights that increasing dependency ratios pose a persistent threat to maintaining this security. To foster long-term food security, government and community programs should promote family welfare planning and provide better education and vocational skills training to have various livelihood activities. The household heads should be encouraged to involve in more income diversification activities such as non-farm and off-farm activities in order to improve their livelihood and hence their food security status. These measures would reduce vulnerability, strengthen rural resilience, and contribute to achieving the Sustainable Development Goal of zero hunger.

References

Adegbite, O. O., and Akinlabi, J. O. (2020). Climatic variability and smallholder agriculture in Southwestern Nigeria: Evidence from Ondo State. *Journal of Environmental and Agricultural Research, 6*(3), 56–68.

Adepoju, A. O., Oladipo, O. O., and Balogun, S. A. (2020). Household food security and coping strategies among rural farmers in Southwest Nigeria. *Journal of Rural Studies, 76*, 150–158.

Afolabi, O. J. (2022). Household size and welfare implications for rural families in Nigeria. *African Journal of Economic Policy, 29*(1), 55–67.

Akinyemi, O. and Olaniyan, A. (2019). Farmer–herder conflict and food security in Nigeria. *African Security Review, 28*(1), 1–17. https://doi.org/10.1080/10246029.2019.1605821

Alade, K. M., and Fagbemi, A. O. (2023). Population dynamics and settlement patterns in Southwestern Nigeria: A focus on Ondo State. *Journal of Geography and Regional Planning, 16*(6), 155–165.

Belonwu, E., Umeri, C., Moseri, H., and Nwabeze, G. (2024). Livelihood diversification among rural farmworker households in Edo State, Nigeria. *Journal of Agricultural Extension, 28*(1), 12–18. https://doi.org/10.4314/jae.v28i1.2

Ezeh, C. I., Okoye, B. C., and Ayinde, J. O. (2023). Household characteristics and their influence on livelihood strategies of smallholder farmers in Nigeria. *Journal of Agricultural Extension, 27*(2), 45–57.

Gani, B. S., Olayemi, J. K., and Inoni, E. E. (2019). Livelihood diversification strategies and food insecurity status of rural farming households in north-eastern Nigeria. *Economics of Agriculture, 66*(4), 1109–1124. https://ea.bg.ac.rs/index.php/EA/article/view/1371

Ogunniyi, A. I., Olagunju, K. O., Kabir, S. K., and Adeyemi, O. (2021). Socioeconomic drivers of food security among farming households in Nigeria: Evidence from smallholder maize farmers. *Social Indicators Research, 155*(2), 583–599. https://doi.org/10.1007/s11205-020-02590-7

Okeke, D. C., Nwankwo, O. C., and Igbokwe, E. M. (2020). Farmer–herder conflict and its implications for food security in Benue and Nasarawa States, Nigeria. *Journal of Agricultural Extension, 24*(1), 32–44. https://doi.org/10.4314/jae.v24i1.4

Oladapo, O. S., Aremu, W. T., Akingbemisola, S. P., Toha, A. O., Olubukola, O. O., and Salaudeen, A.-G. O. (2025). Determinants of livelihood diversification among rural households in Oyo State, Nigeria. *African Journal of Agricultural Science and Food Research, 17*(1), 180–206.

Olajide, B. R., and Ogundele, E. O. (2022). Contributions of livelihood diversification to household food security among rural dwellers in Osun State, Nigeria. *Nigerian Journal of Rural Sociology, 22*(1), 22–27.

Olaniyan, J., Oyedele, T., and Akintobi, F. (2024). Livelihood diversification and food security among rural women in Osun State, Nigeria. *Journal of Food and Nutrition Agriculture, 16*(1), 45–55. https://updatepublishing.com/journal/index.php/jfna/article/view/8734

Oyetunde-Usman, Z., and Olagunju, K. O. (2019). Determinants of food security and technical efficiency among agricultural households in Nigeria. *Economies, 7*(4), 103

Sule Gani, A., Olayemi, J., and Inoni, O. (2019). Effect of livelihood diversification on food security of rural households in Northeast Nigeria. *Economics of Agriculture, 66*(4), 1037–1052. https://doi.org/10.5937/ekoPolj1904037G

Assessing the Cassava Value Web: Implications for Food Security and Economic Livelihoods in Ogbomoso, Oyo State, Nigeria.

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Abstract

This study assesses cassava value web and its implications for food security and economic livelihoods in Ogbomoso, Oyo State, Nigeria. Utilizing a mixed-methods approach, data were collected from 296 respondents through structured questionnaires. Descriptive statistical analysis identified socio-economic characteristics, cassava usage, food security status, and constraints faced by producers. The results show that the largest demographic segment is aged 41-50 years (45.27%), with a significant male representation (65.20%). A majority (79.05%) are married, and most respondents have lower educational levels, with 31.42% having no formal education. Cassava is primarily used for food, with over 95% of households processing it into Lafun, Garri (88.5%), and Fufu (81.8%). Food security analysis reveals that approximately 84% of the population is considered food insecure, with a food insecurity gap of 50.1%, highlighting substantial deprivation among affected individuals. Major constraints identified include high perishability (CI: 2.72), land tenure issues, limited access to credit, and the impacts of climate change. The study concludes that enhancing the cassava value web is crucial for improving livelihoods and food security. Recommendations include implementing training programs in processing and storage, establishing cooperative societies, improving rural infrastructure, and fostering partnerships among stakeholders. Promoting the diverse uses of cassava and adopting sustainable practices are essential for maximizing its potential and ensuring long-term economic development in the region.

Keywords: Cassava, Value Web, Food Security, Economic, Livelihood, Nigeria

Introduction

In Nigeria, cassava is currently utilized for two foremost purposes: human diet and industrial use. Estimates for the percentage of cassava used for industrial utilization range from 5 to 16% while the remaining is directly used for human consumption. Cassava is a perishable commodity with a shelf life of less than three days after harvest. Cassava contains a substance which is known as “Cyanide”, this

substance cannot allow cassava to stay long after harvest for more than 48 hours, the best way of getting rid of this cyanide is through processing of cassava Dixon et al., (2020). Processing provides a means of producing shelf stable products; thereby reducing losses, adding value at a local rural level, and reducing the bulk to be marketed (Phillips *et al*. 2024).

The value web is an approach created by Virchow *et al*. (2016) as a multidimensional proposal for the bioeconomy. The value web considers as its starting point the complete resource (i.e. roots, trunk, leaves, flowers and fruits, and their components) and seeks to identify its different current and potential uses. These uses include human consumption (food) and animal consumption (animal feed), fuels (energy) and industrial materials.

Food security and the value web of cassava are deeply interconnected, each influencing the other in significant ways. Food security refers to the availability, access, and utilization of food to meet the dietary needs of a population, while the value web encompasses the various processes, stakeholders, and resources involved in the production, processing, and distribution of cassava Akinwunmi et al., (2017). This definition encompasses four dimensions: availability, access, utilization, and stability. The primary objective is to investigate the Assessing the Cassava Value Web: Implications for Food Security and Economic Livelihoods in Ogbomoso, Oyo State, Nigeria". The specific research objectives are to: identify the socio-economic characteristics, identify the different food and non-food uses of cassava within the cassava value web, classify households into food security status, and identify constraints faced by actors within the cassava value web.

Study Area

The study was carried out in Oyo State, Nigeria. Oyo state consists of four agricultural zones. Ogbomoso Agricultural Zone was purposively chosen for this study because its relevant in agricutural food productivity. A multi-stage random sampling technique was used to sample the representative number of farm households (respondents). The first stage involved purposive selection of Ogbomoso Agricultural Development Programme (ADP) Zone in Oyo state. The reason for the purposiveness is the incessant cassava production and processing in the study area. This was followed by selection of three Local Government Area from the zone, these are: Ogo-Oluwa, Orire, and Surulere Local Government Area. The last stage was collection of total number of registered farmers from each Local Government Area, then the Yamane's (1967) formula was employed to determine the appropriate sample size, to make a total of two hundred and ninety-six (296) respondents for the study. It is given as;

$$n = \frac{N}{1+Ne^2} \quad \text{..... 3.1}$$

In this equation, n represents the sample size, N is the total population of the selected Local Government Areas, and e is the precision level, set at 5%. This formula was used to derive a total of 296 respondents for the study. While the data collection method is outlined, the justification for the sampling process using Yamane's formula is incomplete without the actual equation provided. Additionally, ethical considerations, such as obtaining clearance or consent for data collection, were not mentioned. Furthermore, the methodology lacks details on the analytical methods or statistical tools employed for data analysis, which are crucial for understanding how the results were derived. Highlighting these aspects would strengthen the methodology section and enhance the study's credibility. Primary data was used for this study, which was collected through structured questionnaire.

Results and Discussion

Table 1 provides insights into the demographic characteristics of the respondents. About 45.27% of respondents are aged 41-50 years, indicating that this age range is the most represented. The second largest group is aged 51-60 years at 29.73%, suggesting a predominantly middle-aged population. Younger respondents (<30 years) constitute only 4.39%, indicating a potential gap in youth involvement in cassava farming. Regarding gender, males represent 65.20% of the respondents, while females make up 34.80%. This significant gender disparity may reflect traditional roles in agriculture and could suggest the need for targeted strategies to engage more women in farming activities. In terms of marital status, 79.05% of respondents are married, indicating that many farmers may have established family support systems. Single individuals account for 9.12%, while widowed (6.42%) and separated (5.41%) individuals represent smaller portions of the population. This marital status distribution may influence household labor availability and decision-making in agricultural practices. When looking at education levels, 31.42% have no formal education, while 39.86% have completed primary education. This suggests that a significant portion of the population has limited educational opportunities, which could affect their access to agricultural training and resources. Secondary education is held by 17.57%, and only 11.15% have attained tertiary education, indicating a need for educational interventions to enhance agricultural productivity. Household size data shows that 55.41% of respondents live in households of five or fewer members, suggesting that most families are relatively small. Households with 6-10 members constitute 37.50%, while those with more than 10 members are only 7.09%. Smaller household sizes may affect labor availability on farms and household income dynamics.

Table 1: Distribution based on the socio-economic characteristics

Variables	Socio-economic	Frequency	Percentage
Age group	<30 years	13	4.39
	31-40 years	43	14.53
	41-50 years	134	45.27
	51-60 years	88	29.73
	>60 years	18	6.08
Gender	Male	193	65.20
	Female	103	34.80
Marital status	Single	27	9.12
	Married	234	79.05
	Widowed	19	6.42
	Separated	16	5.41
Level of education	No formal education	93	31.42
	Primary	118	39.86
	Secondary	52	17.57
	Tertiary	33	11.15
Household size	<=5	164	55.41
	6-10	111	37.50
	>10	21	7.09

Source: Data Analysis, 2024

Food and Non-Food Uses of Cassava

Cassava can be processed into various food and non-food products for household consumption or sale. Table 2 outlines the nine prominent uses of cassava in the study area. Lafun being the most common (95.3%). majority 95.3% of respondents indicated the use of Lafun, making it the most popular cassava product. This high percentage implies that Lafun is a staple in the local diet, indicating strong demand and potential for local production and processing. Likewise, about 88.5% use Garri, which also highlights its importance as a key food source. The widespread consumption suggests opportunities for enhancing production techniques and market access. Fufu, at 81.8%, shows significant usage as well, reinforcing the versatility of cassava in meeting dietary needs. This could lead to initiatives aimed at diversifying processing methods to cater to consumer preferences. Animal Feed, utilized by 81.2%, indicates that cassava plays a crucial role in livestock nutrition. This implies potential for integrating cassava cultivation with livestock farming, which could enhance food security and farmer livelihoods.

Manure/Mulch is used by 63.5%, reflecting the agricultural benefits of cassava by-products. This suggests a need for promoting sustainable practices that utilize waste effectively, improving soil health. Pupuru, at 50.7%, indicates moderate usage, while Tapioca (35.5%) and Starch (31.1%) show lower but significant interest, suggesting opportunities for expanding these markets. Abacha, at 20.3%, is the least produced

product, indicating limited demand or knowledge about its potential. This presents an opportunity for education and market development to enhance its utilization.

Table 2: Distribution based on Food and Non-Food Uses derived from Cassava

Products	Frequency	Ranking
Garri	262 (88.5)	2nd
Fufu	242 (81.8%)	3rd
Abacha	60 (20.3%)	9th
Lafun	282 (95.3%)	1st
Pupuru	150 (50.7%)	6th
Tapioca	105 (35.5%)	7th
Starch	92 (31.1%)	8th
Animal Feed	240 (81.2%)	4th
Manure/Mulch	188 (63.5%)	5th

Source: Data Analysis, 2024; Figures in parenthesis represents the percentage in relation to the total sample size (296).

Classification of the Respondents by their Food Security status

The headcount ratio of 0.840 indicates that approximately 84% of the population is classified as food insecure. This high percentage suggests that a significant majority of individuals do not have sufficient access to food, representing a critical issue for food security in the area. The standard error of 0.051 provides an indication of the variability of this estimate, suggesting that it is relatively precise. The food insecurity gap of 0.501 means that, on average, food-insecure individuals are lacking about 50.1% of the necessary food needed to meet their dietary requirements. This figure highlights the severity of deprivation among those who are food insecure. The standard error of 0.129 indicates a higher level of uncertainty around this estimate compared to the headcount, reflecting more variability in the data. The severity index of 0.342 suggests that the intensity of food insecurity among the affected population is significant. This measure indicates not just the prevalence of food insecurity but also the depth of the problem—how far below the food requirement the food-insecure individuals are. The standard error of 0.127 indicates moderate variability in this estimate, suggesting that while the severity is concerning, there may be some uncertainty in how it applies across the population.

Table 3: Distribution based on Food security status

Food security status	Estimate	Standard error
Headcount	0.840	0.051
Gap	0.501	0.129
Severity	0.342	0.127

Source: Data Analysis, 2024

Constraints faced by actors within the cassava value web

Table 4 indicates that Land tenure issues rank first with a (Constraint Index) CI of 2.72, indicating they are the most critical constraint faced by respondents. This highlights the urgent need for policies that ensure secure land access and ownership, as insecurity can deter investment in cassava production. Climate change ranks second with a CI of 2.17, suggesting it is a significant concern for farmers. This implies that adaptive strategies and support for climate resilience are essential to mitigate adverse effects on cassava yields. Access to information ranks third with a CI of 1.93, indicating a moderate concern. This suggests that improving access to agricultural knowledge and resources could empower farmers to make better decisions, ultimately enhancing productivity. Limited access to inputs ranks fourth with a CI of 1.68, showing it is acknowledged but less critical compared to the top three constraints. Addressing this issue could still improve production efficiency but may not be as impactful as securing land tenure or addressing climate change. Limited access to finance ranks fifth with a CI of 1.47, indicating it is viewed as the least significant challenge. While addressing this constraint could support farmers, it may not be the priority compared to the more pressing issues of land security and climate adaptation.

Table 4: Distribution based the Constraints faced by the Respondents

Constraints Indicators	Level of Agreement							(CI)	
	SD 5	D 4	U 3	A 2	SA1	TWV	N	X	Rank
Limited access to inputs	50	76	72	112	187	497	296	1.68	4
Limited access to finance	30	40	48	106	211	435	296	1.47	5
Climate change	165	188	87	32	171	643	296	2.17	2
Land tenure issues	305	224	135	16	126	806	296	2.72	1
Access to information	75	60	195	78	162	570	296	1.93	3
Mean 1.81								**9.07**	

Source: Data Analysis, 2024

Conclusion

Cassava is a vital crop in Nigeria, significantly contributing to food security and the livelihoods of millions. This study emphasizes its dual role as both a staple food and an industrial product while highlighting the need for improved postharvest and marketing systems. The socio-economic profile of cassava producers shows a predominantly middle-aged, male population with diverse educational levels and household sizes.

Selected References

Akinwumi, I. O., Akangbe, J. A., & Olatoye, R. A. (2017). Determinants of cassava farmers' income in Ondo State, Nigeria. *Agricultural Science Research Journal, 7*(6), 132-137.

Dixon, A. G., Semakula, G., & Omongo, C. (2020). Cassava: A basic energy source for human and animal consumption. In *achieving sustainable cultivation of cassava* (Vol. 2). Burleigh Dodds Science Publishing.

Fonji, V. N. (2017). The economic impact of cassava production in Nigeria. *African Journal of Agricultural Research, 12*(5), 234-242.

Virchow, D., Beuchelt, T., Kuhn, A., & Denich, M. (2016). Biomass-based value webs: A novel perspective for emerging bioeconomies in Sub-Saharan Africa. *Technological and Institutional Innovations for Marginalized Smallholders in Agricultural Development*. https://doi.org/10.1007/978-3-319-25718-1

Innovative Postharvest Technologies for Extending Shelf Life of Fresh Produce: A Review

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Abstract

Postharvest losses of fresh produce represent a major threat to global food security, economic stability, and environmental sustainability**.** Nearly one-third of all food produced is lost or wasted annually, with the highest impact occurring in developing countries, underscoring the urgency of effective intervention. Conventional preservation methods offer limited protection against the biological and microbial processes that drive spoilage. This review explores emerging postharvest technologies, such as bio-preservation, edible coatings, controlled-atmosphere storage, and non-thermal physical treatments, that show significant potential to extend shelf life, reduce waste, and maintain produce quality. The review further discusses key implementation challenges and outlines future directions for the sustainable integration of these technologies into global food systems.

Keywords: Bio-preservation, edible coatings, food waste, postharvest technologies, shelf life.

Introduction

The global food system is increasingly challenged by population growth, climate change, and resource limitations. Postharvest loss of fresh produce significantly contributes to food insecurity, economic waste, and environmental harm (Bisht & Singh, 2024). Fruits and vegetables, due to their perishability and microbial vulnerability, account for a large portion of the nearly one-third of global food production lost annually. In developing regions, losses can reach up to 50%, driven by poor infrastructure and handling practices (Nxumalo & Fawole, 2022).

While conventional methods offer limited solutions, innovations like biocontrol agents, edible coatings, and atmospheric treatments have demonstrated potential in improving shelf life and reducing waste (Oliveira et al., 2021). According to FAO, every dollar invested in reducing these losses may yield up to six dollars in return, highlighting the economic value of targeted interventions (Osei-Kwarteng et al., 2023). Understanding the biological characteristics of fresh produce is essential for crafting successful preservation methods.

Fresh produce is highly perishable due to its moisture-rich composition and rapid metabolic activity, which hasten physiological decline. Ethylene production, respiration, and microbial contamination further

intensify postharvest spoilage (Shan et al., 2023). Addressing these factors through innovative preservation methods is key to maintaining postharvest quality.

Factors Influencing Shelf Life of Fresh Produce

Postharvest shelf life is shaped by physiological, environmental, and biological factors. Rapid respiration and ethylene production accelerate ripening and spoilage, while temperature, humidity, and poor handling increase microbial growth and physical damage (Osei-Kwarteng et al., 2023). Fungal and bacterial contamination further degrade texture and nutrition through enzymatic activity. Recognizing these factors is essential for designing effective preservation strategies.

Conventional Preservation Methods

Traditional postharvest methods like refrigeration and chemical preservatives are commonly used to preserve fresh produce, but they come with significant drawbacks. Refrigeration demands high energy use, contributing to greenhouse gas emissions, while chemical preservatives raise concerns about residue toxicity and consumer health (Baranwal et al., 2022). These issues emphasize the need for safer, more sustainable alternatives.

Emerging Postharvest Technologies

Advanced Cold Storage

Innovations in cold storage include hydrocooling, vacuum cooling, and cryogenic systems that provide better temperature regulation. Solar-powered cold rooms are gaining traction in rural areas, providing affordable and sustainable solutions for smallholder farmers (Osei-Kwarteng et al., 2023).

Edible Coatings and Films

Biodegradable coatings such as chitosan and alginate form protective barriers against moisture and gas exchange. Nano-enhanced coatings offer antimicrobial properties, further extending shelf life and enhancing food safety (Khanna, 2023).

Controlled and Modified Atmosphere Storage

CA/MAS technologies manipulate oxygen, carbon dioxide, and ethylene levels to slow respiration and delay ripening. While effective, these systems require precise control and are often cost-prohibitive for widespread use (Shan et al., 2023).

Bio-preservation

Natural preservatives such as bacteriocins and essential oils inhibit microbial growth without leaving

harmful residues. These methods align with consumer preferences for clean-label products and offer promising alternatives to synthetic chemicals (Oliveira et al., 2021).

Non-Thermal Physical Methods

Technologies like UV-C irradiation, cold plasma, and ozone treatments are gaining attention for their ability to inactivate spoilage organisms without compromising nutritional quality (Khanna, 2023).

Comparative Analysis of Technologies

Table 1. Comparative analysis of innovative Postharvest technologies

Technology	Mechanism	Advantages	Limitations	Applications
Cold Storage	Temperature reduction	Widely used, effective	Energy-intensive	All produce types
Edible Coatings	Barrier formation	Biodegradable, antimicrobial	May alter sensory properties	Berries, tomatoes
Controlled Atmosphere/ Modified Atmosphere Storage.	Gas composition control	Extends shelf life significantly	High cost, complex setup	Apples, bananas
Bio-preservation	Natural antimicrobial agents	Safe, residue-free	Limited spectrum of activity	Leafy greens, herbs
Non-Thermal Methods	Microbial inactivation	Nutrient retention, eco-friendly	Equipment cost, regulatory hurdles	Fresh-cut fruits, sprouts

Sources: (Osei-Kwarteng et al., 2023; Shan et al., 2023; Khanna, 2023)

Challenges and Future Directions

Although postharvest technologies have advanced significantly, their adoption remains limited due to high costs, infrastructure gaps, and the need for skilled personnel. Regulatory hurdles and consumer skepticism also slow implementation. To address these challenges, future efforts should focus on developing affordable, scalable solutions and leveraging digital tools IoT-based cold-chain monitoring systems and AI for predictive spoilage modeling to optimize postharvest management and sustainability.

Conclusion

Emerging postharvest technologies such as edible coatings, bio-preservation, controlled atmosphere storage, and non-thermal methods offer effective solutions to reduce spoilage and extend shelf life. Their adoption can significantly cut food waste and enhance sustainability, especially when supported by infrastructure, training, and digital innovation.

References

Baranwal, J., Barse, B., Fais, A., Delogu, G., & Kumar, A. (2022). Biopolymer: A Sustainable Material for Food and Medical Applications. *Polymers*, *14*(5), 983. https://doi.org/10.3390/polym14050983

Bisht, A., & Singh, S. (2024). Postharvest losses and Management of Horticultural Produce: A Review. *Journal of Scientific Research and Reports*, 30(3), 305-320. https://doi.org/10.9734/jsrr/2024/v30i31881

Khanna, J. (2023). Impact of UV-C radiation on Postharvest Storage and Shelf life of Fresh Produce. *International Journal of Horticulture and Food Science*, *5*(2), 81–83. https://doi.org/10.33545/26631067.2023.v5.i2b.209.

Nxumalo, K., & Fawole, O. (2022). Green Synthesized Nanomaterials as an Alternative to Restricted Chemicals in Postharvest Preservation of Horticultural Crops: A Review. E3s *Web of Conferences*, 337, 05006. https://doi.org/10.1051/e3sconf/202233705006.

Oliveira, K., Fernandes, K., & Souza, E. (2021). Current Advances on the Development and Application of Probiotic-loaded Edible Films and Coatings for the Bio-protection of Fresh and Minimally Processed Fruit and Vegetables. *Foods*, *10*(9), Article 2207. https://doi.org/10.3390/foods10092207.

Osei-Kwarteng, M., Mahunu, G., Abu, M., & Apaliya, M. (2023). Alternative Green and Novel Postharvest Treatments for Minimally Processed Fruits and Vegetables. *IntechOpen*. https://doi.org/10.5772/intechopen.111978.

Shan, Y., Li, T., Qu, H., Duan, X., Farag, M., Xiao, J., & Jiang, Y. (2023). Nano-preservation: An Emerging Postharvest Technology for Quality Maintenance and Shelf-life Extension of Fresh Fruit and Vegetable. *Food Frontiers*, *4*(1), 100–130. https://doi.org/10.1002/fft2.201

Effect of Out-grower Support Level on Wheat Production in Kano and Jigawa States, Nigeria

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Abstract

This study examined the effect of outgrower support level on the technical efficiency of wheat farming households in Nigeria. Using a cross-sectional dataset of 473 wheat farmers across various outgrower models, the study employed a stochastic frontier production function (SFPF) to estimate efficiency levels and determinants. The Outgrower Support Index (OSI) was used to quantify the intensity of support received across models such as Market-only, Market + Technical Assistance, and Market + Input Credit + Technical Assistance (MITA). Results indicated an overall mean technical efficiency of 65.5%, suggesting that farmers operated below the frontier, with potential for a 34.5% efficiency gain. Efficiency varied with support intensity: MITA farmers achieved the highest mean efficiency (65.8%), while those with market-only support recorded lower levels (64.9%). The inefficiency model revealed that access to training, household size, and experience reduced inefficiency, while low support levels and limited institutional engagement increased it. The findings imply that structured, multi-dimensional support enhances technical performance and resource use efficiency. The study recommends scaling the MITA model with farmer co-investment mechanisms to prevent dependency and promote sustainable livelihood outcomes.

Keywords: Outgrower model, Technical efficiency, Wheat farming, Support index, Stochastic frontier

Introduction

Agricultural productivity and efficiency remain central to achieving food security and poverty reduction in sub-Saharan Africa (FAO, 2021). In Nigeria, the wheat subsector is strategic to import substitution and livelihood diversification. However, production inefficiencies persist due to inadequate access to input, technology, and market coordination (Muhammed-Lawal, 2024). Outgrower schemes have emerged as a mechanism for integrating smallholder farmers into formal value chains through contract-based relationships with processors, providing access to inputs, technical assistance, and guaranteed markets (Adekeye et al. 2025). The level of support offered within these schemes significantly determines production performance. Evidence suggests that multi-support models combining technical assistance, input credit, and market assurance can reduce inefficiency and enhance resource productivity (Abate et al., 2018). Yet, little is known about how varying levels of support affect the efficiency of wheat outgrowers in Nigeria, despite the growing policy emphasis on structured support interventions (FAO,

2021). This research therefore investigates how the level of outgrower support influences technical efficiency among wheat farming households, drawing on empirical insights from existing structured support models.

Methodology

The study utilized cross-sectional data from 473 wheat-farming households across key wheat-producing zones Kano and Jigawa States. Data were collected from 10 communities across two agro-ecological zones in the two states, involving 400 wheat growers and 100 non-growers using a four-stage random sampling technique and a structured questionnaire kobo tool software. Although 500 farmers were interviewed, only 473 responses were valid for analyses.

Model Specification

Outgrower Support Index (OSI)

Outgrower support index (OSI) was used to measure level of support available to wheat farmers as adapted from Duke Social Support Index (DSSI). The Likert-type scale methods of Scoring in DSSI was used to assess a 5 – item (Guaranteed market, Training, Extension services, Land, Input Credit) to construct the OSI. The OSI ranges from 0 (no support) to 1 (full support) and a high OSI score (>average) implies a high support, while a lower OSI (<average) score indicates minimal or no structured support.

Outgrower Support Index (OSIi) = $1/n \sum_{(j=1,2.....)}^{n} Xij$

Where:

n = number of items i = Household Unit j = Item of support

Xij = normalized score for farmer i on item j

The outgrower support level was calculated by multiplying the OSIi by 100.

Stochastic Frontier Model

The double-log stochastic frontier model was specified as:

$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_2 \ln D_i + (V_i - U_i)$

where:

Y_i = output(kg of wheat per ha); X_i= Independent variables D_i= irrigation dummy; V_i = random error; U_i = technical inefficiency term.

The Cobb–Douglas functional form was adopted, following Kassie et al. (2021) which provide robust and interpretable elasticity estimates. Technical efficiency scores (TE) were derived as: $TE_i = \exp(-u_i)$ and

ranged between 0 and 1, indicating how close each farmer operates to the efficient frontier. The terms, n, β0 and βi represents natural log, intercept and Parameters to be estimated.

Result and Discussion

Descriptive Statistics

Table 1: Summary Statistics of Explanatory Variables

Variables	Mean	Standard Deviation	Minimum	Maximum
Farm size (Ha)	1.0	0.6155647	0.25	5
Seed quantity (Kg)	100.22	61.55	25	500
Labour (Mandays)	92.925	116.756	20	1621.375
Age (Years)	39.36152	11.972	18	80
Household size (Adult Equivalent)	5	3	1	23
Farming experience	18	12	1	60

Source: Field Survey, 2023

The study showed that wheat farming in the study area is largely practiced by smallholder farmers, as noted by Salami et al. (2022) that most Nigerian farmers cultivate less than 3 ha. The average seed quantity used reflects wide variation due to differences in land size, input access, and management intensity (Ndiritu et al., 2019). Also, the mean labour use of 92.93 mandays (SD = 116.76) indicates substantial heterogeneity, suggesting varying degrees of mechanization and household labour reliance (Adenuga et al., 2020). The average farmer's age implies that most are in their productive age with a moderate availability of family labour while the mean farming experience indicates considerable practical knowledge that may enhance efficiency (Bifarin et al., 2022).

Support Models and Level

Table 2: Distribution of the Respondents according to support received

Issues	Frequency	Percent
Outgrower status		
Non-outgrower	87	18.39
Outgrower	386	81.61
Out-growers Support Models		
Market (Mrkt) Model	171	44.30
Market; Land (MLa) Model	52	13.47
Market; Input/Credit (MIc) Model	16	4.15
Market; Technical assistance (MTa) Model	54	13.99
Market; Input/Credit ;Technical assistance (*MITA*) Model	89	23.06
Market; Land ; Technical Assistance (MLTa) Model	3	0.7
Market; Land ; Input/Credit ; Technical Assistance (MILTA) Model	4	1.04
Level of Outgrower Support		

<0.1	102	21.56
10 - 19.999	43	9.09
20 - 29.99	30	6.34
30 - 39.99	94	19.87
40 - 49.99	71	15.01
50 - 50.99	58	12.26
60 - 69.99	28	5.92
70 - 79.99	40	8.46
>80	7	1.48
Mean	36	
Standard deviation	21.7	

Source: Field Survey, 2023

Table 2 shows that several out-grower support models exist among the wheat farmers in the study area. Guaranteed market is the basis for out-grower scheme. Farmers with only market access is 44.3% with 23.06% of farmers receiving a combination of market access, inputs or credit, and technical assistance (MITa) Model, The Market: Land (MLa) and Market; Technical Assistance (MTa) represented 13.47% and 13.99% amongst the outgrower, respectively. Additionally, there was relatively lower percentages of farmers with access to Market; Land (MLTa) Model and Market; Technical Assistance (MILTa) Model (0.7% and 1.04%, respectively). The varying levels of support, from basic market access to more combined packages, suggest that different farmers have diverse needs and companies provide different support to face distinct challenges within the out-grower schemes.

Efficiency of Wheat Farmers

Table 3: Efficiency of wheat farmers based on their out-grower support models

Support Models Efficiency	Observations	Mean	Minimum	Maximum
Non-outgrower	87	62.94247	8.12690	84.32891
Market	171	64.96216	8.28383	93.52589
ML	49	56.99924	15.8323	87.4523
MTa	54	65.26374	38.56156	94.20583
MITa	89	65.84419	23.49183	90.28329

Source: Data analysis 2024

The result shows that the highest mean efficiency, at 65.84%, is observed in the market, Inputs, and Technical Assistance (*MITa*) model. This combination of support represents a holistic approach where farmers have access to markets, receive essential inputs such as seeds and fertilizers, and benefit from technical assistance. The high efficiency reflects the synergy between these support systems.

Determinants of Outgrower Support for Wheat Production

Table 4: Determinants of Support for Wheat Production among outgrowers

Variables	Coefficient	Standard Error	T-value	P-Value
Farm size	0.038	0.028	1.200	0.230
Seed Quantity	0.717	0.038	16.830	0.000***
Labour use	0.124	0.028	3.800	0.000***
Irrigation Access	0.578	0.092	6.300	0.000***
Age	0.389	0.552	0.710	0.481
Household size	-1.059	0.225	-4.710	0.000***
Gender	-0.349	0.740	-0.470	0.637
Marital status	0.626	0.324	1.930	0.053
Primary Education	-0.014	0.294	-0.05	0.961
Secondary Education	0.007	0.325	0.020	0.982
Tertiary Education	0.213	0.348	0.610	0.541
Farming experience	0.003	0.013	0.240	0.813
Wheat farming experience	-0.915	0.324	-2.830	0.005***
Association Membership	0.269	0.713	0.380	0.706
Number of extension visits	0.008	0.108	0.080	0.938
Training level	0.009	0.006	1.580	0.114
Credit access	0.011	0.298	0.040	0.970
Outgrower support level	-0.035	0.006	-5.380	0.000***
sigma_v	0.328			
/lnsig2v	-2.087			
/lnsig2u	-0.775			
sigma_v	0.352			
sigma_u	0.678			
sigma2	0.584			
Lambda	1.927			

Source: Data analysis 2024, ** coefficient significant at 5%, *** coefficient significant at 1%.

The result shows that seed quantity, labour use, irrigation access, are the main drivers among the wheat farmers. A 1% increase in the quantity of seed leads to about 0.72% increase in wheat output, holding other variables constant. This is in line with Ojo et al. (2022) which emphasise that improved seed usage significantly contributes to higher yields in cereals. Also, while labour use has a positive and statistically significant relationship, it is smaller in magnitude than the seed coefficient and less impactful compared to seed quantity. The coefficient for the irrigation access (0.579) is positive and highly significant (p = 0.000), indicating that farmers who have irrigation access have output level that is 78.4% higher than those who do not. Hence, Irrigation is a critical factor in boosting wheat productivity. The inefficiency variables are household Size, years of experience in wheat farming, and level of outgrower support. Specifically, a 1% increase in the level of support available to the famers decreases inefficiency by -0.036%

($p < 0.001$). This suggests that higher levels of support provided to outgrower, such as access to inputs, technical assistance, and guaranteed markets, significantly increases the efficiency of the farmers. This finding is consistent with the literature on contract farming and outgrower schemes, where farmers receiving support from agribusinesses tend to achieve higher productivity due to improved access to inputs and markets (Poku et al., 2018).

Conclusion and Recommendations

The study concludes that the level of outgrower support significantly affects the technical efficiency of wheat farming households. The integrated MITA model yields the highest efficiency levels. This study therefore recommends that policymakers should replicate the MITA support model structure across states to improve wheat self-sufficiency. The input critical to wheat production are irrigation access and quality seed should be embedded in project designs while farmers who are experienced should be targeted to contribute land and labour as commitments to outgrower scheme to promote ownership. Indices such as Outgrower Support Index (OSI) should be adopted to evaluate support impacts on farmer productivity and efficiency.

References

Abate, G. T., Bernard, T., & de Brauw, A. (2018). The impact of contract farming on income and food security: Empirical evidence from Ethiopia. *World Development*, 107, 223–236. https://doi.org/10.1016/j.worlddev.2018.02.024

Adekeye, M. D. Muhammad-Lawal A., Iyiola, O.A., Owolabi, M.T. (2025). Efficiency of Out-grower Support Models on Wheat Farming Households in Kano and Jigawa States, Nigeria. *Journal of Economics and Allied Research*, Vol 10 (1), 544-554

Adenuga, A. H., Omotesho, O. A., & Adenuga, Y. E. (2020). Labour use and productivity among smallholder crop farmers in Kwara State, Nigeria. *African Journal of Economic Review*, 8(1), 93–112.

Bifarin, J. O., Alimi, T., & Afolayan, S. O. (2022). Experience, efficiency, and productivity among smallholder farmers in developing countries: Evidence from Nigeria. *Agricultural Economics Review*, 23(1), 45–60.

FAO. (2021). The State of Food and Agriculture 2021: Making agrifood systems more resilient. Rome: Food and Agriculture Organization.

Kassie, M., Ndiritu, S. W., & Shiferaw, B. (2011). Determinants of productivity and efficiency in smallholder systems. *Journal of Agricultural Economics*, 62(3), 545–560.

Muhammed-Lawal, A. (2024). Agricultural productivity and efficiency among Nigerian smallholders. *African Journal of Agricultural Economics and Rural Development*, 12(2), 50–63.

Ndiritu, S. W., Kassie, M., & Shiferaw, B. (2019). Adoption intensity and input use under credit constraints: Evidence from smallholder farmers in Kenya. *Agricultural Economics*, 50(3), 339–350. https://doi.org/10.1111/agec.12593

Ojo, T. O., Ojo, M. A., & Bello, R. S. (2023). Pesticide safety practices and health outcomes among arable crop farmers in Nigeria. Journal of Agricultural Safety and Health, 29(1), 11–24.

Poku, A. G., Birner, R., and Gupta, S. (2018). Making contract farming arrangements work in Africa's bioeconomy: Evidence from cassava outgrower schemes in Ghana. *Sustainability*, 10(5), 1604.

Salami, A. O., Ajani, O. I., & Kareem, R. O. (2022). Structure and productivity of smallholder agriculture in Nigeria: Evidence from recent farm-level data. *African Journal of Agricultural and Resource Economics*, 17(3), 203–220.

Comparative Evaluation of the Phytochemical Composition of 'Gari' from Provitamin A Dense (TMS-IKN130010) Cassava Fortified with Bambara Nut, Baobab Pulp, and Date Powder on Storage

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Abstract

This study investigated the comparative phytochemical composition and storage stability of *gari* produced from provitamin A-dense cassava (TMS-IKN130010) fortified with Bambara nut flour, baobab pulp, and date powder in various proportions (FG1–FG6) against an unfortified control (FG7). Phytochemicals including phytates, phenolics, oxalates, cyanogenic glycosides, saponins, tannins, and flavonoids were analyzed at 0, 1, and 3 months of storage. Results revealed that fortification significantly ($p<0.05$) enhanced the phytochemical density compared with the control. FG3 and FG4 exhibited the highest phenolic content (1.93 and 1.86 mg/100 g), while FG1 showed the greatest oxalate (26.8 mg/100 g) and flavonoid (3.86 mg/100 g) levels. Across storage, only slight reductions occurred in phenolics, flavonoids, tannins, and saponins, whereas phytates, oxalates, and cyanogenic glycosides remained largely stable. All phytochemical levels were within WHO/FAO safety thresholds, confirming product safety. The retention of bioactive compounds suggests strong antioxidant and antidiabetic potential, establishing fortified gari as a functional staple food with improved nutritional and health-promoting properties and satisfactory storage stability. This fortification strategy provides a sustainable means to enhance dietary quality, micronutrient density, and functional food potential of cassava-based products in sub-Saharan Africa.

Keywords: Fortified *Gari*, Phytochemicals, Bambara Nut, Baobab Pulp, Storage Stability

Introduction

Cassava (*Manihot esculenta Crantz*) remains a staple food for millions in sub-Saharan Africa; however, its limited micronutrient and bioactive compound content constrains its nutritional value (Eyinla et al., 2019). Fortification with nutrient-rich plant sources such as Bambara nut (*Vigna subterranea*), baobab pulp (*Adansonia digitata*), and date (*Phoenix dactylifera*) has emerged as a viable approach to enhance the

functional and health-promoting qualities of cassava-based foods (Odetokun et al., 2021). These fortificants are excellent sources of polyphenols, flavonoids, vitamins, and minerals that contribute to improved antioxidant capacity and chronic disease prevention (Shukla et al., 2022; Adefegha, 2021). Phytochemicals such as phenolics, flavonoids, saponins, and tannins play critical roles in oxidative stress regulation, glucose metabolism, and immune modulation (Sun et al., 2022). Nonetheless, their stability during storage determines the long-term functional quality of fortified foods (Ajayi et al., 2020). Given the increasing interest in functional *gari* products, there is limited data on how fortification and storage affect their phytochemical composition. This study therefore aimed to evaluate the phytochemical composition and storage stability (0 to 3 months) of fortified *gari* from provitamin A-dense cassava blended with Bambara nut, baobab pulp, and date powder, with emphasis on nutritional safety and functional implications.

Methodology

Provitamin A-dense cassava (TMS-IKN130010) was sourced from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Bambara nut seeds, baobab fruit pulp, and dried date fruits were procured from local markets, cleaned, and processed into flours.

Preparation of Fortified *Gari*

Cassava roots were peeled, washed, grated, and fermented for 96 hours, after which the mash was dewatered, sieved, and roasted into gari. Fortification was performed by blending cassava mash with Bambara nut, baobab pulp, and date flours in predetermined ratios at the point of garification according to Ishola et al., 2025 (Table 1). Unfortified gari (FG7) served as control.

Table 1. Composition ratios of fortified gari samples

Sample	Cassava	Bambara nut	Baobab pulp	Date powder
FG1	80.96	9.52	4.76	4.76
FG2	72.00	16.67	6.67	4.66
FG3	41.67	33.33	16.67	8.33
FG4	38.46	23.12	23.12	15.34
FG5	60.85	10.86	8.20	20.09
FG6	58.44	20.23	5.67	15.67
FG7	100.00	0.00	0.00	0.00

Storage Conditions

Samples were packaged in airtight polyethylene bags and stored at ambient temperature (25–28°C) for three months. Phytochemical analyses were performed monthly.

Phytochemical Analyses

Standard AOAC and spectrophotometric methods were used to quantify phytates, oxalates, cyanogenic glycosides, tannins, saponins, phenolics, and flavonoids. All analyses were done in triplicate.

Statistical Analysis

Data were subjected to one-way ANOVA using SPSS (v.25). Means were separated using Duncan's Multiple Range Test at $p<0.05$.

Results and Discussion

Phytate Content

The phytate values ranged from 0.42 to 0.69 mg/100 g in fortified samples and 0.12 mg/100 g in the control (Table 2). Minimal reductions were observed during storage (FG3: 0.69 to 0.67 mg/100 g). These results align with Eyinla et al. (2023), indicating that phytates remain stable under low-moisture conditions. While excessive phytate intake may impair mineral absorption, the values observed were well below the 25 mg/100 g safety limit (Gupta et al., 2015). Moderate phytate levels are beneficial for their antioxidant and anticancer roles (Lukose et al., 2022).

Phenolic Compounds

Phenolic concentrations were highest in FG3 and FG4 (1.93 and 1.86 mg/100 g). Slight reductions occurred during storage, consistent with oxidative degradation (Hassan et al., 2023). Phenolics play key roles in scavenging reactive oxygen species, improving insulin sensitivity, and mitigating chronic diseases (Shukla et al., 2022). Their stability supports the functional potential of fortified gari as a nutraceutical product.

Oxalates

Oxalate content varied widely, from 3.5 to 26.8 mg/100 g, with FG1 showing the highest concentration due to higher contributions from baobab and Bambara nut (Adelekan et al., 2020). These values are below the 50 mg/100 g risk threshold for calcium oxalate accumulation (Heaney and Weaver, 2021), confirming safety for regular consumption. No significant storage effect was detected.

Cyanogenic Glycosides

All samples exhibited low cyanogenic glycoside content (0.20–0.27 mg/100 g), which decreased marginally over storage. These values are substantially below the FAO/WHO (2013) safety limit of 10 mg HCN eq/kg dry weight, affirming that processing and fermentation effectively detoxify cassava-based products (Eyinla et al., 2019).

Saponins

Saponins ranged between 1.02 and 3.29 mg/100 g, with FG3 showing the highest initial value (3.29 mg/100 g). Minor decreases were observed over three months, consistent with reports of hydrolytic degradation during storage (Ajayi et al., 2020). Saponins are recognized for hypocholesterolemic and antidiabetic effects (Sun et al., 2022), reinforcing the functional value of the fortified products.

Table 2: Phytate and Phenolic content of fortified Gari during storage

Gari Sample	Phytate content (mg/100 g)			Phenolic content (mg/100 g)		
	0 month	1st month	3rd month	0 month	1st month	3rd month
FG1	0.43 ± 0.04^{a}	0.43 ± 0.12^{b}	0.42 ± 0.08^{a}	1.38±0.12^{c}	1.38 ± 0.12^{b}	1.37 ± 0.12^{b}
FG2	0.62 ± 0.16^{b}	0.62 ± 0.16^{a}	0.60 ± 0.26^{b}	1.79±0.22^{f}	1.79 ± 0.22^{f}	1.77 ± 0.22^{f}
FG3	0.69 ± 0.13^{c}	0.68 ± 0.24^{b}	0.67 ± 0.20^{a}	1.93±0.01^{g}	1.93 ± 0.01^{g}	1.91 ± 0.05^{g}
FG4	0.62 ± 0.75^{b}	0.62 ± 0.76^{d}	0.60 ± 0.13^{d}	1.86±0.04^{g}	1.86 ± 0.04^{g}	1.84 ± 0.04^{g}
FG5	0.59 ± 0.12^{d}	0.59 ± 0.17^{b}	0.57 ± 0.15^{b}	0.40±0.01^{a}	0.40 ± 0.05^{c}	0.39 ± 0.05^{c}
FG6	0.64 ± 0.16^{c}	0.63 ± 0.15^{c}	0.62 ± 0.10^{b}	1.67±0.04^{e}	1.60 ±0.04^{e}	1.57 ±0.04^{e}
FG7	0.13 ± 0.25^{c}	0.13 ± 0.54^{b}	0.12 ± 0.54^{c}	0.45±0.05^{b}	0.45 ± 0.01^{b}	0.42 ± 0.01^{b}

Results are mean values of triplicate determination ± standard deviation. Mean value within the same column having the same letter are not significantly different at P<0.05.

Table 3: Oxalates and Cyanogenic Glycosides content of fortified Gari during storage

Gari Sample	Oxalate content (mg/100 g)			Cyanogenic Glycoside (mg/100 g)		
	0 month	1st month	3rd month	0 month	1st month	3rd month
FG1	26.89 ± 0.04^{a}	26.88 ± 0.04^{a}	26.80 ± 0.04^{a}	0.26±0.002^{abc}	0.26±0.002^{abc}	0.23 ± 0.02^{abc}
FG2	3.71 ± 0.21^{b}	3.71 ± 0.21^{b}	3.71 ± 0.21^{b}	0.26±0.01^{abc}	0.26±0.01^{abc}	0.22 ± 0.01^{abc}
FG3	4.66 ± 36.32^{e}	4.66 ± 36.32^{e}	4.64 ± 36.32^{e}	0.27±0.20^{bcd}	0.27±0.20^{bcd}	0.25 ± 0.20^{bcd}
FG4	6.48 ± 0.37^{c}	6.47±0.37^{c}	6.45 ± 0.37^{c}	0.27±0.67^{d}	0.27±0.67^{d}	0.26 ± 0.67^{d}
FG5	10.76 ± 0.40^{d}	10.72 ± 0.40^{d}	10.70 ± 0.40^{d}	0.26±3.50^{abc}	0.26±3.50^{abc}	0.24 ± 3.50^{abc}
FG6	6.00 ± 0.32^{c}	5.70 ±0.32^{c}	5.68 ± 0.32^{c}	0.27±0.35^{cd}	0.27±0.35^{cd}	0.23 ± 0.35^{cd}
FG7	3.48 ± 1.84^{b}	3.48 ± 1.84^{b}	3.46 ± 1.84^{b}	0.26±0.321^{ab}	0.26±0.321^{ab}	0.20 ± 0.32^{ab}

Results are mean values of triplicate determination ± standard deviation. Mean value within the same column having the same letter are not significantly different at P<0.05.

Keys: F= Fortified gari from a combination of Cassava, Bambara Nut Flour, Baobab Pulp Flour, and Date Flour at a ratio of (80.96:9.52:4.76:4.76, respectively); FG2 = Fortified gari from a combination of Cassava, Bambara Nut Flour, Baobab Pulp Flour, and Date Flour at a ratio of (72:16.67:6.67:4.66, respectively); FG3 = Fortified gari from a combination of Cassava, Bambara Nut Flour, Baobab Pulp Flour, and Date Flour at a ratio of (41.67:33.33:16.67:8.33, respectively); FG4 = Fortified gari from a combination of Cassava, Bambara Nut Flour, Baobab Pulp Flour, and Date Flour at a ratio of (38.46: 23.12; 23.12:23:04:15.34, respectively); FG5 = Fortified gari from a combination of Cassava, Bambara Nut Flour, Baobab Pulp Flour, and Date Flour at a ratio of (60.85:10.86:8.20:20.09, respectively); FG6 = Fortified gari from a combination of Cassava, Bambara Nut Flour, Baobab Pulp Flour, and Date Flour at a ratio of (58.44:20.23:5.67:15.67, respectively); and FG7 = Unfortified gari from 100% cassavaG1

Tannins

Tannin content (2.00–3.73 mg/100 g) declined slightly with storage, particularly in FG1 (3.73 to 3.03 mg/100 g). This could be due to oxidative polymerization and complexation with proteins (Oguntoyinbo et al., 2021). The values remained below the 10 mg/100 g safe threshold (FAO/WHO, 2013), suggesting no anti-nutritional hazard. Moreover, moderate tannin levels may enhance antimicrobial and antioxidant activity (Ezeocha et al., 2022).

Flavonoids

Flavonoids were highest in FG1 (3.86 mg/100 g) and lowest in the control (FG7: 1.71 to 1.09 mg/100 g). Reductions during storage corroborate the oxidative sensitivity of flavonoids (Arun et al., 2022). The retention of high flavonoid content in fortified samples supports their potential for glycemic regulation and diabetes management through α-amylase and α-glucosidase inhibition (Adefegha, 2021).

Table 4: Saponins and Tannin content of fortified Gari during storage

Gari Sample	Saponins content (mg/100 g)			Tannins content (mg/100 g)		
	0 month	**1st month**	**3rd month**	**0 month**	**1st month**	**3rd month**
FG1	3.08±0.19^{e}	3.08±0.19^{e}	2.98 ± 0.10^{e}	3.73±0.02^{h}	3.73±0.02^{h}	3.03 ± 0.02^{h}
FG2	2.65±0.39^{d}	2.64±0.39^{d}	2.55 ± 0.47^{d}	2.91±0.01^{c}	2.91±0.01^{c}	2.41 ± 0.05^{c}
FG3	3.29±0.11^{e}	3.29±0.11^{e}	2.84 ± 0.21^{e}	3.54±0.01^{g}	3.54±0.01^{g}	2.94 ± 0.09^{g}
FG4	1.71±0.03^{b}	1.70±0.03^{b}	1.02 ± 0.12^{c}	3.26±0.01^{e}	3.26±0.01^{e}	3.06 ± 0.01^{e}
FG5	2.17±0.01^{c}	2.16±0.01^{c}	2.07 ± 0.01^{h}	2.99±0.011^{d}	2.99±0.011^{d}	2.09 ± 0.011^{d}
FG6	2.18±0.12^{c}	2.16±0.12^{c}	2.08 ± 0.12^{c}	2.18±0.01^{a}	2.18±0.01^{a}	2.00 ± 0.12^{a}
FG7	2.81±0.01^{d}	2.79±0.01^{d}	2.77 ± 0.11^{d}	3.36±0.06^{f}	3.36±0.06^{f}	3.36 ± 0.16^{f}

Results are mean values of triplicate determination ± standard deviation. Mean value within the same column having the same letter are not significantly different at P<0.05.

Keys: FG1 = Fortified gari from a combination of Cassava, Bambara Nut Flour, Baobab Pulp Flour, and Date Flour at a ratio of (80.96:9.52:4.76:4.76, respectively); FG2 = Fortified gari from a combination of Cassava, Bambara Nut Flour, Baobab Pulp Flour, and Date Flour at a ratio of (72:16.67:6.67:4.66, respectively); FG3 = Fortified gari from a combination of Cassava, Bambara Nut Flour, Baobab Pulp Flour, and Date Flour at a ratio of (41.67:33.33:16.67:8.33, respectively); FG4 = Fortified gari from a combination of Cassava, Bambara Nut Flour, Baobab Pulp Flour, and Date Flour at a ratio of (38.46: 23.12; 23.12:23:04:15.34, respectively); FG5 = Fortified gari from a combination of Cassava, Bambara Nut Flour, Baobab Pulp Flour, and Date Flour at a ratio of (60.85:10.86:8.20:20.09, respectively); FG6 = Fortified gari from a combination of Cassava, Bambara Nut Flour, Baobab Pulp Flour, and Date Flour at a ratio of (58.44:20.23:5.67:15.67, respectively); and FG7 = Unfortified gari from 100% cassava.

Storage Implications

Overall, storage caused minimal losses in phenolics, tannins, saponins, and flavonoids, while phytates, oxalates, and cyanogenic glycosides were stable. These patterns reflect the oxidative lability of some phytochemicals and the chemical resilience of others under low-moisture conditions. The stable profile demonstrates that fortified gari maintains nutritional and functional integrity during typical shelf-life conditions, validating its potential as a safe, functional, and shelf-stable food.

Conclusion

Fortifying provitamin A-dense cassava gari with Bambara nut, baobab pulp, and date powder significantly improved the phytochemical composition, particularly in phenolics, flavonoids, and saponins. Storage for three months resulted in negligible reductions in most bioactive compounds, confirming good phytochemical stability. All phytochemical concentrations were within FAO/WHO safe limits, ensuring nutritional safety. The fortified gari therefore represents a valuable functional food capable of enhancing dietary antioxidant intake and promoting metabolic health.

References

Adelekan, A. O., Akinoso, R., and Oyedele, D. J. (2020). Nutritional and anti-nutritional composition of baobab (*Adansonia digitata* L.) pulp and seed flour blends. *Journal of Food Biochemistry, 44*(11), e13439. https://doi.org/10.1111/jfbc.13439

Adefegha, S. A. (2021). Functional foods and nutraceuticals as dietary intervention in chronic diseases: Present status, challenges, and future perspectives. *Food Frontiers, 2*(1), 3–19. https://doi.org/10.1002/fft2.55

Ajayi, O. B., Komolafe, T. R., and Adejumo, I. O. (2020). Changes in phytochemical constituents of stored plant-based foods: A review. *Nigerian Journal of Food Science and Technology, 4*(2), 45–52.

Arun, R., Chitra, P., and Ramesh, T. (2022). Stability and degradation of flavonoids during processing and storage of food products. *Food Chemistry Advances, 1*, 100056. https://doi.org/10.1016/j.focha.2022.100056

Eyinla, T. E., Adebayo, B. C., and Oyeyinka, S. A. (2019). Processing effects on cyanogenic glycosides and nutritional quality of cassava-based foods. *Journal of Food Processing and Preservation, 43*(12), e14231. https://doi.org/10.1111/jfpp.14231

Eyinla, T. E., Oyeyinka, S. A., and Kayode, B. I. (2023). Stability of antinutrients in legume-based foods during processing and storage. *International Journal of Food Properties, 26*(1), 158–172. https://doi.org/10.1080/10942912.2023.2165674

FAO/WHO. (2013). *Safety evaluation of certain food additives and contaminants: Cassava cyanogenic glycosides.* Geneva: Joint FAO/WHO Expert Committee on Food Additives (JECFA).

Gupta, R. K., Gangoliya, S. S., and Singh, N. K. (2015). Reduction of phytic acid and enhancement of bioavailable micronutrients in food grains. *Journal of Food Science and Technology, 52*(2), 676–684. https://doi.org/10.1007/s13197-013-0978-y

Hassan, A. B., Osman, G. A., and Mohamed Ahmed, I. A. (2023). Oxidative stability of phenolic compounds during storage of fortified foods. *LWT - Food Science and Technology, 181*, 114782. https://doi.org/10.1016/j.lwt.2023.114782

Heaney, R. P., and Weaver, C. M. (2021). Oxalates in foods and their role in calcium metabolism. *Advances in Nutrition, 12*(3), 939–945. https://doi.org/10.1093/advances/nmaa154

Ishola, D. T., Bolade, M. K., Ijarotimi, O. S., Sanni, L. O., Ogundele, D. T., & Ishola O. T.. (2025). Assessment of Nutritional Quality and Mineral Composition of Fortified Gari from Provitamin A Cassava, Bambara Nut, Dates, and Baobab Pulp during Storage. Nigerian Journal of Post-Harvest Research, 3(3), 53-64.

Lukose, S., Zarei, M., and Akoh, C. C. (2022). Phytate as a functional food ingredient: Benefits and limitations. *Critical Reviews in Food Science and Nutrition, 62*(18), 4856–4871. https://doi.org/10.1080/10408398.2020.1854682

Odetokun, T. I., Adepoju, P. A., and Fadahunsi, O. (2021). Polyphenol-rich African foods: Implications for chronic disease prevention. *Journal of Functional Foods, 83*, 104561. https://doi.org/10.1016/j.jff.2021.104561

Oguntoyinbo, F. A., Olaniran, A. O., and Obadina, A. O. (2021). Polyphenol and tannin stability in processed and stored African fermented foods. *Food Research International, 143*, 110242. https://doi.org/10.1016/j.foodres.2021.110242

Shukla, S., Kalra, E. K., and Singh, H. B. (2022). Role of dietary polyphenols in oxidative stress and diabetes management. *Frontiers in Nutrition, 9*, 912368. https://doi.org/10.3389/fnut.2022.912368

Sun, H., Wang, Y., and Chen, W. (2022). Saponins: Nutraceutical potential and mechanisms of action in chronic diseases. *Food and Function, 13*(10), 5413–5429. https://doi.org/10.1039/D2FO00732A

Zhou, X., Zhao, H., and Zhang, X. (2022). Interaction between oxalates and gut microbiota: Implications for nutrition and health. *Nutrients, 14*(4), 867. https://doi.org/10.3390/nu14040867

Assessing the Resilience of Maize Farming Households to Climate Shocks in Ogun State, Nigeria

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Abstract

Climate variability characterized by erratic rainfall, drought and flooding, poses a growing threat to maize production in Nigeria. This study examined the resilience of maize farming households to climate shocks in Ogun State, Nigeria. A multistage sampling approach was used to select 120 maize farmers, with data collected through structured questionnaires and interviews. Descriptive statistics, resilience index and multiple regression analysis were employed for data analysis. Findings revealed that farmers were highly exposed to recurrent drought (93.3%), flooding and erosion (75.8%), pest infestation (60%), windstorm (56.7%), and high temperature (50.8%), which resulted in significant yield losses and heightened food insecurity. The major consequences included reduced maize yield (95.8%), income decline (86.7%), rising production costs (81.7%), food shortages (65.8%), livelihood disruptions (55.8%), health risks (46.7%), and asset depletion (40%). Regression analysis showed that education ($p<0.01$), farm size ($p<0.01$), extension access ($p<0.05$), credit availability ($p<0.01$), and cooperative membership ($p<0.05$) significantly improved resilience, whereas larger household size ($p<0.05$) reduced resilience. Coping strategies adopted included adjustment of farming practices ($\bar{x} = 4.44$), agrochemical use ($\bar{x} = 4.31$), livelihood diversification ($\bar{x} = 4.07$), reliance on social networks ($\bar{x} = 3.88$), food rationing ($\bar{x} = 3.34$), and asset liquidation ($\bar{x} = 3.20$). The study concluded that while maize farming households in Ogun State demonstrate moderate resilience, vulnerability persists due to inadequate institutional support. It recommended strengthening climate-smart agricultural policies, enhancing rural credit systems, and expanding extension services to improve climate risk management by all tiers of government in the study area.

Keywords: Climate shock, coping, Maize farmers, Ogun State, Resilience

Introduction

Climate change is one of the most critical challenges confronting global agriculture, with developing nations such as Nigeria bearing the brunt of its impacts. Nigeria's agricultural sector is particularly

vulnerable because of its heavy reliance on rain-fed systems, exposing farmers to extreme weather events including prolonged droughts, erratic rainfall, flooding, and rising temperatures (Omotoso & Omotayo, 2024). These climate shocks not only depress crop yields but also threaten food security, household livelihoods, and the wider economy. Increasingly unpredictable weather patterns disrupt planting and harvesting schedules, causing shortened crop cycles as well as increasing pest and disease outbreaks, resulting in compounded productivity losses compounding productivity losses (Omotayo and Omotoso 2025).

Maize, a major staple food and a critical source of income for Nigerian households, faces growing risks from these climate-induced disruptions (Sato et al., 2020). Enhancing resilience through collaborative actions and strong social networks has therefore become imperative for sustaining productivity, safeguarding livelihoods, and ensuring long-term food security amid increasing climate uncertainties. Resilience is defined as the ability of households to anticipate, absorb, adapt to, and recover from climatic shocks without undermining their long-term sustainability (FAO, 2020). According to Taiwo et al. (2025) household resilience is enhanced by educational level of the farmers, access to extension services, and strong social networks, whereas poverty and inadequate institutional support heighten vulnerability. In maize production, common resilience strategies include the use of drought-tolerant seed varieties, irrigation, soil conservation practices, and livelihood diversification. In the case of Ogun State, empirical evidence on resilience among maize farmers remains scarce. This study therefore addresses this gap by identifying the climate shocks experienced by maize farmers over the past five years, examining their effects on farm households, analyzing the factors that influence resilience, and highlighting the coping strategies employed by maize farming households.

Methodology

The study was carried out in Ogun State, Nigeria, using primary data obtained through structured questionnaires and interview schedules. A multistage sampling procedure was adopted. First, two Local Government Areas (LGAs) were purposively selected based on their prominence in maize production. From each LGA, three villages were randomly chosen, giving a total of six villages. In the final stage, 20 smallholder farmers were randomly selected from each village, resulting in 120 respondents for data collection and analysis.

For data analysis, the study applied both descriptive and inferential techniques. Descriptive statistics such as frequency counts, percentages, means, and standard deviations were used to examine the types of climate shocks encountered, their effects on households, and the coping strategies employed by maize farmers. In addition, multiple regression analysis was conducted to identify the socio-economic and

institutional factors influencing the resilience of maize farming households to climate shocks in the study area. The model is specified as:

$$RI_i = f(\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\ldots.+\beta_nX_n+e_i \quad (1)$$

The dependent variable (RI_i) is an index constructed using indicators such as income stability, access to credit, food security, and coping strategies. The X's are the explanatory variables expressed as: X_1 = Sex of farmers (1 if male; 0 otherwise), X_2 = Age (years), X_3 = Education level (years), X_4 = Household size (number), X_5 = Farm size (hectares), X_6 = Frequency of extension contact, X_7 = Membership of cooperative association (1 if yes; 0 otherwise), X_8 = Access to credit/loan (1 if yes; 0 otherwise), X_9 = Income (₦). β's = parameters to be estimated, ε = error term.

Results and Discussion

Climatic Shocks Experienced by Maize Farmers in the Past Five Years

Table 1 presents the major climate shocks encountered by maize farmers over the last five years. The findings indicate that drought was the most severe challenge, as reported by more than 93% of the households. Flooding and erosion were also widespread, affecting about 75.8% of respondents, while pest infestations were experienced by 60% of the farmers, highlighting their significant role in yield reduction and financial instability. In addition, windstorms were reported by 56.7% of households, whereas high temperature intensity was cited by 50.8%. The pronounced vulnerability of maize to drought agrees with Omotoso and Omotayo (2025), who identified water scarcity as a leading driver of food insecurity in sub-Saharan Africa. Similarly, Omotayo and Omotoso (2025) observed that prolonged dry spells diminish soil moisture, reduce crop yields, and undermine rural livelihoods.

Table 1: Climatic Shocks Experienced by Maize Farmers in the Past Five Years

Climate shocks	Frequency	Percentage
Drought	112	93.3
Flood and Erosion	91	75.8
Temperature	61	50.8
Pests	72	60
Windstorm	66	56.7

Source: Field Survey Data, 2024

Major Effects of Climatic Shocks on Farming Households

Table 2 presents the effects of climate shocks on maize farming households in the study area. The findings reveal that reduced crop yields and productivity (95.8%) were the most immediate impact, as recurrent droughts, floods, and erratic rainfall consistently undermined maize output and heightened the risk of crop failure. This decline in production subsequently resulted in household income losses (86.7%), with farmers reporting reduced sales and unstable earnings. In response to these production challenges,

households faced rising costs of production (81.7%), driven by additional spending on replanting, irrigation, pest control, and recovery measures. The combined effect of poor harvests and high production costs led to food shortages and hunger (65.8%), reflected in limited availability of food, increased market prices, and dependence on less nutritious diets. Climate shocks also contributed to livelihood disruptions (55.8%), compelling some household members to seek off-farm employment, depend on fragile social networks, or engage in temporary migration, all of which weakened resilience in the long run.

Furthermore, health risks (46.7%) such as malnutrition, waterborne diseases, and psychological stress were reported, especially in flood-affected areas. To cushion these impacts, many households resorted to asset depletion and borrowing (40%), often selling livestock, farm tools, or household goods, which further increased their vulnerability to future shocks. These results support Adekunle et al. (2025), who found that climate-induced economic shocks negatively affected farmers' purchasing power and food security in Niger State, Nigeria.

Table 2: Major Effects of Climatic Shocks on Farming Households

Effects of climate shocks	Frequency	Percentage
Reduced maize yield	115	95.8
Income loss	104	86.7
Increased production cost	98	81.7
Food shortage/hunger	79	65.8
Health risks	56	46.7
Livelihood disruptions	67	55.8
Asset depletion/indebtedness	48	40

Source: Field Survey Data, 2024

Factors Influencing Resilience of Maize Farming Households to Climate Shocks

Table 3 presents the multiple regression results on factors influencing the resilience of maize farming households to climate shocks in the study area. Among the functional forms tested, the double-log model was selected as the best fit, based on its higher coefficient of determination (R^2), significant F-value, and the logical consistency of explanatory variables. The R^2 value of 0.699 implies that approximately 70% of the variation in the resilience index is explained by the model, while the F-statistic, significant at the 1% level, confirms the model's overall reliability.

The results indicate that education ($p<0.01$), farm size ($p<0.01$), household income ($p<0.01$), access to credit ($p<0.01$), extension contact ($p<0.05$), and cooperative membership ($p<0.05$) significantly and positively influenced the resilience index of maize farming households. Specifically, a unit increase in education (years of schooling) raised resilience by 1.104 points, highlighting that better-educated farmers are more adaptive to climate shocks. Similarly, farm size had a positive effect, suggesting that larger

landholdings enhance productive capacity and diversification opportunities. This is in agreement with the findings of Adekunle et al. (2025), who noted that larger farms contribute to higher productivity, thereby strengthening resilience. Access to credit and extension services also improved resilience by providing liquidity and exposure to adaptive practices.

On the other hand, household size ($p<0.05$) had a significant negative effect on resilience, as larger family units increase consumption needs and dependency burdens. This supports the findings of Taiwo et al. (2022), who reported that large household sizes raise expenditures and reduce farming investments, thereby weakening resilience to climate shocks.

Table 3: Factors Influencing Resilience of Maize Farming Households to Climate Shocks

Variable	Coefficient	T-ratio	Sig
(Constant)	0.492	2.361	0.001
Sex	0.125	0.126	0.877
Age	0.065	0.051	0.752
Education	1.104***	2.731	0.001
Household size	-0.017**	-2.182	0.032
Farm size	2.1200***	3.544	0.001
Frequency of Extension visit	0.056**	-2.224	0.031
Cooperative association membership	1.739**	-2.066	0.024
Access to loan	1.611***	4.372	0.001
Income	0.000***	2.805	0.001
R^2	0.699		
Adj. R^2	0.617		
F	7.540		

*** and ** indicate significance at 1% and 5% respectively.
Source: Field survey data, 2024

Major Coping Strategies Adopted by the Farming households

In response to climate shocks, maize farming households in Ogun State adopted a range of coping strategies, spanning both short-term survival tactics and longer-term adaptive measures, as revealed by the 5-point Likert scale results presented in Table 4. The most widely practiced strategy was adjustments in farming practices ($\bar{x}$ = 4.44), such as shifting planting dates to match erratic rainfall, intercropping to minimize risks, and cultivating drought-tolerant maize varieties to withstand climatic stress. Many households also relied on the use of agrochemicals ($\bar{x}$ = 4.31) to manage pests and weeds exacerbated by climate variability. While effective, this practice raised production costs and carried potential health and environmental risks. Livelihood diversification ($\bar{x}$ = 4.07) was another common strategy, with farmers engaging in petty trading, artisanal work, or off-farm employment to supplement income and reduce dependence on maize farming alone. Social networks and group support ($\bar{x}$ = 3.88) also played a crucial

role, as families, neighbors, and farmer groups provided labor sharing, emergency loans, and access to planting materials.

Table 4: Major Coping Strategies Adopted by the Farming households

Coping Strategies	Mean	Std. Deviation
Adjustment of farming practices	4.44	0.502
Agrochemicals	4.31	0.673
Livelihoods diversification	4.07	0.702
Reliance on social networks	3.88	1.011
Food rationing	3.34	0.644
Asset liquidation and borrowing	3.20	1.214

Source: Field Survey Data, 2024

In more direct coping measures, households often adopted food rationing ($\bar{x}$ = 3.34), which involved reducing meal portions, skipping meals, or prioritizing children's nutrition over adults. Similarly, asset liquidation and borrowing ($\bar{x}$ = 3.20) were employed, with families selling livestock, farm tools, or household goods, and turning to informal lenders or relatives for credit. Although these strategies offered temporary relief, the reliance on reactive measures highlighted the households' limited access to sustainable, long-term resilience-building options.

Conclusion and Recommendations

The study concludes that maize farming households in Ogun State demonstrate moderate resilience to climate shocks. However, exposure to recurrent droughts, floods, and pests continues to undermine productivity and food security. Education, institutional support, and access to credit emerged as key drivers of resilience, while large household sizes constrained adaptive capacity. The study recommends strengthening farmers' access to education, credit, extension services, and climate-smart technologies while promoting livelihood diversification and social capital to enhance resilience against climate shocks by all tiers of government and other stakeholders.

References

Adekunle, O.A., Babatunde, R.O., Akanbi, S.O. Ayeni, M.D. & Obalola, O.T. (2025). Assessment of the Effects of Climate-related Shocks on Farming Households' Food Security in Niger State, Nigeria. *Yuzuncu Yil University Journal of Agricultural Sciences,* 35(1), 107-120.

FAO. (2020). Core Indicators for Resilience Analysis: Toward an Integrated Framework to Support HarmonizedMetricswww.fao.org/publications.

https://www.fsinplatform.org/sites/default/files/paragraphs/documents/Core_Indicators_Resilience_Analysis_Publication.pdf

Omotoso, A.B., & Omotayo, A.O. (2024). Enhancing dietary diversity and food security through the adoption of climate-smart agricultural practices in Nigeria: micro level evidence. *Environ. Dev. Sustain*., 1–18, doi:10.1007/s10668-024-04681-8.

Omotoso, A.B., & Omotayo, A.O. (2025). Benefits of manure and drought-resistant maize varieties on farmers' welfare status in South Africa. *Agric. Biosci.*, 6, 0021.

Omotayo, A.O., & Omotoso, A.B. (2025). Climate-smart agricultural technology and gender-differentiated food, and water security: Evidence from smallholder sunflower (Helianthus annuus L.) Farmers. *Agric. Water Manag.*, 308, 109276.

Sato, G.J., Joshua, M.K., Ngongondo, C., Chipungu, F., Malidadi, C., & Monjerezi, M. (2020). *Evaluation of different tillage systems for improved agricultural production in drought-prone areas of Malawi*. In: Climate Variability and Change in Africa. Springer, Cham, pp. 157–167.

Taiwo, O.D., Hamzat, O.A., Adesanlu, A.A., Adigun, A.K. & Ibhonitie, B.E. (2025). Effects of Climate Variability on Technical Efficiency of Maize Production among Farmers in Remo North Local Government Area, Ogun State, Nigeria. *Moor Journal of Agricultural Research,* 26(1), 31 – 39.

Analysis of Waste Management Practices among Households in Akure North Local Government Area of Ondo State, Nigeria.

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Abstract

Wastes are materials that arise from animal and human activities and often discarded as useless or unwanted. This study analyzed household waste management practices in Nigeria with focus on Akure North Local Government Area of Ondo State. The Awareness, perceived environmental effects, Adaptation strategies and constraints to effective waste management practices among 120 household representatives were explored. Data elicited were subjected to descriptive and inferential statistics. Most (54.0%) of the respondents were female, 54.2% being 40 years old and below with 81.7% representing 98 people having minimum of secondary education. The average household size was about six persons reflecting the possibility of generating household wastes in the study area. Findings further revealed that awareness and knowledge of waste management were relatively high among respondents, with an overall mean score of $\bar{x}$ = 1.67 (SD = 0.46) where most respondents agreed that environmental sanitation protects households against diseases. Mostly ranked perceived constraints to effective waste management were inadequate infrastructure, inefficient collection systems, and corruption and lack of accountability among households with scores above the mean value (4.13). The most endorsed strategies supported by households for adaptation to waste management were reduction of litters through re-use and recycling, multiple use of household items such as containers and minimizing waste generation through reduced packaging, all with mean scores above $\bar{x}$ = 4.30. The findings underscore the need for integrated waste management policies that focus on public education and sensitization thereby protecting both human health and the environment.

Keywords: Waste, Household, Management, Adaptation.

Introduction

Waste is broadly defined as any item or materials generated and disposed of, or intended to be disposed of, by a person in possession of it (Agbesola, 2022). However, different definitions of waste exist based on the conditions under which legal nature and geographical location of generation. According to Uchegbu (2020), waste management is "a planned system of effectively controlling the production, storage,

collection, transportation, processing, and disposal or utilization of waste in a sanitary, aesthetically acceptable, and economical manner." It encompasses all administrative, financial, legal, and planning functions, as well as all physical aspects of waste disposal. Sanitation is one of the basic factors which decisively affect the nature or outcome of quality life of human development (Sheethal & Shashikantha, 2016). It is a fundamental requirement to ensure safe health, environment and the overall wellbeing of the society. According to Odukoya (2002), lactates from wastes at a dumpsite are potential sources of contamination for both surface and groundwater. Domestic waste management has become an intractable problem in most Nigerian cities. There is no doubt that our cities are being flooded with the problems of unsorted domestic waste. The majority of the urban and semi-urban areas are currently fighting to clear mounting piles of domestic waste from their environments. Overflowing dumps, unattended heaps of domestic waste emanating from household, domestic, or kitchen sources, markets, shopping, and business centers are encroaching on these strategic centers of beauty, peace, and security (Agwu, 2022). This study aimed at analyzing the waste management and sanitation practice among households in Akure north LGA, Ondo State with a view to proffering a lasting solution to the problem of improper waste disposal that constitutes environmental pollution and deterioration of human health which leads to illness and death in our societies. The study analyzed the level of awareness about waste management, perceived effect of waste management practices among the households and the adaptation strategies for improving waste management in the study area. The finding of this research will be beneficial to the researchers, households at community levels, policymakers in governments and non-governmental organizations, health educators and public health educators.

Methodology

The study was carried out in Akure North Local Government Area of Ondo State. Multi-stage sampling procedure was employed to select 120 respondents across four communities within the L.G.A. Data obtained with a structured questionnaire from representative household members, who were adults, were analysed with descriptive statistics such as tables and charts and inferential statistical analysis including Correlation and Regression. The socio-economic characteristics of the household members and the level of awareness and knowledge about waste management practices among households were analyzed using descriptive statistics which were frequency distribution mean and percentages. The effect of waste management practices among households and the adaptation strategies for improving waste management among household in the study area were analyzed using a five-point likert scale.

Results and Discussions

The socio- economic characteristics of the households reveals a mean age of approximately 41 years with a standard deviation of 13, suggesting that most respondents fall within the economically active age bracket. This implies that a majority of the respondents are capable of making informed decisions about waste management. This finding aligns with Akinbile and Adisa (2021), who noted that active-age groups in Nigeria are more involved in environmental management and community sanitation practices. 54.0% of respondents were female, while 46% were male.

The distribution reveals with dominance of female respondents in the sample. This could be that women are more involved in household waste management, the male as it is dictated by their domestic roles. This result is supported by Oloruntoba et al. (2020), who observed that women in Nigeria often bear greater responsibility for sanitation and household waste disposal. The educational status revealed that nearly half of the respondents (49.2%) had secondary education, while 32.5% attained tertiary education. This implies a relatively literate population, capable of understanding and adopting sustainable waste management practices. This finding supports Ajibade and Oyediran (2022), who argued that higher educational attainment enhances environmental awareness and improves household waste disposal behaviour in Nigerian communities.

The household's awareness of waste management revealed an overall awareness score $\bar{x}$ = 1.67 (SD = 0.46), suggesting a generally positive level of knowledge on what management awareness. The highest ranked awareness statement was that environmental sanitation protects against diseases ($\bar{x}$ = 1.85, SD = 0.36). These practices are basic hygiene measures and are often promoted during community sanitation campaigns, which may explain their prominence. Perceived environmental effects of poor sanitation by the household reveals perception mean score of $\bar{x}$ = 4.13 (SD = 1.05), which indicates a high level of agreement across most items. The most highly ranked effect was that improperly managed waste attracts pests, rodents, and spreads diseases ($\bar{x}$ = 4.31, SD = 1.01; 1st). This was closely followed by exposure to waste causing respiratory problems and infections ($\bar{x}$ = 4.28, SD = 0.98; 2nd) and pollution of air, water, and soil ($\bar{x}$ = 4.25, SD = 0.99; 3rd). These results reflect strong community recognition of the direct health and environmental risks posed by poor sanitation. This is consistent with Ogwueleka (2021), who found that Nigerian households often link poor waste disposal to increased incidence of diseases and contamination of environmental resources.

The perceived constraints to waste management shows the perceived constraints limiting proper waste management in Akure North. The overall mean score was $\bar{x}$ = 4.06 (SD = 1.07), which suggests that respondents strongly agreed with most of the listed challenges. The highest-ranked constraint was inadequate infrastructure ($\bar{x}$ = 4.26, SD = 1.01; 1st), followed by inefficient waste collection systems ($\bar{x}$ =

4.21, SD = 1.04; 2nd). Respondents also strongly emphasized corruption and lack of accountability ($\bar{x}$ = 4.15, SD = 1.06; 3rd) as well as high cost of waste management ($\bar{x}$ = 4.14, SD = 1.05; 4th). These results point to systemic issues in Nigeria's waste management sector, where institutional weaknesses and insufficient facilities remain pressing challenges. This is in line with Akinyemi et al. (2021), who found that inadequate infrastructure and poor collection systems are the most reported bottlenecks to sustainable waste management in Nigeria. On the other hand, constraints such as rapid population growth and urbanization ($\bar{x}$ = 3.93, SD = 1.11; 9th), limited resources ($\bar{x}$ = 3.89, SD = 1.12; 10th), and limited access to technology and innovation ($\bar{x}$ = 3.82, SD = 1.15; 11th) were ranked lowest. While still considered important, these were not perceived as immediate barriers compared to infrastructure and governance problems. This suggests that households recognize structural and political constraints more readily than demographic or technological factors. Nnaji and Okoro (2020) similarly reported that households often attribute poor waste management to visible problems like inadequate infrastructure and corruption rather than less tangible issues such as technology gaps or population pressure.

Adaptation strategies for improving waste management by respondents' perception indicated an overall mean score of $\bar{x}$ = 4.20 (SD = 1.03), showing that respondents strongly supported the listed strategies. The most highly ranked strategies were reduction of litter through reuse and recycling ($\bar{x}$ = 4.36, SD = 0.97; 1st), multiple use of items such as bags and containers ($\bar{x}$ = 4.32, SD = 0.99; 2nd), and minimizing waste generation by reducing packaging ($\bar{x}$ = 4.30, SD = 1.00; 3rd). These responses reflect a growing household recognition of simple, practical, and cost-effective strategies for minimizing waste. This finding is consistent with Ojo and Abiodun (2021), who observed that Nigerian households increasingly support reuse and recycling measures as sustainable alternatives to open dumping. The least endorsed strategies were incineration of garbage with magnetic separation ($\bar{x}$ = 4.00, SD = 1.09; 9th) and covering ashes after burning ($\bar{x}$ = 4.09, SD = 1.07; 8th). While still viewed positively, these were considered less feasible by households compared to recycling and reduction measures. This suggests that households prefer strategies that are practical and low-cost rather than those requiring specialized facilities or advanced technologies. Similar observations were made by Adamu et. al. (2020), who reported that while Nigerian communities recognize the potential of incineration and landfill engineering, adoption remains low due to infrastructural and financial limitations.

Regression analysis explains 32% of variance in awareness (R^2 = 0.32, F (4,115) = 13.6, $p < .001$). Education is the strongest and statistically significant predictor ($\beta = 0.45$, $p < .001$); a one-level increase in education is associated with an average 1.74-point increase in awareness on the 12–24 scale. Age has a small but significant negative effect ($\beta = -0.18$, $p = .03$). Gender and household size were not significant predictors

in the multivariate model. Overall, education emerges as the principal determinant of household awareness after controlling for other socio-economic factors (Ajibade & Oyediran, 2022; Oloruntoba et. al., 2020).

Conclusion and Recommendations

Waste management is a common practice among households in Akure North Local Government Area of Ondo State, Nigeria. Awareness and knowledge of waste management are relatively high among respondents but they are faced by constraints such as inadequate infrastructure, inefficient collection systems, and corruption limiting sustainable waste management in the study area. Strengthening public education and sensitization programs, Improvement of waste management infrastructure and collection systems, Promoting and supporting household-level waste reduction and recycling, enforcing existing waste management regulations and Investment in modern waste management technologies must be encouraged by individual households, communities and government agencies.

References

Adamu, A., Musa, H., & Ibrahim, T. (2020). Household perspectives on sustainable waste management in Nigeria: Opportunities and challenges. *Environmental Research and Public Health, 17(22), 1–12.*

Agwu, M. O. (2022): "Issues and challenges of solid waste management practices in port-harcourt city, Nigeria-a behavioural perspective." *American Journal of Social and Management Sciences*. 3.2 (2022): 83-92.

Ajibade, A., & Oyediran, S. (2022). Education and sustainable household waste management in Nigeria: Evidence from urban communities. *Journal of Sustainable Development in Africa, 24*(1), 112–126.

Akinbile, L. A., & Adisa, R. S. (2021). Socio-economic characteristics influencing waste disposal practices among households in Nigeria. *Journal of Environmental Management and Sustainability, 12*(3), 45–56.

Akinyemi, O. M., Adediran, A. O., & Aluko, O. O. (2021). Challenges of sustainable solid waste management in Nigeria: A review. *Environmental Management and Sustainable Development. 10*(2), 45–60.

Nnaji, C. C., & Okoro, C. V. (2020). Perceived barriers to effective waste management in Nigeria: Evidence from households. *Journal of Waste Management & Research, 38*(9), 1024–1035.

Odukoya, O.V., Arowolo, T. & Bamgbose, O. (2022). Effects of Solid Waste Landfill on Underground and Surface Water Quality at Ring Road, Ibadan, Nigeria. *Global Journal of Environmental Science, 1: 43-52.*

Ogwueleka, T. C. (2021). Public perception of health and environmental impacts of poor waste management in Nigeria. *Environmental Challenges. 4*, 100128.

Ojo, O., & Abiodun, A. (2021). Public attitudes towards recycling and sustainable waste practices in South-West Nigeria. *Journal of Environmental Studies and Sustainability, 5*(3), 89–101.

Oloruntoba, E. O., Adewumi, J. R., & Ilemobade, A. (2020). Household waste management practices in urban Nigeria: A gender perspective. *African Journal of Environmental Studies, 15*(2), 89–101.

Sheethal M. P & Shashikantha S. K. (2016): A cross-sectional study on the coverage and utilization of qsanitary latrine in rural field practice area of a tertiary care hospital in Southern Karnataka, India. *International Journal of Community Medical Public Health.* 3: 1540-1543.

Uchegbu, S. N. (2020). Environment, Sanitation, and Health. *Environmental Review Journal.* 206-214.https://www.researchgate.net/publication/269702413

Economic Analysis of Climate-smart Adaptation Strategies Adoption among Sugarcane Farmers in Niger State: Implications for Sustainable Agriculture

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Abstract

Climate change poses significant challenges to agricultural systems worldwide, including the sugarcane sector in Niger; therefore, there is a need to investigate the adoption of climate-smart adaptation strategies among sugarcane farmers in Niger State, the hub of sugarcane production, and explore the implications for sustainable agriculture. Specifically, we identified the climate-smart adaptation practices adopted by sugarcane farmers; analyzed the profitability of sugarcane in Niger State; and identified the constraints in the use of climate-smart adaptation practices in Niger State. The research employs the use of cross-sectional data from 120 sugarcane farmers drawn from a three-staged simple random sampling technique across Niger state. The data were analyzed using descriptive statistics, Gross margin analysis, and a Likert-type scale. The study reveals that sugarcane farmers in Niger State are experiencing adverse effects of climate change, which have led to reduced sugarcane yields and diminished farm incomes, threatening the livelihoods of farmers and the sustainability of the sugarcane industry in the region. Farmers thus are adopting various climate-smart adaptation strategies such as planting on wetlands, intercropping with vegetables, soil conservation techniques, and irrigation. The profitability analysis reveals a gross margin of 242,356.325 Naira/Ha of land cultivated. Challenges hindering the widespread adoption of climate-smart practices include limited access to information, inadequate access to improved seedlings and fertilizer, and limited access to credit. Policymakers, researchers, and stakeholders need to address these barriers and develop supportive policies and programs that incentivize and facilitate the adoption of climate-smart practices among sugarcane farmers.

Keywords: Climate change, Sugarcane, Sustainability, Adaptation strategies, Profitability analysis.

Introduction

One of the major issues facing small-scale farmers globally has been identified as climate change (Fekete, 2021). A change in climate will have a negative impact on the production and supply of food because climate influences the types and yields of crops and animals as well as the length of cropping seasons (Abbas et al, 2022). This limits the ability of agriculture to fulfill its primary role as a source of food. The

output and production of a farm may be impacted by climatic factors such as low precipitation, high temperatures, a growing desert, and less rainfall. Heat waves can lead to heat stress in both plants and animals, which has a detrimental effect on how much food is produced. Extremely hot spells are particularly detrimental to crop output.

Climate Smart Agriculture (CSA) was created as a solution. FAO reports that despite the potential advantages, the adoption of CSA techniques by farmers has been very modest worldwide (van Tilburg & Hudson, 2022). Thus, a variety of incentives have been implemented in several nations to encourage farmers to embrace CSA. It is crucial to use such tactics to guarantee the agricultural sector's long-term survival and protect farmers' way of life.

Due to its strategic position and numerous uses in both agriculture and industry, sugarcane is one of the most valuable commodities farmed worldwide. Its height ranges from two to six meters. Every species of sugarcane has the ability to interbreed, and the actual commercial cultivars are erratic cross-breeds. Throughout the world, sugarcane (Saccharum officinarum L.) is a significant crop for both sugar and bioenergy because of their high sensitivity to natural disasters, low adaptation capacity, inadequate forecasting capabilities, and lack of mitigation measures, developing nations are particularly predicted to suffer significant effects from climate change on sugarcane output (de Medeiros Silva et al., 2019).

Climate change-related increases in the frequency and severity of extreme environmental conditions may have had a negative impact on sugarcane production and will likely continue to do so (Gul et al., 2022). Geographical location and capacity for adaptation influence how much climate change will affect sugarcane. The adaptation of farming systems to climate change in sugarcane production requires taking advantage of the potential benefits and minimizing potential adverse impacts on crop production.

Therefore, a better understanding of the functions of these climate/weather factors and their impacts on sugarcane production can help manipulate plants to meet human needs and formulate adaptation or mitigation strategies. This research seeks to contribute to the existing body of knowledge by providing evidence-based recommendations and policy insights to foster climate-resilient and sustainable agricultural practices. Ultimately, the findings of this study are anticipated to facilitate informed decision-making among farmers, policymakers, and stakeholders, fostering a more resilient and sustainable future for the sugarcane sector in Niger State.

In line with the foregoing, this study seeks to answer the following pertinent questions:

a) What are the climate-smart adaptation practices used among sugarcane farmers in Niger State?
b) How profitable is sugarcane in Niger State?

c) What are the constraints in the use of climate-smart adaptation practices in Niger State?

Methodology

Study Area

The study area lies in Niger State, Nigeria (8°11′–11°20′ N, ~4°15′ E), covering approximately 4,240 km². It falls in the Guinea-savannah vegetation belt, with mean annual rainfall between 800 and 1,000 mm and 187–220 rainy days per year. The rainy season runs from late April to October (peak in July), followed by a six-month dry season from November to April. Average minimum and maximum temperatures are about 26 °C and 36 °C respectively, while relative humidity ranges from ~60 % (January–February) to ~80 % during June–September. The vegetation supports crops such as sugar-cane (chewing cane), rice, sorghum, millet, yam, groundnut and cotton.

Sampling Technique and Sample Size

The study targeted sugarcane farmers in Niger State. A three-stage random sampling technique was employed. In the first stage, Gbako and Bida LGAs were purposively selected for their high sugarcane production. In the second stage, three sugarcane-producing communities were chosen from the two LGAs. In the final stage, 41 respondents were selected from Bangie (Bida LGA), and 35 and 44 from Biramafu and Wuye Sakonba (Gbako LGA), respectively, totaling 120 farmers (Mohammed & Abdullahi, 2022).

Source of Data

The study relies on Primary data obtained by the use of Semi-structured questionnaire deployed by the kobo toolbox app on android phones.

Data Collection

Primary data were collected from 120 farmers using semi-structured questionnaires, personal interviews, and direct observation. The data covered farmers' socio-economic characteristics, perceptions of climate change, climate-smart adaptation practices, and constraints to their adoption.

Analytical Techniques

In the course of this study, the following analytical techniques were used:

Descriptive Statistics

Descriptive statistics was used to analyze the climate-smart adaptation practices used by the respondents. This was done by using mean, range, percentages, and frequency distribution.

Gross Margin Analysis

Gross margin analysis was used to determine the profitability of sugarcane production in the study area.

GM=TR-TVC

Where,

GM=Gross margin

TR= Total revenue

TVC= Total variable cost

Likert Type Scale

Likert scale was employed to determine the constraints in the use of climate-smart agricultural practices in the study area. Tambo et al., 2021)

Results and Discussions

Climate Smart Adaptation Practices (CSAP) Adopted by Sugarcane Farmers

Table 1 shows the climate-smart adaptation practices used by sugarcane farmers in the study area. The result shows that the use of wetlands is the most used CSAP, it has the highest mean score of 3.83 followed by intercropping with vegetables, next to that is soil conservation technique, the use of organic manure, followed by irrigation, crop rotation, planting of early maturing varieties, planting drought and heat tolerant varieties, planting of stress-tolerant varieties, planting of disease resistance varieties, followed by mulching which can be deduced from the data that it is not used by sugarcane farmers in the study area

In any production process, costs are incurred in the production of output and returns are obtained from sales of such output produced. Table 2 present the cost and returns associated with the production activities of the farmers on per hectare basis. The cost includes the variable costs contributing by labor, fertilizer and herbicides.

Table 1: Climate Smart Adaptation Practices

PRACTICES	AU F (%)	OU F (%)	RU F (%)	NU F (%)	Score	MS
Use of wetland	99(82.5)	21(17.5)	0(0)	0(0)	459	3.83
Intercropping with vegetables	96(80.0)	22(18.3)	1(0.8)	1(0.9)	453	3.78
Soil Conservation Technique	68(56.7)	51(42.5)	1(0.8)	0(0)	427	3.56
Irrigation	67(55.8)	51(42.5)	2(1.7)	0(0)	425	3.54
Use of organic manure	22(18.3)	55(45.8)	42(35.0)	1(0.9)	338	2.82
Crop Rotation	7(5.8)	34(28.3)	76(63.3)	3(2.6)	285	2.38
Planting of early-maturing varieties	0(0)	3(2.5)	65(54.2)	52(43.3)	191	1.59
Planting Drought and Heat-Tolerant Varieties	0(0)	5(4.2)	57(47.5)	58(48.3)	187	1.56
Planting of stress-tolerant varieties	0(0)	5(4.2)	34(28.3)	81(67.5)	164	1.37
Planting of disease-resistant varieties	0(0)	0(0)	22(18.3)	98(81.7)	142	1.18
Mulching	0(0)	0(0)	0(0)	120(100)	120	1.00

Table 2 shows the cultivation of a hectare of land of sugarcane yielded an average gross margin of ₦96,942.53, while the total cost incurred was ₦71,804.94. The major variable costs incurred by the respondents were cost of hired labor, herbicides and fertilizer. The result also reveals that the average return to investment was ₦2.20. Thus, the results shows that sugarcane production in the study area was very profitable. (Adedeji et al. 2023) reported similar profitability margins among sugarcane and maize farmers in Nigeria using gross margin analysis. Profitability has been linked to improved access to input resources and efficient farm management practices (Enete & Onyekuru, 2020).

Constraints to Adopting Climate Smart Adaptation Practices in the Study

The major constraints were identified and ranked in descending order as presented in table 3. Inadequate information was ranked the first constraint to the practice of climate-smart adaptation practices having the highest mean score of 3.78 followed by the unavailability of improved seed, having the mean score of 3.77. High cost of fertilizer having the mean score of 3.58 was next and inadequate water for irrigation also have the mean score of 3.29 followed by inadequate funds having 3.25 while unavailability of extension workers having the mean score of 3.14 followed by inadequate access to credit facilities having the mean of 2.98 followed by unavailability of labor having the mean score of 2.76 followed by transportation access having the mean score of 2.30 followed by shortage of land which has the least mean score of 1.98. Inadequate information was identified as the major constraint to the practice of climate-smart smart in the study area

Table 2: Gross Margin Analysis

Variables	Value (₦)
Total Revenue (TR)	158,060.42
Variable Costs (VC)	
Cost of fertilizer	14,100.00
Cost of labor	22,720.83
Cost of pesticide	2,537.50
Cost of herbicide	12,562.50
Cost of seed/cultivars	0
Cost of transportation	3,518.98
Cost of Maintenance	5,678.08
Total Variable Cost (TVC)	61,117.89
Total Fixed Cost	10,687.05
Total Cost	71,804.94
Gross margin (TR-TC)	96,942.53
Net Farm Income (GM-TFC)	86,255.48
Operation ratio	0.45
Return to investment on ₦1 invested TR/TC	2.20

Table 3: Constraints to Adopting Climate Smart Adaptation Practices in the study

Constraints	VS F (%)	S F (%)	LS F (%)	NS F (%)	Score	MS
Inadequate Information	97(80.)	20(16.7)	3(2.5)	0(0)	**454**	**3.78**
Unavailability of improved seed	94(78)	24(20.)	2(1.7)	0(0)	**452**	**3.77**
High Cost of Fertilizer	76(63.3)	38(31.7)	5(4.2)	1(0.8)	**429**	**3.58**
Inadequate water for irrigation	52(43.3)	52(43.3)	15(12.5)	1(0.9)	**395**	**3.29**
Inadequate Funds	35(29.2)	80(66.7)	5(4.1)	0(0)	**390**	**3.25**
Unavailability of extension workers	52(43.3)	44(36.7)	13(10.8)	11(9.2)	**377**	**3.14**
Inadequate access to credit facilities	22(18.3)	73(60.8)	25(20.9)	0(0)	**357**	**2.98**
Labor unavailability	12(10.0)	70(58.3)	35(29.2)	3(2.5)	**331**	**2.76**
Transportation Access	12(10.0)	32(26.7)	56(46.7)	20(16.6)	**276**	**2.30**
Shortage of Land	3(2.5)	20(16.7)	69(57.5)	28(23.3)	**238**	**1.98**

Conclusion

Sugarcane production is very profitable in Niger state. Cultivation on wetlands is the most important CSAP adopted in the study area. The major constraints identified by the sugarcane farmers in the study area were: inadequate information, unavailability of improved seed, high cost of fertilizer, and inadequate water for irrigation. The unavailability of extension workers is also one of the major constraints to the use

of CSAPs in the study area. Hence interventions that would enhance the adoption of CSAPs in the study area should be intensified.

References

Abbass, K., Qasim, M. Z., Song, H., et al. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research, 29*(32), 42539–42559. https://doi.org/10.1007/s11356-022-19718-6

Adedeji, O. A., Oladele, O. I., & Saka, J. O. (2023). Profitability and resource use efficiency among smallholder maize farmers in Nigeria. *Journal of Agricultural Extension and Rural Development, 15*(1), 12–22. https://doi.org/10.5897/JAERD2022.1311

Adewuyi, S. A., Omotesho, O. A., & Bello, M. (2021). Adoption of climate-smart agricultural practices among smallholder farmers in Nigeria. *Agricultural Economics Review, 22*(1), 45–59.

Adedeji, O. A., Oladele, O. I., & Saka, J. O. (2023). Profitability and resource use efficiency among smallholder maize farmers in Nigeria. *Journal of Agricultural Extension and Rural Development, 15*(1), 12–22.

Amadu, F. O., McNamara, P. E., & Miller, D. C. (2020). Understanding the adoption of climate-smart agriculture: A synthesis of studies in sub-Saharan Africa. *Agriculture, 10*(5), 180. https://doi.org/10.3390/agriculture10050180

Ayanlade, A., & Radeny, M. (2020). COVID-19 and food security in sub-Saharan Africa: Implictions of lockdown during agricultural planting seasons. *npj Climate and Atmospheric Science,3*(27). https://doi.org/10.1038/s41612-020-00161-0

Chandiposha, M. (2013). Potential impact of climate change on sugarcane and mitigation strategies in Zimbabwe. *African Journal of Agricultural Research, 8*(24), 2814–2818.

De Carvalho, A. L., Menezes, R. S. C., & Nobrega, R. S. (2015). Impact of climate changes on potential sugarcane yield in Pernambuco, northeastern Brazil. *Renewable Energy, 78*, 26–34.

Enete, A. A., & Onyekuru, A. N. (2020). Economic analysis of cassava-based farming systems in southeastern Nigeria. *Journal of Agriculture and Food Security, 5*(2), 85–98.

FAO. (2014). *Climate-smart agriculture sourcebook*. Food and Agriculture Organization of the United Nations.

Gul, A., Chandio, A. A., Siyal, S. A., Rehman, A., & Xiumin, W. (2022). How climate change is impacting major crops in Pakistan: An exploration from long- and short-run estimation. *Environmental Science and Pollution Research, 29*(18), 26660–26674.

Kassie, M., Teklewold, H., Marenya, P., Jaleta, M., & Erenstein, O. (2020). Understanding the adoption of multiple sustainable agricultural practices in sub-Saharan Africa. *Land Use Policy, 99*, 104856. https://doi.org/10.1016/j.landusepol.2020.104856

Mohammed, A., & Abdullahi, A. (2022). Socioeconomic determinants of smallholder farmers' participation in climate-smart agriculture in northern Nigeria. *African Journal of Agricultural and Resource Economics, 17*(1), 112–126.

Nnadi, F. N., Chikaire, J., & Egwu, G. E. (2021). Factors affecting adoption of climate-smart agricultural practices among smallholder farmers in Nigeria. *Journal of Agricultural Extension, 25*(3), 52–61.

Ozor, N., Eboh, E. C., & Madukwe, M. (2020). Profitability and constraints to adaptation strategies among farmers in sub-Saharan Africa. *Journal of Climate Change and Development, 6*(2), 45–58.

Shiferaw, B., Tesfaye, K., & Kassie, M. (2022). Climate-smart agriculture in Africa: Emerging evidence on impacts and pathways. *Agricultural Systems, 200*, 103419. https://doi.org/10.1016/j.agsy.2022.103419

Tambo, J. A., Wünscher, T., & Owusu, E. S. (2021). Adoption of climate-smart agricultural practices in Africa: Evidence from Ghana. *Food Policy, 102*, 102038. https://doi.org/10.1016/j.foodpol.2021.102038

Tessema, I., Simane, B., & Adgo, E. (2021). Determinants of climate-smart agriculture adoption and its impact on household income: Evidence from Ethiopia. *Environment, Development and Sustainability, 23*(9), 13410–13427.

Van Tilburg, A. J., & Hudson, P. F. (2022). Extreme weather events and farmer adaptation in Zeeland, The Netherlands: A European climate change case study. *Science of the Total Environment, 844*, 157212. https://doi.org/10.1016/j.scitotenv.2022.157212

The Impact of Climate Fluctuations on Poultry Farming in Kwara State, Nigeria

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Abstract

Climate fluctuation is a long-lasting alteration in the average values of climate factors such as temperature, rainfall, humidity, and soil moisture, resulting from alterations in the composition of atmospheric gases. Livestock production, particularly the poultry industry, is being endangered by climate fluctuations. This study examined the impact of climate fluctuation on poultry production in Kwara State. The specific objectives were to assess the level of awareness of climate fluctuations, information sources, perception of the effect of climate fluctuations and measures to mitigate the effect of climate fluctuations by the farmers. One hundred and fifty poultry farmers were sampled for this study. Data were collected with interview schedule, described with frequencies and percentages, and analyzed with Pearson's Product Moment Correlation. Result shows that 86.9% of the farmers were male, 76.9% were married, 92.3% had tertiary education, 53.8% had poultry farming as their primary occupation with 10 years mean year of experience, 69.2% had their source of capital from self. Majority of the farmers were aware of high temperature, varying rainfall pattern and high rainfall intensity. Television, family and friends, and radio were the major sources of information of the respondent. The main impact of climate fluctuation were higher disease outbreaks, high cost of feeding, and high maintenance costs. Well-ventilated housing, more space per birds and more water served are the major strategies to address the effect of climate fluctuation. There is a significant relationship between the sources of information and the level of awareness of climate fluctuation by the farmers ($r = 0.368$, $P = 0.021$). The study concluded that the poultry farmers should be up to date on information on climate change and its effect as well as the strategies to mitigate the effect so as to increase poultry production thereby contributing to food security in the country.

Keywords: Climate Fluctuation, Coping Strategies, Poultry Farming, Livestock Production

Introduction

Poultry farming remains one of the most accessible and economically significant forms of livestock production in Nigeria. It serves as a vital source of income, nutrition, and employment for a large segment

of the population, particularly in urban and peri-urban areas where demand for animal protein continues to grow (Abadula et al., 2022). In recent years, the poultry sector has experienced considerable growth due to increasing investments, improved breeding techniques, and expanding markets. However, this progress is now under serious threat from the growing influence of climate fluctuations. Changes in climatic conditions, such as irregular rainfall patterns, rising temperatures, prolonged dry spells, and sudden shifts in humidity pose significant challenges to poultry farming systems (Ngongolo & Mrimi, 2024). These environmental stressors can affect birds' physiological functions, reduce feed efficiency, increase susceptibility to diseases, and lead to higher mortality rates (Oke et al., 2024). Consequently, climate variability has the potential to destabilize poultry productivity and threaten the livelihoods of farmers who rely on it for economic survival.

Kwara State, especially the Ilorin area, has become a notable hub for poultry farming due to its favorable market access, availability of inputs, and the concentration of experienced farmers. Yet, despite its strategic importance, many poultry farmers in the region continue to struggle with the unpredictable nature of weather conditions, often without adequate information or coping strategies (Ifabiyi et al., 2024). It is therefore essential to understand how farmers perceive the impact of climate fluctuations on poultry production, as perception often shapes response and adaptation. This study was conducted to investigate poultry farmers' perceptions of the effects of climate fluctuations on poultry production in Ilorin, Kwara State. Specifically, the study assessed the socioeconomic characteristics of the poultry farmers; ascertained their awareness of climate fluctuations; identified their sources of information on climate fluctuations; described farmers perceived effects of climate variation on poultry production; and isolated strategies employed in mitigating the effects of climate fluctuations on poultry production.

Methodology

The study was conducted in Ilorin, Kwara State, focusing on poultry farmers in the three metropolitan LGAs: Ilorin East, Ilorin West, and Ilorin South, selected for their high concentration of poultry farms. Using a multistage sampling technique, eleven towns across the LGAs were selected, and a total sample of 154 small- and medium-scale poultry farmers involved in broiler and layer production was obtained through purposive and snowball sampling. Primary data were collected using a structured interview schedule. The data were analyzed using descriptive statistics (such as frequencies and percentages) to summarize key variables, while Chi-square was used to test the relationship between farmers' socioeconomic characteristics and their climate adaptation strategies, with all analyses carried out using SPSS version 25.

Results and Discussion

Socioeconomic Characteristics of the Respondents

Table 1 indicates that majority (80.5%) of the respondents were male with a mean age of 47years, corroborating Bullock (2023) showing the more men are involved in livestock production activities than women. It also shows that 76.9% of the respondents were married showing the significance of the enterprise in meeting family needs and welfare. Majority (87.5%) of the poultry farmers had tertiary education implying that most of the respondents were educated enough to avail themselves with information on climate fluctuation and its adaptive strategies. However, low income as 3.7% of the poultry farmers make less than 50,000 annually from poultry enterprise and it is mostly self-financed (69.2%) rather than relying on external financing. This might be due to the challenges in accessing external funding.

Awareness of climate fluctuations

Table 2 shows that a fluctuation in climate is obvious and needs no second guessing. Poultry keepers were aware of higher temperature (100%), irregular rainfall pattern (92.3%), high rainfall intensity (91.8%), prolonged dry season (84.6%) and unfamiliar disease symptoms (53.8%). This agrees with Pianta and Sisco (2020) who reported that climate change revolve around high temperature and irregular rainfall.

Sources of information

The results in Table 3 show that poultry farmers in the study area obtain information on climate fluctuations from several sources, with other poultry farmers being the most common source (93.2%), followed closely by the internet (88.1%). Television (69.2%) and family and friends (68.2%) were also frequently used, while radio (61.5%) and print media (53.8%) played moderate roles. Extension workers were the least reported source (38.5%), indicating limited contact with formal agricultural advisory services. This opposes the findings of Popoola et al., (2020) who reported that the internet was not a popular source of information on climate change.

Table 1: Socioeconomic Characteristics of the Respondents

Variables	Frequency	Percentage
Sex		
Male	124	80.5
Female	30	19.5
Age		
≤30	1	0.7
30-45	51	33.1
46-60	99	64.2
>60	3	2
Mean= 47.25years		
SD= 6.32		
Marital Status		
Single	24	15.4
Married	118	76.9
Divorced	12	7.7
Education		
No formal Education	3	1.8
Primary	5	3.5
Secondary	11	7.2
Tertiary	135	87.5
Annual Income		
<50,000	6	3.7
50,001-100,000	47	30.8
100,001-150,000	18	11.7
>150,000	83	53.8
Source of Capital		
Self	106	69.2
Family and friends	16	10.3
Loan	32	20.5

(Source: Survey, 2025)

Table 2: Awareness of climate fluctuations

Variables	Frequency	Percentage (%)
Awareness of high temperature within the farm	154	100
Awareness of irregular rainfall pattern	142	92.3
Awareness of high rainfall intensity	141	91.8
Awareness of prolonged dry season	130	84.6
Awareness of unfamiliar disease symptoms within the birds	83	53.8

Table 3: Sources of information

Variables	Frequency	Percentage (%)
Other poultry farmers	144	93.2
Internet	136	88.1
Television	107	69.2
Family & Friends	105	68.2
Radio	95	61.5
Print media	83	53.8
Extension workers	59	38.5

(Source: Survey, 2025).

Effects of climate variation on poultry production

Table 4 shows that the climate fluctuations have a significant effect on various aspects of poultry production. Specifically, the highest reported effects are increased feed intake, high feeding costs, and a high rate of disease occurrence. These factors can all contribute to challenges in maintaining poultry health and productivity, ultimately affecting the profitability and sustainability of poultry farming operation. This implies that the farmers need to be prepared to manage these challenges effectively. Additionally, the relatively lower reported effect of feed wastage implies that while it is still a concern, it may be perceived as less significant posed by climate fluctuations in poultry production.

Table 4: Perception of the effects of climate variation on poultry production

Variable	SD	D	A	SA	Mean
Increased feed intake	0(0)	4(2.3)	56(36.4)	94(61.3)	3.58
High feeding cost	0(0)	12(7.7)	47(30.8)	95(61.5)	3.54
High rate of disease outbreaks	2(1.1)	4(2.8)	68(44.1)	80(52.0)	3.47
Resistance to treatment	4(2.3)	8(5.4)	95(61.5)	47(30.8)	3.20
low productivity	0(0)	5(3.5)	113(73.4)	36(23.1)	3.20
High maintenance costs	0(0)	12(7.7)	118(76.9)	24(15.4)	3.08
Wastage of feed	2(1.3)	45(29.5)	71(46.2)	36(23.1)	2.92

(Source: Survey, 2025) *SD-Strongly Disagree, D-Disagree, A-Agree, SA-Strongly Agree*

Strategies for Controlling Effects of Climate Fluctuations on Poultry Production

The findings in Table 5 indicates that poultry farmers employ various strategies to reduce the negative effects of climate fluctuations on production. The most commonly adopted measures include providing well-ventilated housing (98.2%), creating more space per bird (92.3%), and supplying more water to birds (91.2%), showing strong emphasis on improving comfort and reducing heat stress. Additionally, many farmers maintain better hygiene (88.9%), plant shades around poultry pens (84.6%), and reduce heat exposure within housing (84.6%). Less commonly practiced strategies include changing feed formulation (61.5%) and use of chemotherapy (53.8%), indicating that while farmers prioritize environmental and managerial adjustments, fewer rely on nutritional or medical interventions. This is in line with Vandana et al., (2021) who reported that with well-ventilated shelter design providing shading, cooling device and good ventilation, birds may be more vulnerable to climate change.

Table 6 shows the relationship between measures used in controlling effects of climate variation and some socioeconomic characteristics of the respondents. Age and education level were significantly related to strategies in controlling effects of climate fluctuation. This is in line with the findings of Clayton and Karazsia (2020) which implied that age and education level is a determinant of how an individual will be exposed to various ways of controlling the effects of climate change.

Table 5: Strategies for controlling effects of climate fluctuations on poultry production

Variables	Frequency	Percentage
Provision of a well-ventilated housing	151	98.2
Provision of more space per bird	142	92.3
More water should be served to the birds	140	91.2
Provision of better hygiene	137	88.9
planting of shades around pens	130	84.6
supply of less heat to the birds	130	84.6
Change in feed formulation	95	61.5
Chemotherapy	83	53.8

(Source: Survey, 2025)

Table 6: Relationship between socioeconomic characteristics of respondents and strategies in mitigating climate fluctuation

Variables	Chi-square value	Df	Significance	Remark
Sex	22.012	1	0.721	NS
Age	82.127	3	0.000	S
Education	75.233	2	0.000	S

df= degree of freedom; S= Significant; NS= Not Significant, Significant at p<0.05.
(Source: Survey, 2025)

Conclusion and Recommendations

The study concluded that majority of poultry farmers in Ilorin, Kwara State were male, married and educated. Most of them were aware of high temperature, irregular rainfall pattern, and high rainfall intensity. Some of the effects of climate variation on poultry production are increase in feed intake, high feeding cost and high rate of disease outbreak. These adverse effects of climate variation were mitigated in poultry production through provision of a well-ventilated housing, provision of more space per birds, and serving of more water to the birds.

The study therefore recommends that poultry farmers should be well informed on the best practices to reduce the adverse effect of climate change on poultry enterprise through research and extension, using appropriate communication channels to ensure optimum production. Efforts should be made to reduce human activities that contribute to climate change.

References

Abadula, T. A., Jilo, S. A., Hussein, J. A., & Abadura, S. Z. (2022). Poultry production status, major constraints, and future prospective. *Journal of World's Poultry Science*, *1*(1), 22-28.

Bullock, R. M., Miriti, P., & DuttaGupta, T. (2023). Young women's and men's climate adaptation practices and capacities in Kenya livestock production systems. *Frontiers in Sustainable Food Systems*, 7, 1197965.

Clayton, S., & Karazsia, B. T. (2020). Development and validation of a measure of climate change anxiety. Journal of environmental psychology, 69, 101434.

Ifabiyi, J. O., Banjoko, I. K., Shuaib, O. M., Komolafe, S. E., & Oladejo, A. O. (2024). Status of climate smart poultry production practices in Kwara State, Nigeria. *SVU-International Journal of Agricultural Sciences*, *6*(3), 14-23.

Ilorin Atlas, (1958). Geography Department University of Ilorin.

Jimoh, H. I., (2003). Erosion Tolerance Range of Land use surfaces: Implication on Land Resource use and Management Techniques in Ilorin Nigeria. *Int. J. Environ. Stud*., 60: 446.

Ngongolo, K., & Mrimi, D. (2024). Climate change and poultry production: Enhancing resilience and sustainability through climate-smart practices, a review. *Berkala Penelitian Hayati*, *30*(3), 116-124.

Oke, O. E., O. A. Akosile, A. I. Oni, I. O. Opowoye, C. A. Ishola, J. O. Adebiyi, A. J. Odeyemi, B. Adjei-Mensah, V. A. Uyanga, and M. O. Abioja (2024):. "Oxidative stress in poultry production." *Poultry Science* 104003.

Pianta, S., & Sisco, M. R. (2020). A hot topic in hot times: how media coverage of climate change is affected by temperature abnormalities. *Environmental Research Letters,* 15(11),114038.

Popoola, O. O., Yusuf, S. F. G., & Monde, N. (2020). Information sources and constraints to climate change adaptation amongst smallholder farmers in Amathole District Municipality, Eastern Cape Province, South Africa. *Sustainability*, 12(14),5846.

Vandana, G. D., Sejian, V., Lees, A.M., Pragna, P., Silpa, M. V., & Maloney, S.K. (2021). Heat stress and poultry production: impact and amelioration. *International Journal of Biometeorology*, 65,163-179.

Maize Farmers' Access to Extension Service Delivery in Selected Local Government Areas of Kebbi State, Nigeria.

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Abstract

The study was conducted to examine maize farmers' Access to Extension Service delivery in selected Local Government Areas in Kebbi State, Nigeria. The objectives of the study were to describe the socio-economic characteristics of Maize farmers, ascertain sources of information, and identify constraints to maize farmers' access to extension service delivery in the study area, as well as factors that influence maize farmers' access to extension information. A three-stage sampling technique was employed in selecting one hundred and fifty respondents. A questionnaire was designed, and the results were subjected to both descriptive (frequency counts, percentages, mean, and standard deviation) and inferential (linear Regression Analysis) statistical analysis. Simple. The results showed that the primary source of information was through religious leaders (99.30%) and neighboring communities (98.6%). Government policies have the highest mean value of 3.64 as a constraint that hinders access to extension services among Maize farmers in the study area. The regression analysis indicated that farm size positively and significantly affects access to extension services. The major challenges were government policies, climate change, and high cost of farm inputs. We recommend that the Government and NGOs work to improve the accessibility of extension services. This can be achieved by hiring more extension agents, enhancing their training, and ensuring that extension services reach rural farmers regularly. The government should review agricultural policies to make them more farmer-friendly and provide financial support, such as subsidized inputs and easy access to credit facilities, to reduce financial burdens and encourage greater participation in agriculture.

Key words: Maize Farmers, Access, Extension Service Delivery, Food Security gand Constraints.

Introduction

Maize is a vital crop in Nigeria, serving as a staple food and a source of income for many farmers (CBN, 2019). However, maize production in Nigeria faces numerous challenges, including low yields, limited adoption of improved technologies, and poor access to markets (Adegbola et al., 2017). Effective extension service delivery is crucial for tackling these challenges and boosting maize productivity. Extension services are essential in spreading improved maize production techniques. Nonetheless,

maize farmers in Nigeria, especially in Zuru, Kebbi State, encounter significant obstacles in accessing extension services (Kebbi State Agricultural Development Project, 2018). Research shows that limited access to extension services is a key barrier to maize production in Nigeria (Adegbola et al., 2017; Ogunsumi & Akinbode, 2015). Factors like insufficient funding, limited personnel and infrastructure, poor communication and outreach, and ineffective service systems hinder the delivery of extension support to maize farmers (Ogunsumi & Akinbode, 2015). Agricultural extension services are vital for sharing information, technologies, and innovations that can improve farmers' productivity and income. These services are especially important for smallholder farmers who often lack access to the latest farming knowledge and techniques. In Nigeria, maize is a major crop grown widely across many states, including Kebbi. Despite its importance, maize farmers in this region face numerous hurdles, such as low yields, limited access to quality seeds, and inadequate extension support. Kebbi State is mainly an agricultural region, with a large portion of its population engaged in maize farming, which makes maize production in Kebbi State is crucial for food security and economic development. But these farmers need access to extension services since this is the only means by which they can be educated on innovation to boost their production. This study aims to explore maize farmers' access to extension services in selected local government areas of Kebbi State, highlighting gaps and opportunities for improvement. This study seeks to address these issues through targeted research questions. What are the socio-economic characteristics of the maize farmers in the study area? ii. What are the available sources to access extension information by maize farmers? iii. What are the constraints hindering maize farmers' access to extension service delivery in the study area? The general objective of this study is to examine maize farmers' access to extension service delivery in Kebbi State, Nigeria. The specific objectives ofthis research are to: describe the socio-economic characteristics of the maize farmers in the study area. ii. What are the available sources to access extension information for maize farmers? iii. Identify the constraints hindering maize farmers' access to extension service delivery in the study area?

Ho: There is no significant relationship between socio-economic characteristics of the respondents and access to extension services.

Methodology

The study was conducted in Kebbi State, which is located in the northwestern part of Nigeria. Kebbi State is known for its agricultural activities, with crops such as maize, rice, and sorghum being the main agricultural products in the region. The population for this study comprises all maize farmers in the selected study areas. A three-stage sampling technique was used for this study. The first stage was the purposive selection of two (2) Local Governments that are well into maize production in Kebbi State, which are Zuru and Yauri Local Government Areas, Kebbi State. The second stage is the random

selection of five (5) communities from each of the selected local government areas. In the third stage, fifteen (15) respondents were selected from the ten communities to make a sample size of one hundred and fifty (150) respondents used for this study. Data was collected with the aid of a structured questionnaire. The instrument for data collection was closely examined by experts in the field of Agricultural Economics and Extension Services at Kwara State University to ensure face, content, and structural validity. The test-retest method was employed to determine the reliability of the instrument for data collection. The process was repeated after two weeks, and the correlation coefficient of r=0.8 was obtained, and enough to ascertain the reliability of the instrument for data collection.

The dependent variable of the study was the constraint hindering maize farmers' access to extension service delivery. This was measured using a four-point rating scale. (Not a constraint =1, Not severe=2, Severe=3, Very severe=4). Scores were aggregated, and a mean was generated, which was ranked and adopted as a measure of the severity of the challenges hindering extension service delivery. The independent variables were measured as follows: Socio-economic Characteristics and available sources of information were highlighted, and respondents were required to indicate the sources available to them, on a dichotomous scale graduated as Yes=1, No=0**.** Data collected from the field survey was subjected to both descriptive (frequency counts, percentages, mean, and standard deviation) and inferential statistical (Multiple linear Regression Analysis) to test the hypothesis of the study.

The mean age of 48 years implies a middle-aged farming population. The largest age group is 41-50 years (32.2%). This aligns with findings from the National Agricultural Extension and Research Liaison Services (NAERLS) 2023 report, which noted an aging farming population in Nigeria.

The average farm size of 4 hectares suggests predominantly smallholder farming, which is typical in Nigeria. This implies a need for extension services tailored to small-scale farming operations.

With an average of 18 years of experience, these are seasoned farmers, suggesting that extension services should leverage this experience while introducing innovations.

Result from Table 2 shows the respondents' sources of information for agricultural practices. Religious leader's rank 1st as the major source of information to the maize farmers in the study area. This implies that extension services should consider partnering with religious leaders to enhance message delivery and adoption of agricultural practices. Neighboring communities' rank 2nd and the high reliance on neighboring communities suggests strong social networks among farmers. Extension services could leverage these networks for peer-to-peer learning and demonstration effects. Family & friends and Government agencies both rank 3rd. The equal importance of family and government agencies is noteworthy. The role of family aligns with (Mgbakor et al. 2023), who emphasized the influence of

family networks in Nigerian agriculture. For government agencies, this high ranking suggests that official channels are reaching farmers effectively.

Table 1: Distribution of the respondents based on their socio-economic characteristics

Variables	Frequency	Percentage	Mean score	Standard deviation
Sex				
Male	61	41.8		
Female	85	58.2		
Age				
20-30	20	13.7	48years	12.4
31-40	20	13.7		
41-50	47	32.2		
51-60	35	24.0		
>60	24	16.4		
Marital Status				
Single	19	13.0		
Married	107	73.3		
Separated	8	5.5		
Widowed	12	8.2		
Level of education				
No formal education	32	21.9		
Primary	25	17.1		
Secondary	49	33.6		
Tertiary	40	27.4		
Household size				
1-5	84	57.5	5persons	3.17
6-10	53	36.3		
11-15	9	6.2		
Farm size(hectares)				
1-3	67	46.2	4hectares	1.24
4-6	78	53.8		
Types of farming				
Small holder	8	5.5		
Large-scale	105	71.9		
Subsistence	24	16.4		
Commercial	9	6.2		
Farming experience				
1-10	34	23.4	18years	9
11-20	62	42.8		
21-30	49	33.8		
Occupation				
Farming	109	74.7		
Trading	23	15.8		
Civil servant	12	8.2		
Business man/woman	2	1.4		
Farmers Association				
Yes	69	47.3		
No	77	52.7		
Annual Income				
100,000-500,000	10	6.8	N1,306,466	1049250.734
500,001-1,000,000	85	58.2		
1,000,001-5,000,000	51	34.9		

Source: Field survey, 2024

Table 2: Distribution of the respondent based on their sources of information on extension services

Sources	Yes F(%)	No F(%)	Rank
Religious leaders	145(99.3)	1(0.7)	1st
Neighboring Communities	144(98.6)	2(1.4)	2nd
Government Agencies	142(97.3)	4(2.7)	3rd
Community leaders	141(96.6)	5(3.4)	4th
Radio	141(96.6)	5(3.4)	4th
Non-governmental Organization (NGO)	139(95.2)	7(4.8)	5th
Private companies	132(90.4)	14(9.6)	6th
Television	123(84.2)	23(15.8)	7th
Internet	92(63.0)	54(37.0)	8th

Source: Field survey, 2024

Table 3: Distribution of the respondents based on the constraints hindering access to extension services

Constraints	NC F (%)	NS F (%)	S F (%)	VS F (%)	Mean	Rank
Government policies	3(2.1)	2(1.4)	39(26.7)	102(69.9)	3.64	1st
Climate change	2(1.4)	6(4.1)	41(28.1)	97(66.4)	3.60	2nd
High costs of farm inputs	2(1.4)	4(2.7)	48(32.7)	92(63.0)	3.58	3rd
Climate change and environmental challenges	0(0.0)	8(5.5)	62(42.5)	76(52.1)	3.47	4th
Limited exposure and awareness	6(4.1)	8(5.5)	44(30.1)	88(60.3)	3.47	4th
Segregation between male and female farmers	5(3.4)	12(8.2)	44(30.1)	85(58.2)	3.43	6th
Ineffective extension service	2(1.4)	25(17.1)	30(20.5)	89(61.0)	3.41	7th
Poor access to credit	2(1.4)	6(4.1)	77(52.7)	61(41.8)	3.35	8th
Religious and traditional beliefs	4(2.7)	2(1.4)	86(58.9)	54(37.0)	3.30	9th
Socio-cultural constraints	8(5.5)	9(6.2)	62(42.5)	67(45.9)	3.29	10th
Poor access to production facilities	0(0.0)	12(8.2)	114(78.1)	20(13.7)	3.05	13th
Presence of bottle-necks in accessing agro-credits	0(0.0)	4(2.7)	132(90.4)	10(6.8)	3.04	14th
Lack of access roads and means of transportation	4(2.7)	8(5.5)	115(78.8)	19(13.0)	3.02	15th
Inadequate extension Workers/Agents	4(2.7)	6(4.1)	119(81.5)	17(11.6)	3.02	15th

Source: Field survey, 2024 NC = Not a constraint, NS = Not severe, S = Severe, VS = Very severe

Government policies ranked 1st as a major challenge, and the top ranking as a challenge aligns with Adedoji et al. (2023) study, which highlighted how ineffective policies can hinder extension service delivery. This suggests a critical need for policy reform to better support extension services and farmers. Climate change ranks 2nd, reflecting the growing impact of environmental factors on agriculture. Extension services need to incorporate climate-smart agricultural practices and provide farmers with strategies to adapt to changing climatic conditions. The high cost of farm inputs ranks 3rd, and its significance on extension service delivery is noteworthy. This implies that there's a need for interventions to make farm inputs more affordable, possibly through subsidies or cooperative purchasing schemes.

The size of the farm land has a positive and significant impact on access to extension services. Farmers with larger farms may have more resources and opportunities to access such services. This finding aligns with existing literature, which suggests that larger-scale farmers are more likely to have access to extension services due to their commercial farming orientation and capacity to implement the advice provided (Mwangi & Kariuki, 2015). The Type of farming has a negative relationship, suggesting that certain types of farming are associated with greater constraints in accessing extension services. For instance, subsistence farmers may face more challenges compared to commercial farmers. This could be due to the lack of specialized extension programs targeted at smallholder or subsistence farmers (Melesse, 2018).

Table 4: Linear regression showing the relationship between socio-economic characteristics of the respondents and constraints hindering access to extension services.

Predictors	Standardized Coefficients		t	Sig.
	B	Std. Error		
(Constant)	55.759	3.672	15.187	.000
Age	.141	.043	1.434	.154
Sex	.039	.968	.446	.656
Marital status	.056	.745	.573	.567
Level of education	-.035	.407	-.421	.674
Household size	-.145	.149	-1.665	.098
edFarm size	.234	.346	2.909	.004
Type of farming	-.299	.710	-3.560	.001
Farming experience	.021	.061	.213	.831
Annual income	-.038	.000	-.495	.621

Source: Field survey, 2024 R^2 = .284, Adjusted r square = .225, F = 4.832

Conclusion and Recommendations

The study found that religious leaders, neighboring communities, and family & friends were the most available and utilized sources of information by the respondents, while extension agents were the least utilized. Religious leaders and the Radio were the most preferred. Government policies, climate change, high cost of farm inputs, amongst others, were major challenges hindering the farmers' access to adequate and frequent extension service delivery. Emanating from the findings and conclusions of this study, the following recommendations were made; Government and non-governmental organizations should enhance the frequency and accessibility of extension services. This can be achieved by employing more extension agents, improving their training, and ensuring that extension services reach rural farmers regularly. The government should review its agricultural policies to ensure they are farmer-friendly and provide financial support, such as subsidized inputs and easy access to credit facilities, to alleviate these financial burdens and encourage greater participation in agriculture. Extension services should incorporate religious leaders and community-based figures in their dissemination strategies.

References

Adedoji, S.A., Oluwatayo, I.B., & Aromolaran, A.B. (2023). Ineffective policies and extension service delivery in Nigeria: A critical analysis. Journal of Agricultural Extension, 27(1), 1-15.

Adegbola, P.Y., Oluwatayo, I.B., & Aromolaran, A.B. (2017). Assessment of maize farmers' access to extension services in Oyo State, Nigeria. Journal of Agricultural Extension, 21(1), 1-12.

Central Bank of Nigeria (CBN). (2019). Annual report and statement of accounts.

Kebbi State Agricultural Development Project. (2018). Zuru Local Government Area agricultural development plan.

Melesse, A. (2018). Agricultural extension services for smallholder farmers: Challenges and opportunities. Journal of Agricultural Education and Extension, 24(3), 257-271.

Mgbakor, M.C., Onyemauwa, C. S., & Ehirim, N. C. (2023). Influence of family network on agricultural productivity among smallholder farmers in Nigeria. Africa Journal of Abdullahi, S. (2022). Accessibility of agricultural extension services among maize farmers in Kebbi State, Nigeria. Journal of Agricultural Extension, 26(1), 45-58.

Mwangi, M., Kariuki, S., & Gichangi, A. (2015). Factors influencing access to agricultural extension services among farmers in Kenya. Journal of Agricultural Science and Technology, 15(4), 931-943.

National Agricultural Extension and Research Liaison Service (NAERLS). (2023). Agricultural extension in Nigeria: Challenges and opportunities. NAERLS Publication Series, 23(1), 1-20.

Ogunsumi, L. O., & Akinbode, S. O. (2015). Assessment of agricultural extension services in Nigeria: A review. Journal of Agricultural Science and Technology, 15(4),3

Assessment of Agricultural Extension Services for Women and Youth Cooperatives in Anambra State, Nigeria.

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Abstract

Agricultural extension services support farmers in Anambra State through education and technology transfer, but their effectiveness is hindered by staffing shortages, poor research linkage, limited funding, and cultural barriers, particularly impacting youth and women in cooperatives. This study assessed the effectiveness of extension services in addressing the challenges of youth and women cooperatives in Anambra State, focusing on gender equality and women's empowerment principles. Using multi-stage and purposive sampling because of the specific group of respondents needed for the study. One hundred and twenty farmers (equal numbers of women and youth) were selected from two agricultural zones for data collection. Results showed that women slightly out-numbered men in cooperatives, with most participants being middle-aged and engaged primarily in crop farming. Youth cooperatives had the highest membership, highlighting the potential for innovation and empowerment. Key constraints identified included financial limitations, cultural and gender barriers, inconvenient meeting timings, lack of female extension workers, and low awareness of available services. Extension activities combining group training, farm visits, and demonstrations were found to be more effective in promoting gender equality and empowerment. Women's participation in cooperatives yielded significant benefits such as reduced production costs, rural community development, skill enhancement, improved market access, and stronger bargaining power, although financial support and risk management remained challenges. The study underscores the need to restructure extension services with increased financial inclusion, gender-sensitive staffing, and culturally appropriate engagement methods to enhance the impact on youth and women farmers. These findings support targeted policy interventions to strengthen extension delivery and empower marginalized groups for sustainable agricultural development in the region.

Keywords: Agricultural Extension, Cooperatives, Women, Youth.

Introduction

Agricultural extension services play a crucial role in supporting farmers through education, technology transfer, and problem-solving related to agriculture (Mgbakor et al. 2013). These services are essential for the cultivation of land, raising animals, and improving farming conditions, particularly for rural farmers (Mgbakor et al. 2013). However, the effectiveness of these services can vary, especially concerning the specific challenges faced by youth and women in agricultural cooperatives. In Nigeria,

agricultural extension has historically faced numerous challenges, including inadequate staffing, weak linkages with agricultural research, poor staff mobility, and insufficient financial support (Agwu et al. 2023). These issues have led to calls for restructuring the agricultural ministry to give more autonomy to extension services, although such reforms have often been resisted (Olayemi et al. 2021). Furthermore, a study in Anaocha Local Government Area of Anambra State revealed that a significant proportion of farmers have never been visited by extension workers, indicating a gap in service delivery (Mgbakor et al. 2013). . The study also found that most of the cooperators benefited in the area of crop resistant varieties as technology transferred to them (50%) and accepted the use of audio visuals, method demonstration and result demonstration as good strategy for disseminating farm information (Mgbakor et al 2013).

Women's access to agricultural extension services is particularly constrained by cultural restrictions, domestic responsibilities, language barriers, and a shortage of female extension agents Latif (2023). Despite women's significant role in agricultural development, their contributions are often underrated, and they face numerous problems that hinder their progress Latif (2023). Cooperatives have been identified as valuable tools for youth development, with a positive relationship existing between cooperative activities and youth development (Okoli, 2018). These societies can address the socio-economic deprivations faced by the youth, offering opportunities for development and empowerment (Okoli, 2018).

Given these contexts, assessing the effectiveness of extension services in addressing the challenges of youth and women cooperatives in Anambra State is crucial. This assessment will consider the principles of gender equality and women's empowerment in agriculture, aiming to identify gaps and propose strategies for improvement (Odera & Mulusa, 2020). By focusing on these areas, extension services can be better tailored to support the specific needs of these groups, promoting sustainable agricultural development and empowerment in the region (Okafor, 2019).

Methodology

The study was conducted in Anambra State. The State have four Agricultural zones with 24 extension blocks and 20 circles. The zones are Aguata zone, Awka zone, Anambra and Onitsha zones. Multi stage and purposive sampling techniques were used to elicit information for the study. In the first stage, two agricultural zones of the state were involved in the selection of the respondents for the study Awka and Anambra. In the second stage, one block in each zone was purposively selected because of their involvements in agricultural production, giving a total number of two blocks. Third stage involved the selection of three circles from each block and were purposively selected for the same reason. Lastly, twenty (20) farmers (10 Women and 10 Youths) were randomly selected from each circle giving a total of 120 farmers for the study. Data were analyzed with the use of descriptive statistics.

Descriptive statistics such as, frequency counts, percentage, 3- and 5-point likert scale ratings was used to reach logical conclusion.

Results and Discussions

The result of the socio-economics table revealed that (53.33%) of the respondents were female farmers slightly outnumber male farmers (46.67%). This highlights the active participation of women in agricultural cooperatives, possibly due to their roles in subsistence farming and household food security. The higher proportion of female members aligns with studies showing that women are often key players in rural agriculture and cooperative activities, especially in developing countries like Nigeria (Nwankwo &Akonu, 2019). Policies should focus on empowering women through targeted training and credit schemes. The result on the age of the respondents indicated that majority (80%) of the farmers fell within the age range of 31-50, with a mean age of 39.5 years. This indicates that cooperatives are dominated by middle-aged individuals, who are likely more experienced and physically capable of engaging in farming activities.

The predominance of middle-aged farmers suggests a strong labor force but raises concerns about the sustainability of agricultural labor as younger generations may migrate to urban areas for non-agricultural jobs (Anigbogu et al. 2015). It was also discovered that married individuals constituted 60%, suggesting that family responsibilities may drive participation in cooperatives to enhance income and food security. For education Levels, most farmers have primary education (33.33%), while 40% have secondary or tertiary education combined. This reflects moderate literacy levels, which can influence the adoption of modern farming techniques and cooperative management practices. The moderate educational attainment among members could limit the adoption of advanced farming methods but also provides an opportunity for targeted extension services to improve skills (Olabisi et al, 2015).

Crop farming was discovered as the major primary occupation of the respondents which constituted (66.67%), followed by processing and marketing agricultural products (13.33% each). This emphasizes the reliance on crop production as a livelihood source. The dominance of crop farming underscores its importance in rural livelihoods but also highlights the need for diversification into livestock rearing and value-added processing to mitigate risks from crop failures (Atapattu et al. 2025)

For cooperative Membership: Youth cooperatives have the highest membership (60%), followed by women cooperatives (26.67%). Mixed-gender cooperatives are less common (13.33%), and no membership was recorded for farmers' associations. The high membership in youth cooperatives suggests that younger farmers are recognizing the benefits of collective action, which could be leveraged to introduce innovative farming practices and technologies (Nweke & Emejulu, 2022).

Table 1: Socio-economic Characteristics of the Women and Youth Cooperative Members

Variable	Frequency N= 120	Percentages (100)	Mean
Sex			
Male	56	46.67	
Female	64	53.33	
Age			
21-30	16	13.33	39.5
31-40	48	40.00	
41-50	48	40.00	
51 and above	8	6.67	
Marital Status			
Single	40	33.33	
Married	72	60.00	
Widowed	8	6.67	
Level of Education			
No formal education	16	13.33	
Primary education	56	33.33	
Secondary education	24	20.00	
Tertiary education	24	20.00	
Primary Occupation			
Crop Farming	80	66.67	
Livestock Rearing	8	6.67	
Processing Agric Products	16	13.33	
Marketing Agric Products	16	13.33	
Membership of Cooperative			
Youth Cooperative	72	60.00	
Women Cooperative	32	26.67	
Mixed-gender cooperative	16	13.33	
Farmers Association	0	0	

Source: Field Survey, 2024

The result from table 2 revealed that financial constraints with Mean of 2.85 ranked first (1st). Financial barriers are the most significant challenge, as cooperatives often lack access to affordable credit to invest in agricultural inputs or modern technologies. Studies show that financial institutions impose strict requirements, making it difficult for small-scale farmers, especially women and youth, to secure loans (Lai-Solarin, et al. 2024). This aligns with earlier findings of Owolabi et al. (2011) who discovered that low-income levels among women farmers hinder their ability to utilize extension services effectively, it is also in agreement with the study on dairy cooperatives in Nigeria that found 64% of the respondents lacked access to credit, which limited their ability to scale operations and adopt modern farming practices (Lai-Solarin, 2024). This issue has been persistent over the years, as noted in earlier studies emphasizing the need for financial inclusion in rural areas.

Secondly were cultural and gender barriers with Mean of 2.76 and Ranked second (2nd). Cultural norms and gender roles often restrict women's participation in extension activities. Women may face

societal discouragement or restrictions on interacting with male extension agents (Jiggins et al. 1997) additionally, traditional household responsibilities limit their availability for training sessions. Earlier studies also highlighted cultural constraints as a major barrier. For example, Muslim women in Northern Nigeria were found to have limited contact with male extension agents due to cultural and religious practices. This underscores the need for culturally sensitive approaches, such as employing female extension workers or organizing sole women sessions.

Inconvenient Timing and Location of Meetings with Mean of 2.58 and ranked third (3rd).The timing and location of extension meetings often conflict with women's household duties or are inaccessible to youth in remote areas. Flexible scheduling and local venues could mitigate this issue. Previous studies similarly noted that inconvenient meeting arrangements disproportionately affect women due to their dual roles in domestic and agricultural activities. Modern strategies suggest organizing sessions at "sanctioned" locations or providing transportation subsidies to improve attendance.

Lack of Female Extension Workers with Mean of 1.90 Ranked fourth (4th). The absence of female extension workers limits women's comfort and willingness to engage with extension services. Male-dominated staffing in extension services has been a long-standing issue globally (Jiggins, 1997). Historical data reveal that countries like the Philippines have successfully deployed female field staff to address this gap, but such initiatives remain rare elsewhere globally (Jiggins, 1997). This challenge remains under-addressed despite decades of advocacy for gender-sensitive staffing in agricultural programs.

Finally, lack of awareness, with a mean score of 1.82 and ranked fifth, was identified as a key constraint. Many cooperatives remain unaware of available extension services or how to access them. Awareness campaigns targeting rural communities could help bridge this gap. Earlier research (Mincemoyer, 2004) also highlighted low awareness especially among women and youth as a major barrier.

Table 2: Challenges Faced by Youth and Women Cooperatives in Accessing and Utilizing Extension Services.

Challenges	Mean	Rank
Financial Constraints	2.85	1st
Culture and Gender barrier	2.76	2nd
Inconvenient timing and Location of meeting	2.58	3rd
Lack of Female Extension Worker	1.90	4th
Lack of Awareness	1.82	5th

Source: Field Survey, 2024, Acceptable mean score is 2.0

The result on Table 3 explains the effectiveness of extension activities for enhancing gender equality and women's empowerment highlights three activities: Group Training, Group Training + Farm Visit,

and Group Training + Farm Visit + Demonstration, with respective effectiveness rates of 26.67%, 40%, and 33.3%. Group Training (26.67%) This activity alone shows limited effectiveness, likely due to its lack of practical, hands-on engagement. For Group Training + Farm Visit constituted (40%). Adding farm visits significantly improves effectiveness by combining theoretical knowledge with practical application. Group Training + Farm Visit + Demonstration constituted (33.3%): Demonstrations further enhance learning but may require more resources, slightly reducing scalability.

The European Bank for Reconstruction and Development (EBRD) highlighted the importance of scaling gender-responsive services, including participatory approaches that integrate practical demonstrations and technical cooperation. This aligns with the findings that combining multiple extension activities (e.g., farm visits and demonstrations) yields better results.

Table 3: Effectiveness of Extension Activities for Enhancing Gender Equality and Women's Empowerment

Extension Activities	Frequency	Percentages
Group Training	32	26.67
Group Training + Farm Visit	48	40
Group Training + Farm Visit + Demonstration	40	33.3

Source: Field Survey, 2024

The result on Table 4 presents the level of outcomes of women's participation in cooperative activities. The table showed that Lower Production Cost with a mean of (3.82) ranked first as a major outcome of women's participation in cooperative activities. Cooperatives help women reduce production costs, likely through economies of scale and shared resources. This aligns with recent findings that cooperatives can improve economic efficiency for women farmers (Aduna et al. 2023).

Rural Community Development had a mean of (3.75) and ranked second major outcome of women's participation in cooperative activities. Women's participation in cooperatives contributes significantly to rural development. This is consistent with the ILO's observation that cooperatives have a positive impact on women's empowerment and community development (ILO, 2015).

Similarly, respondents identified Knowledge and Skill Development with mean of (3.73) as third outcome of women participation in cooperative activities. Cooperatives serve as platforms for women to acquire new skills and knowledge. This outcome is supported by recent studies showing that cooperative membership enhances women's access to training and information. (Aduna et al. 2023)

Other outcome of women participation in cooperative is Better Market Access with mean of (3.64) and ranked fourth. Cooperatives improve women's access to markets, which is crucial for their economic empowerment. This aligns with current trends in cooperative development focusing on market linkages for women farmers (ILO, 2015). Stronger Bargaining Power with mean of (3.28) ranked

fifth. Women gain increased negotiating power through cooperative participation. This outcome is consistent with recent findings that cooperatives enhance women's collective voice in economic transactions (Aduna et al. 2023).

Another important outcome of women participation in cooperative as was reported by farmers is Improved Financial Support with mean of (2.30) and ranked sixth. While ranked lower, cooperatives still provide some financial benefits to women members. This aligns with ongoing efforts to increase women's access to financial services through cooperatives (ILO, 2015).

Finally, is Risk Sharing Stability with mean of (2.28) and ranked seventh outcome of women participation in cooperative activities. Cooperatives offer a degree of risk mitigation for women, though ranked lowest among the outcomes. This reflects the continuing challenge of providing comprehensive risk management solutions for women in agriculture (Aduna et al. 2023).

These outcomes demonstrate the multifaceted benefits of women's participation in cooperatives, ranging from economic advantages to social and skills development. The rankings suggest that immediate economic benefits (lower costs, market access) and community development are perceived as the most significant outcomes. However, there's room for improvement in financial support and risk management aspects of cooperative activities for women.

Table 4: Level of Outcomes of Women's Participation in Cooperative Activities

Level of outcomes	Means	Rank
Lower Production Cost	3.82	1st
Rural Community Development	3.75	2nd
Knowledge and Skill Development	3.73	3rd
Better Market Access	3.64	4th
Stronger Bargaining Power	3.28	5th
Improved Financial Support	2.30	6th
Risk Sharing Stability	2.28	7th

Source: Field Survey, 2024. Acceptable mean score is 3.0

The research affirms that women's participation in cooperatives yields critical benefits, including cost reduction, skill development, and improved market access. A multi-faceted approach is therefore recommended, combining financial inclusion initiatives, gender-sensitive staffing, and awareness campaigns to overcome existing constraints. Such targeted interventions are essential to fully harness the potential of agricultural cooperatives for fostering sustainable rural development.

Conclusion

This study of assessment of agricultural extension services for women and youth cooperatives in Anambra State identifies a dynamic socio-economic profile with clear implications for rural development. While this profile underpins agricultural productivity, significant barriers persist,

especially for youth and women. These include financial constraints, cultural norms, and inconvenient extension service logistics.

References

Abdul Latif Jameel Poverty Action Lab (J-PAL). (2023). Improving agricultural information and extension services to increase small-scale farmer productivity. J-PAL Policy Insights. Last modified September 2023.

Aduna, T. T., & Woldeyes, Z. W. (2023). Assessment of rural women participation in farmers multipurpose cooperatives: The case of Agarfa District, Bale Zone, Oromia Region, Ethiopia. Journal of Agricultural Extension and Rural Development, 15(1), 46–54.

Agwu, A. E., Suvedi, M., Chanza, C., Davis, K., Oywaya-Nkurumwa, A., Najjingo Mangheni, M., & Sasidhar, P. V. K. (2023). Agricultural extension and advisory services in Nigeria, Malawi, South Africa, Uganda, and Kenya. Partnerships for Innovative Research in Africa (PIRA) Research Report. Alliance for African Partnership, Michigan State University.

Anigbogu, T. U., Agbasi, O. E., & Okoli, I. M. (2015). Socioeconomic factors influencing agricultural production among cooperative farmers in Anambra State, Nigeria. International Journal of Academic Research in Economics and Management Sciences, 4(3).

Atapattu, A. J., Nuwarapaksha, T. D., Udumann, S. S., & Dissanayaka, N. S. (2025). Integrated farming systems: A holistic approach to sustainable agriculture. In Agricultural diversification for sustainable food production (pp. 89–127). Springer Nature Singapore.

International Labour Organization. (2015). Global survey shows rising women's participation in cooperatives: An ILO-ICA joint survey reflects gains for women in cooperatives while pointing to the need for better recognition by governments.

Jiggins, J. R., Samanta, K., Olawoye, J. E., Aguilera, J., & Tempelman, D. E. (1997). Improving women farmers' access to extension services. Improving Agricultural Extension a Reference Manual, 73-80.

Lai-Solarin, W. I., Bamidele, J., Joel, O. J., Tata, T., Abubakar, U. P. E., Joel, A. F., & Sennuga, S. O. (2024). Challenges and benefits of extension service delivery for dairy cooperatives in Kaduna State, Nigeria. Nigeria Journal of Agricultural Extension and Rural Economics, 1(1), 1–14.

Mgbakor, M. N., Uzendu, P. O., & Ogbumuo, M. G. (2013). Role of agricultural extension services in assisting farmers' multi-purpose cooperative societies in Anaocha L.G.A. in Anambra State, Nigeria. International Journal of Sustainable Agriculture, 5(2), 56–65.

Mincemoyer, C., Perkins, D., & Lillehoj, C. (2004). Perceptions of the Cooperative Extension Service: A community resource for youth and family programs. The Journal of Extension, 42(5), 8.

Nwankwo, F. O., & Akonu, S. C. (2019). Agricultural Cooperatives and Rural Poverty Reduction among Rural Farmers in Anambra State, Nigeria. International Journal of Trend in Scientific Research and Development, (IJTSRD) 1(4), 56-70.

Nweke, G. F., & Emejulu, G. A. (2022). Democratic leadership and non-financial performance of farmers cooperative societies in Anambra Agricultural Zone. International Journal of Trend in Scientific Research and Development, 6(2), 591.

Odera, J. A., & Mulusa, J. (2020). SDGs, gender equality and women's empowerment: What prospects for delivery. In Sustainable development goals and human rights (pp. 95–118). Springer.

Okafor, I. P. (2019). Effects of agricultural extension services on the performance of members of women agricultural cooperatives in South East, Nigeria. International Journal of Trend in Scientific Research and Development, 4(4).

Okoli, E. (2018). Assessment of the contribution of cooperative societies in the development of the youth: A case study of selected cooperative societies in Dunukofia Local Government Area, Anambra State, Nigeria. Department of Cooperative Economics and Management, Faculty of Management Science, Nnamdi Azikiwe University, Awka, Anambra State.

Olabisi, T. A., Obianuju, A. E., Kamaldeen, L., & Ifoema, O. P. (2015). Evaluating farmers' access to productive resources through cooperative societies and its effects on their performance in rural communities of Anambra State, Nigeria. International Journal of Scientific & Technology Research, 4(9), 37–44.

Olayemi, S. S., Ope-Oluwa, A. A., & Angba, C. W. (2021). Evolution of agricultural extension models in Sub-Saharan Africa: A critical review. International Journal of Agricultural Extension and Rural Development Studies, 8(1), 29–51.

Owolabi, J. O., Abubakar, B. Z., & Amodu, M. Y. (2011). Assessment of farmers (women)' access to agricultural extension, inputs and credit facility in Sabon-Gari Local Government Area of Kaduna State. Nigerian Journal of Basic and Applied Science, 19(1), 87–92.

From Nut to Income: Women's Economic Empowerment through Bambara Processing in Enugu State, Nigeria

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Abstract

Despite its important significance in people's diets and also a source of employment for women in Enugu state, Nigeria, there appear to be issues in the processing, profitability, and use of Bambara groundnut in the study area. The study analyzes the economic empowerment of empowerment of under-utilized legumes using Bambara nuts among Women processors in Enugu State. Three-stage sampling techniques were used to select 120 women processors. Primary data were obtained through a semi-structured questionnaire and were analyzed using gross margin, stochastic frontier model, and Likert-type scale. The results revealed that the gross margin is ₦347,238.14. Age, household size, education level, labor cost, and quantity of Bambara nuts have highly significant effects on the technical efficiency of Bambara nut processing. The most significant constraints are poor government support, high costs of inputs, and price variation. The study therefore, recommend that, government and related stakeholders, such as NGOs and Bambara nut producers, should establish programs to assist Bambara nut processors, provide subsidies for the raw materials required, and implement initiatives to support them.

Keywords: Bambara nuts, Technical efficiency, Women, Nigeria

Introduction

The African seed known as "Bambara groundnut" (*Vigna subterranean (l) verdc*) is consumed locally as a vegetable. This herbaceous, short-leaved annual crop plant grows to a height of approximately 15 cm, and its roots contain a large number of nitrogen-fixing nodules that enhance the quality of the soil. The Bambara nut falls under the plant family Fabaceae. Bambara nut is a legume that is utilized in both human and animal feeding, notably by monogastric animals, as a source of protein. It originated in West Africa and It is widely grown particularly, in South and Western Africa. The Bambara tribe which presently resides in Mali, is the source of the word's origin. (Ogundele, Minnar, & Emmambux, 2017), where it is produced both as a food and a source of revenue. The Bambara nut (*Vigna subtrranea*), a legume rich in protein and minerals (Nwadi et al., 2020), serves as a cornerstone food source for millions across Africa. Beyond its nutritional benefits, the Bambara nut thrives in hot, dry conditions typical of semi-arid Africa and even enhances soil fertility. It is also classified as a

nutraceutical and functional food. Due to its hard shell when mature, processing (boiling, soaking, and dehulling) is necessary for transforming it into flour for preparing nutritious local delicacies like bean cake (koose), steamed bean paste in leaves (Tubani), and boiled bean paste (Gablee) (Ayogu et al., 2017). Known by various names depending on location, okpa (Igbo), epiroro (Yoruba), gurjiya (Hausa) in Nigeria, aboboi (Ghana), and nzama (Malawi), the Bambara nut enjoys widespread consumption across Africa.

Since women harvest, sell, and process the majority of the Bambara nut crop, female subsistence farmers find it very helpful. As processing Bambara nuts benefits the women both socially and environmentally, it is a significant economic activity for women in many parts of Africa. For a lot of women in Africa, it is also a source of money, which enables them to support the welfare of their families and communities. As roasted Bambara groundnuts need less capital and skills, women are more fully integrated in their processing and sales, which is consistent with their historic position as processors (Ene-Obong et al., 2013). Majority of households in Enugu State utilize Bambara groundnut products in their meals, the state can be considered dependent on these items. Despite the significant roles of Bambara groundnut in people's diets and as a source of employment for women in Enugu state, there appear to be challenges in the processing and utilization of Bambara groundnut in the area. Furthermore, the study area has not conducted sufficient research on the profitability of Bambara groundnut processing, particularly for women. The objective of this research is to:

1. estimate the costs and returns associated with processed Bambara nuts,
2. assess the technical efficiency of Bambara nut processing, and
3. identify the constraints of Bambara nut processing in the study area.

Material and Methods

Study area: It was carried out in Enugu State, Nigeria.

Population of the study: They are women processors of Bambara nuts

Sample Techniques and Sample Size: Three-stage sampling techniques were used for the selection of respondents, who were women processors of Bambara nuts in the area. The first stage entails the purposeful selection of the Udi LGA, which is known for the involvement of women processing Bambara nuts, and also the high consumption of okpa, which is obtained from processing Bambara nuts into flour. The second stage involves the use of a random selection of three (3) communities out of 22 communities in Udi LGA. The third stage entails a random selection of forty (40) women processors of Bambara nuts from the three (3) communities selected in the Udi LGA. A total of one hundred and twenty (120) women processors of Bambara nuts were selected for the study.

Analytical Techniques

Gross margin analysis was used to estimate the costs and returns of processed Bambara nuts. Gross Margin is given as:

GM = TR – TVC …… (1) Where: GM = Gross margin (₦) , TR = Total Revenue (₦), TVC = Total Variable Cost (₦)

TR = p x q ……Where, p = price of the product, q = quantity that was sold

Stochastic frontier model was used to analyze the technical efficiency of Bambara nut processing and was presented in the form of Cobb-Douglas production function, which is given as follows:

$Y = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + \beta_6 lnX_6 + \beta_7 lnX_7 + V_1 - U_I$…….. (3)

Where: Y = processed Bambara flour (kg), X1 = quantity of fuel (liters), X2 = cost of labor (naira), X3 = quantity of Bambara nuts (kg), X4 = cost of packaging (naira), X5 = cost of equipment used for milling, grinding and sieving, X6 = cost of transportation (naira), X7 = processing experience (years), V1-U1 = error value, β1- β7 are the coefficients of the independent variables.

The inefficiency model is specified as follows

$Ui = \delta 0 + \delta 1\ lnZ1 + \delta 2\ lnZ2 + \delta 3\ lnZ3 + \delta 4\ lnZ4$……(4)

Ui inefficiency effect $Z1$ = age (years) Z2 = level of education (years of formal schooling)

$Z3$ = household size (number of persons in a household) All variables are analyzed in their natural logs (ln)

A five-point Likert-type scale was used to identify the major constraints to processing Bambara nuts. It is represented below as:

Very Severe = 5, Severe = 4, Mildly Severe = 3, Not Severe = 2, Not a Problem = 1

Results and Discussion

The cost and return of processing Bambara nuts in the research area are shown in Table 1, indicates that ₦1,071,879.17 is for total revenue and ₦724,641.03 for total variable costs (Bambara nuts, gasoline, water, packaging material, transportation, electricity, and labour). These figures were utilized to determine the gross margin, which came out to be ₦347,238.14. The high value of the gross margin suggests that, for the women in the study region, processing Bambara nuts is a feasible and profitable enterprise, with labour and Bambara nut costs accounting for the majority of costs. This resonates with the finding of Ikechukwu (2014), that based on profitability analysis, processing

Bambara groundnuts in Enugu State is profitable. Additionally, the analysis reveals that 11.6% of the processor's monthly income comes from processing Bambara nuts.

Table 1: Gross margin analysis of Bambara Nut processing

Variables	Amount (₦)
Total Revenue (TR)	1,071,879.17
Variable Costs:	
• Bambara Nut	644,700
• Amount of Fuel	11,964.25
• Water	377.2
• Packaging Materials	19,445.83
• Transportation	5,352.5
• Electricity	1,902.5
• Labor Cost	40,898.75
Total Variable Cost (TC)	724,641.03
Gross Margin (TR – TVC)	347,238.14
% Contribution to monthly Income	11.6%

Source: Field Survey, 2023.

Results in Table 2, provides information about the MLE model's statistical significance and technical efficiency attributes. It can be deduced from the MLE result that, Age, household size, education level, labor cost, and quantity of Bambara nuts have highly significant effects (significant at 1%) on the technical efficiency of Bambara nut processing. This result conforms to the findings of Adebayo and Adekunle (2020), the study discovered that one important factor influencing technical efficiency in the processing of Bambara groundnuts was the quantity of nuts produced. Also, the cost of packaging, the cost of transportation, and the processing experience also show moderate effects on the technological effectiveness of Bambara nut processing. Quantity of Fuel, Cost of Equipment Used, and the constant term, although significant, do not show much variability or practical significance in this context.

Table 2: Analysis of factors affecting the Technical Efficiency of Bambara nut Processing

Variables	Coefficients	Standard-Error	T-Ratio
Constant	0.0649***	0.0008	82.2151
Quantity of Fuel	0.0000	0.0000	-0.1992
Cost of labor (X_1)	1.0005***	0.0003	3555.7408
Quantity of Bambara nuts(X_2)	-0.0157***	0.0006	-25.8671
Cost of Packaging (X_3)	0.0000**	0.0000	2.1799
Cost of equipment used(X_4)	0.0000	0.0000	0.5674
Cost of Transportation(X_5)	0.0000**	0.0012	2.3195
Processing experience(X_6)	0.0028**	0.0012	2.3195
Age(Z_1)	-0.2301***	0.0194	-11.8421
Education(Z_2)	0.1650***	0.0112	14.7062

Household size(Z_3)	0.6545***	0.0773	8.4677
Sigma-squared	0.8146***	0.0755	10.7891
Gamma	1.0000***	0.0000	308852.0100

Log likelihood function = 69.7656, LR test of the one-sided error = 275.0544
Asterisks indicate significant level, ***= 1%, **= 5%, *= 10%
Source: Field Survey, 2023.

Results in Table 3 revealed that poor government support is the most significant constraint faced by Bambara nut processors in the area, followed by the high cost of inputs required for processing. This aligns with the findings of Onubuogu and Esiobu (2014), who also identified inadequate government support and high input costs as major challenges. Price variation ranked third, largely due to increasing input costs and rising inflation. Other key constraints included high transportation costs, poor sales, and high labor expenses. These findings indicate that despite the availability of some equipment, resources remain insufficient to meet processors' needs.

Table 4: Constraints to Bambara nut processing

Constraints	Very Severe	Severe	Mildly Severe	Not Severe	Not a Problem	Mean	Rank
Poor government support	116 (97.48)	1 (0.84)	1 (0.84)	0 (0.00)	1(0.84)	4.94	1st
High costs of inputs	115 (95.83)	1 (0.83)	2(1.67)	0 (0.00)	2 (1.67)	4.89	2nd
Price variation	110 (91.67)	7 (5.83)	1 (0.83)	2 (1.67)	0 (0.00)	4.87	3rd
High cost of transportation	99 (82.50)	16(13.33)	4 (3.33)	0 (0.00)	1 (0.83)	4.76	4th
Poor sales	94 (78.33)	17 (14.17)	6 (5.00)	3(2.50)	0 (0.00)	4.68	5th
High cost of labor	79 (65.83)	24 (20.00)	15 (12.50)	2 (1.67)	0(0.00)	4.50	6th
Inadequate access to inputs	75 (63.03)	33 (27.73)	7 (5.880)	3 (2.52)	1 (0.84)	4.49	7th
Poor storage facilities	41 (34.17)	42 (35.00)	33 (27.50)	2 (1.67)	2 (1.67)	3.98	8th
Market instability	39 (32.50)	46 (38.33)	28 (23.33)	5 (4.17)	2 (1.67)	3.95	9th
Inadequate processing equipment and machineries	45 (37.50)	29 (24.17)	41 (34.17)	1(0.83)	4 (3.33)	3.92	10th
Gender based discrimination	4 (3.33)	9 (7.50)	98 (81.67)	3 (2.50)	6 (5.00)	3.02	11th

Percentages in parenthesis

Source: Field survey, 2023.

Conclusion and Recommendations

The study concludes that the economics of Under-utilized legumes such as Bambara nut is crucial as it helps to improve economic empowerment, eradicating poverty, ensuring nutritional security and enhancing the wellbeing of women. Based on the findings of the study, several recommendations are proposed. The government and relevant stakeholders, including NGOs and Bambara nut producers, should initiate programs aimed at supporting Bambara nut processors. Efforts should also be made to

encourage male participation in the processing sector by providing incentives that attract their skills and expertise. Furthermore, the government should prioritize the construction of accessible roads to reduce the high transportation costs faced by processors. In addition, the provision of modern, efficient, and affordable tools and equipment for Bambara nut processing is recommended to enhance productivity and overall profitability in the sector.

References

Adebayo, C. O., & Adekunle, O. A. (2020). Technical efficiency of Bambara groundnut production in Oyo State, Nigeria. Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension, 19(2), 30-37.

Ali, S., & Khan, M. (2014). Technical Efficiency of Wheat Production In District Peshawar Pakhtunkhwa Pakistan. Sarhad Journal of Agriculture, 30(4), 433-441 (Pdf) Profitability And Efficiency Of Bambara Groundnut Production In Nigeria: A Case Study.

Ayogu, R., Edeh, R., Madukwe, E., and Ene-Obong, H. (2017). Commonly consumed foods. Food Nutr. Bull. 38, 65–77.

Cosmas Ikechukwu, A. (2014). Profitability and challenges in bambara groundnut processing and utilization among small-holder households in enugu state, nigeria. Journal of Research in Agriculture,11(2). https://www.irdionline.org/world/article/PROFITABILITY%20AND%20CHALLENGES%20IN%20BAMBARA.pdf

Ene-Obong, H. N., Sanusi, R. A., Udenta, E. A., Williams, I. O., Anigo, K. M., Chibuzo, E. C., Aliyu, H.M., Ekpe, O. O. and Davidson, G. I. (2013). Data collection and assessment of commonly consumed foods and recipes in six geo-political zones in Nigeria: Important for the development of a National Food Composition Database and Dietary Assessment. In: Food Chemistry, 140(3):539-546.

Esekhade, T. U., Mesike, C. S., Idoko, S. O., & Okore, I. K. (2014). Gross margin analysis of rubber based cropping systems in Nigeria. African Journal of Agricultural Research, 9(37), 2834–2840. https://doi.org/10.5897/ajar2014.8942.

Mohammed, H. (2016). Analysis of profitability and production efficiency of small-scale Bambara nut farming in Kajuru local government area of Kaduna state (unpublished master's thesis). Ahmadu Bello University, Zaria, Kaduna.

Mubaiwa, J., Fogliano, V., Chidewe, C., Bakker, E. J., & Linnemann, A. R. (2018). Utilization of bambara groundnut (Vigna subterranea (L.) Verdc.) For sustainable food and nutrition security in semi-arid regions of Zimbabwe. PLOS ONE, 13(10), e0204817. https://doi.org/10.1371/journal.pone.0204817

Nwadi, O. M. M., Uchegbu, N. and Oyeyinka, S. A. (2020). Enrichment of food blends with Bambara groundnut flour: Past, present, and future trends. Legume Science 2(1):e25. https://doi.org/10.1002/leg3.25

Ogundele, O. M., Minnaar, A. and Emmambux, M. N. (2017). Effects of micronation and dehulling of pre-soaked Bambara groundnut seeds on microstructure and functionality of the resulting flours. 214:655-663. DOI: 10.1016/j.foodchem.2016.07.022

Onubuogu, G. C., & Esiobu, N. S. (2014). Trends, perceptions and adaptation options of Bambara groundnut (Vigna subterranea (L.) Verdc.) producers in Imo State, Nigeria. International Journal of Food and Agricultural Economics, 2(1), 91-108.

Empowering Rural Women and Youth through Climate-Smart Agriculture: Opportunities, Challenges, and Best Practices

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Abstract

Women and youth play a crucial role in agricultural development in Africa, particularly in Nigeria**,** driving food production, economic growth, and food security. However, their contributions are hindered by persistent challenges such as limited access to land, credit, modern technologies**,** and socio-cultural constraints, all of which are further aggravated by climate change**.** Climate-Smart Agriculture (CSA) offers an integrated solution to enhance productivity, resilience, and sustainability. This review explores the opportunities and challenges of empowering rural women and youth through CSA, highlighting key strategies such as drought-tolerant crops, solar-powered irrigation, mobile-based information systems, community training**,** and inclusive policies. Despite these opportunities, barriers related to access, awareness, and institutional support persist. Strengthening policy frameworks, financial inclusion, and capacity-building initiatives targeting women and youth is essential to unlock their potential, enhance resilience, and ensure sustainable agricultural transformation in Africa.

Keywords: Food Security, Rural Development, Women Empowerment, Youth Engagement.

Introduction

Agriculture remains vital to Africa's economies, particularly Nigeria, where it sustains livelihoods and ensures food security (Olamide Emmanuel et al., 2020). Although women and youth contribute significantly to food production, they face socio-economic and cultural barriers that limit participation (Dwomoh, 2022; Jennifer & Enwelu, 2023). Youth involvement continues to decline due to migration and the perception of agriculture as unprofitable (Mwololo et al., 2022). This reduced engagement has lowered productivity and increased vulnerability to climate change impacts such as droughts and floods (Tuan et al., 2024). Climate-Smart Agriculture (CSA) provides an integrated approach to enhance productivity, resilience, and sustainability (Kurtaslan, 2021).

Key CSA practices include drought-tolerant crops, agroforestry, efficient water management, and the use of digital advisory tools and renewable energy technologies (Zougmoré et al., 2023). By mitigating

climate risks and improving access to agricultural infrastructure, CSA strengthens food security, creates livelihood opportunities, and makes agriculture more attractive to women and youth (Rabha & Saikia, 2021). This review explores CSA's potential to empower these groups and promote inclusive, sustainable agricultural development.

Roles and Challenges of Women and Youth in Agriculture

In developing countries, women and youth play vital roles in agriculture, contributing significantly to food production, processing, and household nutrition**,** with women producing nearly half of Africa's food (Swinbank, 2021). Youth represent a dynamic labor force capable of driving innovation and technological advancement in the sector. However, both groups face major challenges, including limited access to land, credit, and agricultural inputs**,** which hinder productivity and sustainability (Heckert et al., 2022).

Women often lack decision-making power and land ownership, reducing their overall empowerment (Nchanji et al., 2023), while youth are discouraged by the sector's low profitability and limited technological access**.** Furthermore, socio-cultural barriers, weak land tenure systems, and financial constraints exacerbate these challenges (Nagaraju & Priya, 2024). Empowering women and youth through climate-smart agriculture (CSA) is therefore essential to enhance productivity, resilience, and long-term agricultural sustainability (Jennifer & Enwelu, 2023).

Opportunities for Youth and Women Empowerment through Utilization of CSA Technologies

The adoption of Climate-Smart Agriculture (CSA) technologies presents significant opportunities for empowering women and youth in agriculture. Access to innovations such as mobile-based weather and market information systems, solar-powered irrigation, and climate-resilient seed varieties enhances productivity and profitability (Dupuis et al., 2022; Jennifer & Enwelu, 2023). Capacity-building initiatives, including training programs and farmer field schools, strengthen knowledge and promote the adoption of sustainable CSA practices (Khan, 2025). Furthermore, improved market integration through value chains and cooperatives enables women and youth to increase income and establish agribusinesses, as demonstrated by women-led cooperatives adopting drought-tolerant crops in Nigeria (Bullock & Crane, 2021; Bello et al., 2021).

Challenges Hindering Empowerment of Women and Youth within the Agricultural Sector:

Despite the promising opportunities, several challenges persist in the empowerment of women and youth within the agricultural sector:

1. Socioeconomic Barriers: Limited access to credit, agricultural inputs, land, and technology restricts the adoption of CSA practices, leading to underperformance in agricultural productivity (Dwomoh, 2022; Ali & Kumar, 2024).

2. Cultural and Gender Discrimination: Societal norms often discourage women from participating in decision-making processes, directly affecting their empowerment and economic independence (Kumar et al., 2023).
3. Youth Perceptions on Agriculture: A prevailing view of agriculture as an unprofitable venture diminishes youth interest and investment in agricultural careers (Gabriel et al., 2020).
4. Inadequate Government Support: Insufficient institutional support and corruption can hinder the effectiveness of CSA initiatives, complicating the empowerment landscape for women and youth (Jennifer & Enwelu, 2023; Olagunju, 2024).
5. Climate-Related Risks: The increasing frequency of climate-related events such as droughts, floods, and pest outbreaks can undermine productivity and deter farmers from adopting innovative practices (Das & Pal, 2023).

Best Practices for CSA Adoption

To promote empowerment through climate-smart agriculture, it is vital to create an enabling environment through:

i. Policy and Institutional Support: Governments, NGOs, and international agencies must collaborate to develop effective policies that encourage CSA adoption among women and youth Rok & Mpakaniye, 2022). Programs providing technical assistance and resources can enhance sustainable agricultural practices.
ii. Extension Services for Gender Sensitivity: Implementing targeted, gender-sensitive extension programs can significantly improve CSA uptake among women and youth (Zougmoré et al., 2023).
iii. Supportive Policies: Reforming land tenure, establishing microfinance schemes, and providing subsidies for CSA technologies can incentivize participation and foster a culture of empowerment (Langton, 2023).
iv. Technology and Innovation Training Programs: Developing training programs focused on CSA for rural women and youth and promoting affordable and accessible technologies will enhance engagement and participation (Kurtaslan, 2021). Encouraging involvement in agricultural value chains and decision-making processes is also essential (Das & Pal, 2023; Rok & Mpakaniye, 2022).
v. Start-Up Grants for Youth-Led Initiatives: Providing financial support for innovative agribusiness projects initiated by youth can catalyze entrepreneurship and sustain long-term interest in the agricultural sector (Bello et al., 2021; Olagunju, 2024).

Conclusion

Empowering rural women and youth through climate-smart agriculture presents a multifaceted strategy to enhance agricultural productivity, build resilience against climate change, and drive socio-economic development. By addressing existing barriers and leveraging best practices, stakeholders can foster inclusive agricultural systems that enable meaningful participation and long-term sustainability in Africa's agricultural landscape.

References

Women in Developing Agriculture by Adopting Strategies for their Empowerment India. *IJMRSET*, 7(05), 9847-9853. https://doi.org/10.15680/ijmrset.2024.0705048

Ayinde, O. E., Olarewaju, A. O., Chimeze, V., Omotesho, K. F., Ogunlade, I., & Olaoye, G. (2023). Gender-based analysis of risk management and improved technology adoption among small-scale maize farmers in Kwara state. *Agrosearch*, 22(1), 70-84. https://doi.org/10.4314/agrosh.v22i1.7

Bello, L., Baiyegunhi, L., Mignouna, D., Adéoti, R., Nguezet, P., Abdoulaye, T., … & Awotide, B. (2021). Impact of Youth-in-Agribusiness Program on Employment Creation in Nigeria. *Sustainability*, 13(14), 7801. https://doi.org/10.3390/su13147801

Bullock, R. and Crane, T. (2021). Young Women's and Men's Opportunity Spaces in Dairy Intensification in Kenya. *Rural Sociology*, 86(4), 777-808. https://doi.org/10.1111/ruso.12385

Das, S. and Pal, P. (2023). Assessment of Entrepreneurship Development through Attracting and Retaining Youth in Agriculture (Arya). SFS. https://doi.org/10.53555/sfs.v10i1s.2304

Dupuis, S., Hennink, M., Wendt, A., Waid, J., Kalam, M., Gabrysch, S., … & Sinharoy, S. (2022). Women's Empowerment through Homestead Food Production in Rural Bangladesh. *BMC Public Health*, 22(1). https://doi.org/10.1186/s12889-022-12524-2

Dwomoh, D. (2022). Modeling Inequality of Access to Agricultural Productive Resources in Coastal and Non-coastal Rural Communities in Central Region of Ghana: Implication for Food Security and Women Empowerment. https://doi.org/10.21203/rs.3.rs-1838567/v1

Gabriel, N., Isyak, I., & Ahmed, N. (2020). Effect of Youth Empowerment Programs on Youth Unemployment in Kaduna South Local Government Area of Kaduna State. *Kampala International University Interdisciplinary Journal of Humanities and Social Sciences*, 1(1), 134-148. https://doi.org/10.59568/kijhus-2020-1-1-09

Heckert, J., Martínez, E., Seymour, G., Pereira, A., Roy, S., Kim, S., … & Malapit, H. (2022). Development and Validation of a Health and Nutrition Module for the Project-Level Women's Empowerment in Agriculture Index (Pro-WEAI+HN). *Maternal and Child Nutrition*, 19(2). https://doi.org/10.1111/mcn.13464

Jennifer, I. and Enwelu, I. (2023). Utilization of Information and Communication Technologies among Rural Women and Youth in Agriculture in Abia State, Nigeria. *Asian Journal of Agricultural* https://doi.org/10.9734/ajaees/2023/v41i81997

Khan, J. (2025). Determinants of Farmer Empowerment and Employment in Major Agriculture Sectors in Bangladesh. *Journal of International Development*, 37(6), 1307-1323. https://doi.org/10.1002/jid.70005

Kumar, A., Yadav, R., Saikanth, D., Tripathi, G., Sharma, A., Meinam, M., … & Shukla, A. (2023). The Impact of Social Media on Agricultural Youth: Empowering the Next Generation in India. *Asian Journal of Agricultural Extension Economics & Sociology*, 41(10), 260-267. https://doi.org/10.9734/ajaees/2023/v41i102167

Kurtaslan, T. (2021). Comparison of Conventional Production and Good Agricultural Practices (GAP) in Greenhouse Grown Strawberry. *Asian Journal of Advances in Agricultural Research*, 1-13. https://doi.org/10.9734/ajaar/2021/v15i230146

Langton, M. (2023). Challenges and Opportunities of Women and Youths Financial Inclusion in the Context of AFCFTA. Case Study of Sub-Saharan Africa. *International Journal of Innovative Research in Multidisciplinary Education*, 02(11). https://doi.org/10.58806/ijirme.2023.v2i11n08

Mwololo, H., Nzuma, J., & Githinji, L. (2022). Determinants of Farmer Empowerment in Agriculture in Kenya: A Tobit Approach. *Heliyon*, 8(12), e11888. https://doi.org/10.1016/j.heliyon.2022.e11888

Nagaraju, L. and Priya, N. (2024). Role of women in sustainable agricultural growth., 125-133. https://doi.org/10.48001/978-81-966500-8-7-13

Nchanji, E., Kamunye, K., & Ageyo, C. (2023). Thematic Evidencing of Youth-Empowering Interventions in Livestock Production Systems in sub-Sahara Africa: A Systematic Review. *Frontiers in Sustainable Food Systems*, 7. https://doi.org/10.3389/fsufs.2023.1176652

Olagunju, F., Babatunde, R., & Adeojo, R. (2020). Potential of climate smart agriculture in preventing postharvest loses: instant fufu powder production among rural women in Oyo state, Nigeria. *Asian Journal of Agricultural Extension Economics & Sociology*, 134-145. https://doi.org/10.9734/ajaees/2020/v38i830396

Olagunju, O. (2024). Harnessing Artificial Intelligence for Youth Engagement in Agriculture: Lessons from Global Practices and Prospects for Nigeria. *IJASSE*, 2(2), 83-94. https://doi.org/10.59890/ijasse.v2i2.1490

Olamide Emmanuel, A. B. E., Ojo, O. I., & Omotoso, D. C. The Nigerian Political Economy and Agricultural Sector.

Rabha, P. and Saikia, M. (2021). Women Participation in Agriculture with Special Reference to Kamrup District of Assam. *IJEE*, 57(4), 57-4. https://doi.org/10.48165/ijee.2021.

Rok, B., & Mpakaniye, D. (2022). Analysis of the Effects of Microfinance Social-Economic Intervention on Women and Youth Empowerment in Juba (Case of Rufi in Juba). *Strategicjournals*, 9(1). https://doi.org/10.61426/sjbcm.v9i1.2218

Swinbank, V. A. (2021). Women feed the world: Biodiversity and culinary diversity/food security and food sovereignty. In *Women's Food Matters: Stirring the Pot* (pp. 187-218). Cham: Springer International Publishing.

Tuan, C., Lee, J., Nayga, R., & Quach, D. (2024). Can Women Empowerment enhance Rice Productivity? The Case of Vietnam. *Sustainable Development*, 32(6), 6274-6285. https://doi.org/10.1002/sd.3025

Zougmoré, R., Castellanos, A., Dossou-Yovo, E., Gonsalves, J., Lamien, N., & Segnon, A. (2023). Supporting Prosperity through Better Mobility and Rural Reinvigoration., 51-62. https://doi.org/10.1017/9781009227216.006.

Land Use Change and Environmental Sustainability: A Case Study of Ido Local Government Area in Ibadan, Southwestern Nigeria

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Abstract

The dynamics of land use and land cover significantly influence environmental sustainability, particularly in areas undergoing rapid urbanization growth. This study assessed land use change in Ido Local Government Area, Ibadan from 2005 to 2025, with emphasis on vegetation loss, built-up expansion, and sustainability implications. Multi-temporal satellite imagery (2005, 2015, and 2025) was produced using supervised classification in ArcGIS 10.8. Descriptive statistics and percentage change analysis were used to measure shifts in land cover. Result of study revealed a sharp reduction in dense vegetation, 57.47% in 2005 to 4.74% in 2025, while built-up areas increased from 4.44% to 23.60% within the same period. The variations in shrubs/grasslands and sparse vegetation suggested a moderate degradation of ecological cover. These transformations reflect an increase in human activities driven by urbanization, agriculture, and infrastructural development. The study highlights the increased risks of biodiversity loss, reduced groundwater recharge, soil erosion, and a decrease in ecosystem resilience, which threaten long-term environmental sustainability. The study concludes that unregulated land use change undermines ecological balance and local livelihoods. It recommends proactive adoption of agroforestry, sustainable urban planning, and integrated land management practices to balance development with conservation needs.

Keywords: Land Use Change, Environmental Sustainability, Vegetation Loss, Agroforestry, Southwestern Nigeria

Introduction

Land use change is a foremost drive to environmental degradation and biodiversity loss in developing countries like Nigeria. Rapid urbanization, agricultural expansion, and infrastructural development frequently change natural ecosystems into degraded landscapes with reduced ecological functions (FAO, 2020; Alayande, 2016). In Nigeria, particularly in urban–rural areas, the effects of vegetation loss aside biodiversity reduction include soil erosion, groundwater depletion, and climate-induced flooding (Oyinloye, 2011; Akinyemi *et al*., 2013).

Ibadan, underlain by Precambrian Basement Complex rocks, provides fertile grounds for agriculture but is increasingly threatened by unregulated land use practices (Oyinloye, 2011). Ido Local

Government Area (LGA), located on the outskirts of Ibadan metropolis has experienced rapid land transformation in recent years. Thus, understanding its spatio-temporal land use dynamics is crucial for designing policies that promote environmental sustainability. This study aims to assess land use and land cover changes in Ido LGA between 2005 and 2025; relate vegetation and land degradation patterns to geological formations and propose sustainable land use strategies that promote environmental sustainability.

Materials and Methods

Study Area

Ido LGA lies in the Southwestern part of Oyo State, Nigeria, within latitudes 7°20'N and 7°40'N and longitudes 3°45'E and 4°00'E. The climate is humid tropical, with mean annual rainfall of 1,250–1,500 mm. The study area supports diverse land uses including agriculture, forestry, and settlements. Geologically, the region is dominated by migmatite-gneiss complexes, quartzite ridges, and granitic intrusions, which influence soil fertility and vegetation distribution (Odeyemi, 1993).

Data Collection

Land use/land cover data for 2005, 2015, and 2025 were derived from Landsat imagery (30 m resolution) processed using supervised classification in ArcGIS 10.8. Accuracy assessment was conducted using ground-trothing points, existing topographic maps and literatures.

Data Analysis

Data were computed using the following equation 1,2 and 3 for percentage of land use, net change in land use class and percentage change respectively. Data were also analyzed using descriptive statistics.

1. Percentage of land use class

$$Percentage = \frac{Area\ of\ Class(ha)}{Total\ area\ (ha)} x100 \quad (1)$$

2. Net change of land use class

$$Net\ Change = Area_{\ Final\ year} - Area_{Intial\ year} \quad \textbf{(2)}$$

3. Percentage change

$$Percentage\ change = \frac{Net\ change}{Area_{intial\ yesr}} \quad \textbf{(3)}$$

Results and Discussion

Land Use and Land Cover Dynamics

Land use and land cover (LULC) changes between 2005 and 2025 are presented in Table 1, 2 and Figure 1. Four land use classes were delineated: built-up areas, dense vegetation, shrubs/grasslands, and sparse vegetation.

Table 1. Land Use/Land Cover Distribution in Ido LGA (2005–2025)

Land Use Class	2005 Area (ha)	%	2015 Area (ha)	%	2025 Area (ha)	%	Change (2005–2025, %)
Built-up Areas	3871.11	4.44	19796.73	22.68	20582.18	23.60	+19.16
Dense vegetation	50154.72	57.47	8909.78	10.21	4137.12	4.74	–52.73
Shrubs/ grasslands	13348.70	15.30	9812.90	11.24	33070.52	37.91	+22.61
Sparse vegetation	19905.55	22.81	48759.67	55.87	29489.27	33.81	+11.00
Total	87265.61	100	87279.09	100	87279.09	100	—

(This Study, 2025)

Table 2: Net and Percentage Change (2005–2025)

Land Use Class	Net Change (ha)	% Change (2005–2025)
Built-up areas	+16,711.07	+431.7%
Dense vegetation	-46,017.60	-91.8%
Shrubs/Grasslands	+19,721.82	+147.8%
Sparse vegetation	+9,583.72	+48.1%

(This Study, 2025)

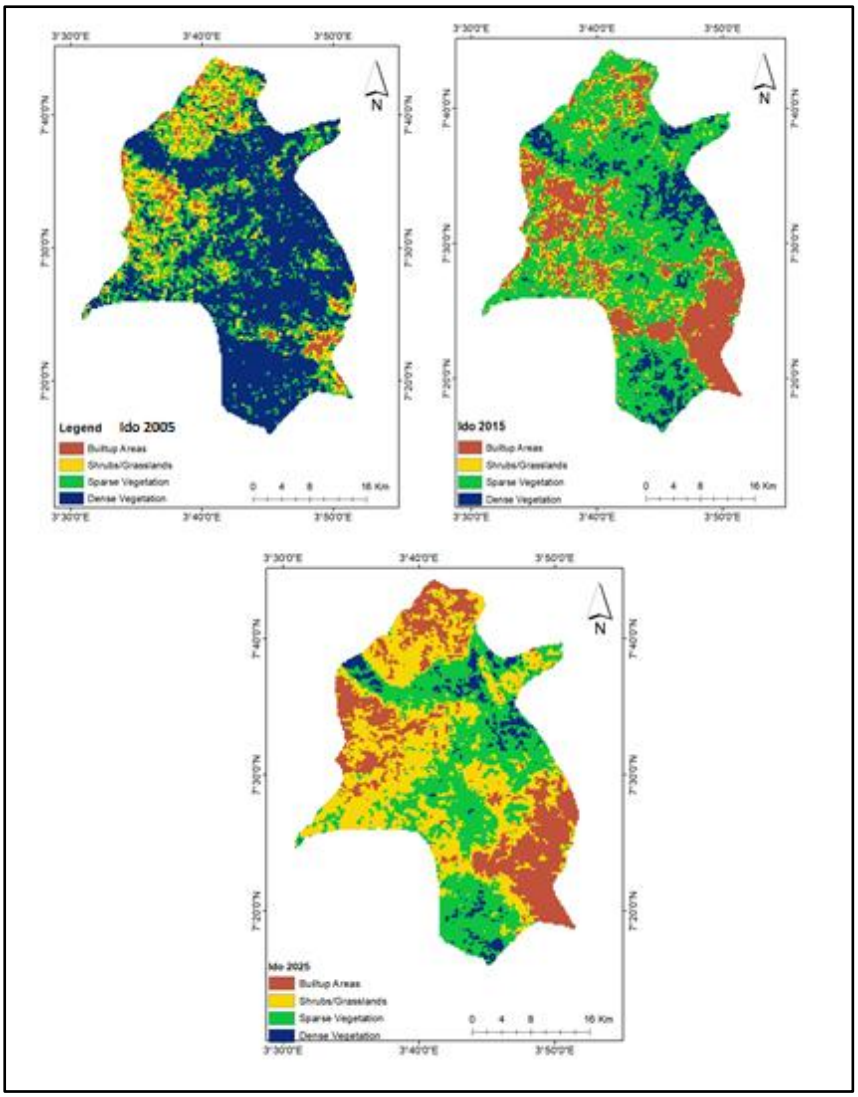


Figure 1: Map showing the land use and land cover change.

The study revealed significant transformations in land use and land cover from 2005 to 2025. There was a drastic decline in dense vegetation (–91.8%), whereas built-up areas saw an expansion of over four times (+431.7%). Additionally, shrubs and grasslands experienced an increase (+147.8%) as transitional cover, while sparse vegetation exhibited moderate growth (+48.1%).

The findings also indicate that dense vegetation decreased by 52.73% during the period from 2005 to 2025, primarily attributed to deforestation and the expansion of agricultural land, which resulted in considerable vegetation loss. The built-up areas expanded fivefold, an indication of peri-urban growth of Ibadan, while the increase in shrubs and grasslands suggests that degraded forests are being transformed into secondary vegetation. The variations in sparse vegetation reflect changes in agricultural land use and the presence of abandoned plots. These findings are consistent with previous studies conducted in Ibadan, which identified deforestation and peri-urban sprawl as significant factors driving changes in land cover (Ayanlade, 2016; Olokeogun et al., 2018).

Implications for Environmental Sustainability

1. Groundwater Recharge

The decrease in dense vegetation from 57.47% in 2005 to 4.74% by 2025 indicates a diminished capacity for infiltration. Vegetation typically enhances groundwater recharge by improving soil porosity and minimizing surface runoff. Its absence results in increased runoff, decreased recharge, and a decline in groundwater sustainability.

2. Soil Erosion and Land Degradation

The loss of vegetation exposes soil to erosion, particularly on sloped terrains. Sparse vegetation now covers 33.81% of the study area, which heightens vulnerability to sheet erosion, gully formation, and sedimentation in streams.

3. Slope Stability and Structural Risks

The expansion of urban areas into geologically unstable regions raises the likelihood of landslides and foundation failures. The increase in built-up land (+16,711 ha) without adequate geotechnical planning may result in structural instability, especially in regions with clay-rich soils that are susceptible to shrink-swell cycles.

4. Flooding Hazards

The rise in impervious surfaces due to urban growth decreases infiltration and increases water runoff, thereby elevating flood risks. The loss of vegetation further reduces the natural drainage capacity, this aligns with the finding of Ajibade et al., (2021) on climate-induced flooding in Southwestern Nigeria.

5. Biodiversity and Ecosystem Services

The reduction of vegetation leads to decrease in soil carbon storage, nutrient cycling, and habitat diversity. While shrub lands may temporarily replace forests and provide ground cover, they are inadequate for sustaining biodiversity. This situation poses a threat to long-term ecological resilience and undermines sustainability objectives

Conclusion

The study revealed a significant decline in dense vegetation, rapid urban development, and an increase in shrubland areas, indicating intensified human activities driven by urbanization, agriculture, and infrastructure expansion. These changes pose risks such as biodiversity loss, reduced groundwater recharge, soil erosion, and weakened ecosystem resilience, threatening long-term environmental sustainability. The study concludes that unregulated land use changes disrupt ecological balance and local livelihoods. It recommends adopting agroforestry, sustainable urban planning, and integrated land management practices to harmonize development with environmental conservation.

References

Ajibade, F. O., Ajibade, T. F., Idowu, T. E., Nwogwu, N. A., Adelodun, B., Lasisi, K. H., & Adewumi, J. R. (2021). Flood-prone area mapping using GIS-based analytical hierarchy frameworks for Ibadan city, Nigeria. *Journal of Multi-Criteria Decision Analysis*, *28*(5-6), 283-295.

Akinyemi, F. O. (2013). An assessment of land-use change in the Cocoa Belt of south-west Nigeria. *International Journal of Remote Sensing*, *34*(8), 2858-2875.

Ayanlade, A. (2016). Evaluating environmental change impacts on ecological services in the Niger Delta of Nigeria. *Ife Research Publications in Geography*, *11*(1), 111-125.

FAO (2020). *Global Forest Resources Assessment*. Food and Agriculture Organization of the United Nations, Rome.

Nair, P. K. R. (2012). Carbon sequestration studies in agroforestry systems: a reality-check. *Agroforestry Systems*, 86(2), 243–253.

Odeyemi, I. B. (1993). A comparative study of remote sensing data in geological mapping of basement rocks in Southwestern Nigeria. *Journal of Mining and Geology*, 29(2), 77–84.

Oyinloye, A. O. (2011). Geology and geotechnical appraisal of some parts of Ibadan, Southwestern Nigeria. *Earth Sciences Research Journal*, 15(2), 67–76.

Assessment of Sustainable Livelihood Strategies among Rural Women Farmers in Kwara State, Nigeria

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Abstract

Sustainable livelihood strategies are key to economic empowerment and other benefits among rural women farmers in Kwara state. The study therefore, assessed sustainable livelihood strategies among rural women farmers in Kwara State, Nigeria. The specific objective was to: describe the socioeconomic characteristics of rural women, examine their level of participation in sustainable strategies, assess influencing factors, examined benefits, and identify constraints. A Three-stage sampling technique was used to select 124 rural women farmers. Results revealed that the majority of respondents were married women aged around 50-51 years with limited formal education, primarily engaged in small-scale crop farming with an average of 34.3 years of experience. Crop farming was the major livelihood strategy (56.5%), followed by trading (14.5%), with overall low diversification. Factors influencing sustainable livelihoods included the availability of farmland, weather conditions, access to credit, and cost of inputs. The main benefits identified were increased income and improved livelihoods. Significant constraints includes inadequate financial support and weak institutional support. Household size and farm size showed a significant positive relationship with participation in sustainable livelihood strategies. The study concludes that while rural women are active in farming, their overall participation in diverse livelihood strategies is low due to inadequate finance, weak support systems, and lack of inputs. Recommendations include providing grants, credit facilities, subsidized inputs, training, promoting cooperative formation, implementing policies for land accessibility, and improving institutional support to encourage livelihood diversification.

Keywords: Assessment, sustainability, strategies, Livelihood, Rural women.

Introduction

In Nigeria, rural women farmers are instrumental in ensuring household sustenance and community development despite facing socio-economic and environmental challenges. Rural women are known for their attempts to sustain the economic life and wellbeing of their households through their engagements in many activities such as production and processing that can promote their livelihoods (Nnodim, 2019). According to United Nations Women, (2015), rural

women are key agents that will bring about the transformational economic, social changes and environmental protection that are required for achieving sustainable development in agriculture.

However, the performance of the agricultural sector is still below expectation in many countries due to the fact that women, who are often crucial resources in agriculture and the rural economy, face diverse constraints such as inadequate access to productive resources in the course of carrying out their livelihood activities (Adebayo &Adekunle,2013; Njukietal.,2016). These challenges underscore the critical need to examine the concept of livelihood particularly as it relates to how rural women navigate these obstacles to sustain their economic and social well-being.

Livelihood is the means by which individual or households secure the necessities of life, such as food, water, shelter and clothing, through various activities, assets and resources. According to(United Nations Development(UNDP),2011. A livelihood comprises the capabilities, assets and activities required for a sustainable means of living. Different people have different lifestyles and ways of meeting their needs. Similarly, households perform various activities to gain and maintain their livelihoods. Livelihood entails those activities that are performed to live for a given life span whilst securing water, food, medicine, shelter, clothing and capacity to acquire the mentioned necessities.

Sustainable livelihoods are those that can withstand external shocks, adapt to changing conditions, and continue to provide for individuals and their households. For rural women farmers in Kwara State, achieving sustainable livelihoods involves overcoming barriers such as climate change, poor infrastructure, and socio-economic inequalities. Sustainable livelihood are crucial for achieving rural developing and addressing poverty, especially among rural women farmers, who contribute significantly to agricultural production and food security (Science Direct ,2019). Poverty and food insecurity have been increasingly recognized as integral parts of sustainable development. This has led to poverty reduction and food security being key components of both the millennium and sustainable development goals (Ahmadu, &Edeoghon, 2018).

Addressing the challenges and achieving these goals is crucial to attaining sustainable development. In order to achieve sustainability, it is essential and important that the economic needs of the rural women households in terms of food security and poverty alleviation are met through their agricultural livelihood activities such as production and processing. These activities should meet their daily minimum calorie and protein requirements, as well as their daily minimum income requirement. (Adams 2017; Ajadi *et al*., 2015).

Based on the foregoing, the study was designed to describe the socioeconomic characteristics of rural women and to examine their level of participation in sustainable livelihood strategies. It also aimed to assess the factors that influence their participation, explore the benefits derived from engaging in such strategies, and identify the major constraints hindering their active involvement.

Methodology

The research was carried out in Kwara State, Nigeria. Kwara state is located between latitudes 70 45' and 90 30' North and longitudes 20 30' and 60 25' East, with its capital in Ilorin. The state comprises 16 Local Government Areas (LGAs) and has Agriculture as its mainstay. With an annual rainfall that ranges from 1000 mm to 1500 mm and an average temperature that varies between 300 C and 350 C, crops commonly grown include Cassava, Rice, Maize, Kolanut, Cocoa, Coffee, Tobacco, Beniseed, Cotton, Palm produce, and Vegetables such as Amaranthus, Okra, and Pepper (Omotesho et al., 2019). A three-stage sampling technique was used for this study. The first stage involved purposive selection of Local Government Areas (LGA's) based on agricultural activity and the presence of rural women farmers in the LGAs. The second stage involved random selection of communities within the selected LGA's. In the final stage, 124 rural women farmers were randomly selected from the chosen communities to serve as respondents for the study. The Kobo collect App was use to utilized and gather the data efficiently. The instrument was divided into 6 stages.

Results and Discussion

Socio-Economic Characteristics of Respondents

The results presented in Table 1 indicate that the average age of the respondents was 50.9 years, suggesting that rural women in Kwara State are advancing in age and may soon lack the physical strength required for the strenuous activities associated with their livelihoods. Most of the respondents were married (87.1%), with an average household size of approximately seven persons. This marital status implies potential access to family labor, as spouses and household members may assist in physically demanding farming tasks. This finding aligns with the report of Aremu et al. (2023), which noted that most rural women in Kwara State had household sizes ranging between five and ten members. The study further revealed that the respondents had an average of 5.4 years of formal education, cultivated an average farm size of 3.8 hectares, and had been involved in farming for an average of 34.3 years. These findings corroborate the report by Falola et al. (2020), which highlighted long-term engagement in farming among rural women. The average annual income realized was ₦652,725.94, an amount expected to provide reasonable financial support for household expenses,

particularly since most respondents were married, with their husbands typically bearing primary financial responsibilities.

Table 1: Average Age of the Respondents

Variables	Frequency=124	Percentage	Mean±SD
Age in years			
≤ 35	11	8.9	50.9±10.5
36 – 45	35	28.2	
46 – 55	40	32.3	
Above 55	38	30.6	
Marital status			
Married	108	87.1	
Otherwise	16	12.9	
Years of formal education			
0 (no formal)	49	39.5	5.4±.3.5
1 – 6 (primary)	32	25.8	
7 – 12 (secondary)	36	29.0	
12 and above (tertiary)	7	5.6	
Household size in persons			
≤ 4	16	12.9	6.7±2.5
5 – 8	90	72.6	
Above 8	18	14.5	
Farm size in hectares			
≤ 5	103	83.1	3.8±3.8
6 – 10	17	13.7	
Above 10	4	3.2	
Farming experience in years			
≤ 10	13	10.5	34.3±10.6
11 – 20	13	10.5	
Above 20	98	79.0	
Annual Income in naira			
≤ 500,000	82	66.1	652,725.94±
500,001 – 1,000,000	35	28.2	142,938.43
Above 1,000,000	7	5.6	

Source: Field survey, 2025

Level of Participation in Sustainable Livelihood Strategies

Results in Table 2 indicate the frequency of participation in sustainable livelihood strategies. Results of mean rating of participation in Table 3 reveal that Crop farming (mean=3.72±0.70) ranked first, Trading/business (mean=2.71±1.10) ranked second, Livestock farming (mean=2.33±1.25) ranked third, while Bee keeping (mean=1.15±0.52) was ranked tenth position as the least participated means of sustainable livelihood. Findings further established that crop farming having score above 3.0 (equivalent to always) is the commonly engaged sustainable livelihood of rural women in Kwara State. By implication, crop farming is the most prominent means of sustainable livelihood of rural women in Kwara State. This finding confirms reports that found agriculture as the main sustainable livelihood

activities rural women in Kwara State (Aremu et al., 2023; Popoola et al., 2023). According to Falola (2023), agriculture contributed the most to the total household income of rural women in Kwara State.

Table 2: Distribution of respondents by frequency of participation in sustainable livelihood strategies

Sustainable Strategies	Always	Occasionally	Rarely	Never	Mean	Rank
Crop farming	101(81.5)	17(13.7)	0	6(4.8)	3.72±0.70	1st
Trading	32(25.8)	54(43.5)	8(6.5)	30(24.2)	2.71±1.10	2nd
Livestock farming	30(24.2)	34(27.4)	7(5.6)	53(42.7)	2.33±1.25	3rd
Hairdressing	9(7.3)	15(12.1)	4(3.2)	96(77.4)	1.49±0.97	4th
Fish farming	9(2.4)	11(8.9)	18(14.5)	92(74.2)	1.40±0.75	5th
Handicraft	2(1.6)	6(4.8)	10(8.1)	106(85.5)	1.23±0.61	6th
Tailoring	1(0.8)	9(7.3)	6(4.8)	108(87.1)	1.22±0.61	7th
Bead-making	0	6(4.8)	7(5.6)	111(89.5)	1.15±0.48	8th
Artisan	1(0.8)	5(4.0)	5(4.0)	113(91.1)	1.15±0.51	9th
Bee keeping	2(1.6)	3(2.4)	6(4.8)	113(91.1)	1.15±0.52	10th

Source: Field survey, 2025

Categorization of Participation in Sustainable Livelihood Strategies

Results in Table 3 reported the total participation score of each respondent was grouped into 3 categories. Results show that 71.0% were grouped as having low participation, 17.7% were grouped as having moderate participation while 11.3% were grouped as having high participation. Findings imply that rural women participation in various sustainable livelihood strategies available in the rural area was low. This may be attributed to their high involvement in farming activities, with very low diversification of livelihood options. This finding confirms previous studies that found low livelihood diversification of strategies among rural women in Kwara state (Falola et al. 2023) and Enugu state (Mukaila et al., 2021) respectively.

Table 3: Categorization of level of participation in sustainable livelihood strategies

Obtained score	Level	Frequency	Percentage
10 – 20	Low	88	71.0
21 – 30	Moderate	22	17.7
31 – 40	High	14	11.3
Total		124	100.0

Possible score range 10 - 40

Factors Influencing the Participation of Sustainable Livelihood Strategies

Results in Table 4 shows factors influencing the practice of sustainable livelihood strategies were displayed in Table 5. Results show that availability of farmland (mean=3.71±1.20) ranked first. Despite the participation of women in agriculture and food production, rural women in Kwara state still suffer the availability of land for cultivation of crops. This is consistent with several literature that previous establish access to land as a major factor affecting women participation in agriculture (Adebayo & Worth, 2024; Agbor &Eteng, 2018). Additionally, weather conditions (mean=3.40±1.33) ranked second as factor indicated by respondents. This finding may be attributed their high involvement in farming activities as a chosen sustainable livelihood strategy. In this direction, studies have proven that weather variability has high effect on farming generally while have specifically shown the effect on women farmers in Nigeria (Duru et al., 2022; Ifeanyi-obi, 2023). Other factors indicated were access to credit/loans (mean=3.37±1.83) ranked third, cost of input (mean=3.35±1.32) ranked fourth, while government policies (mean=2.56±1.37) ranked tenth position as the least factor considered to affect the sustainable livelihood of women.

Table 4: **Distribution of respondents by agreement to factors affecting the practice of sustainable livelihood strategies**

Factors	SA	A	N	D	SD	Mean	Rank
Availability of farmland	31(25.0)	61(49.2)	7(5.6)	15(12.1)	10(8.1)	3.71±1.20	1st
Weather conditions	24(19.4)	54(43.5)	13(10.5)	14(11.3)	19(15.3)	3.40±1.33	2nd
Access to credit/loans	62(50.0)	12(9.7)	1(0.8)	8(6.5)	41(33.1)	3.37±1.83	3rd
Cost of input	25(20.2)	46(37.1)	16(12.9)	21(16.9)	16(12.9)	3.35±1.32	4th
Availability of agricultural inputs	11(8.9)	64(51.6)	17(13.7)	18(14.5)	14(11.3)	3.32±1.17	5th
Knowledge on the Sustainable livelihood strategies	18(14.5)	44(35.5)	21(16.9)	20(16.1)	21(16.9)	3.15±1.32	6th
Availabilityof products	25(20.2)	43(34.7)	7(5.6)	21(16.9)	28(22.6)	3.13±1.49	7th
Market of products	20(16.1)	50(40.3)	5(4.0)	18(14.5)	31(25.0)	3.08±1.48	8th
Level of education	6(4.8)	31(25.0)	29(23.4)	37(29.8)	21(16.9)	2.71±1.16	9th
Government policies	14(11.3)	22(17.7)	20(16.1)	31(25..0)	37(29.8)	2.56±1.37	10th

Source: Field survey, 2025

Benefits of Practicing Sustainable Livelihood Strategies

Results in Table 5 display the benefits derived in Participation in sustainable livelihood strategies. Findings show that Increased income (mean=2.69±0.48) ranked, improved livelihood (mean=2.37±0.59) ranked second, access to better market opportunities (mean=2.35±0.56) ranked third, while reduced cost of farming (mean=2.10±0.63) ranked sixth position as the least indicated barrier. Findings imply that increased income, improved livelihood, and access to better market opportunities were the foremost benefits of rural women participation in sustainable livelihood strategies. Finding agree with studies that previous indicated that women participation in rural livelihood empower them to earn more income and sustain household livelihood (Falola et al., 2023).

Table 5: Respondents' Level of benefits of Sustainable Livelihood Strategies

Benefits	Very beneficial	Beneficial	Not beneficial	Mean	Rank
Increased income	86(69.4)	37(29.8)	1(0.8)	2.69±0.48	1st
Improved livelihood	53(42.7)	64(51.6)	7(5.6)	2.37±0.59	2nd
Access to better market opportunities	48(38.7)	71(57.3)	5(4.0)	2.35±0.56	3rd
Better Soil Facility	47(37.9)	73(58.9)	4(3.2)	2.35±0.54	4th
Higher crop yield	47(37.9)	69(55.6)	8(6.5)	2.31±0.59	5th
Reduced Cost of Farming	31(25.0)	74(59.7)	19(15.3)	2.10±0.63	6th

Source: Field survey, 2025

Constraints to Practice of Sustainable Livelihood Strategies

Results in Table 6 shows the severity of constraints to practicing sustainable livelihood strategies by respondents. Results showed that financial constraints (mean=2.56±0.65) ranked first, Weak institutional support (mean=2.10±0.71) ranked second, lack of modern farming equipment (mean=2.01±0.66) ranked third, climate change and environmental challenges (mean=1.99±0.63) ranked fourth, while social and cultural change (mean=1.56±0.64) ranked eight position as the least constraint indicated. Findings imply that finance, weak institutional support and inadequate of modern farming equipment were the most serious constraints affecting rural women participation in sustainable livelihood strategies in Kwara State. This report is in line with finding by Popoola et al. (2023) that large number of rural women still suffer inadequate access to finance/credit facilities in Kwara State.

Test of Hypothesis

The results of PPMC analysis of the relationship between socioeconomic characteristics of respondents and their participation in sustainable livelihood strategies are presented in Table 7. Findings reveal that household size in persons ($r = 0.191$, $p<0.05$), and size of farmland in hectares ($r = 0.219$, $p<0.05$) were the only socioeconomic variable showing statistical significant relationship with

women participation in sustainable livelihood strategies. This implies that increase number of persons in their household and increase number of hectares of land cultivated for crop farmers which was indicated as the major means of their livelihood will implies a better participation in sustainable livelihood strategies. In this case, the null hypothesis is rejected while the alternative is accepted

Table 6: Distribution of respondents by seriousness of constraints to practicing sustainable livelihood strategies

Constraints	Very serious	Serious	Not serious	Mean	Rank
Financial constraints	80(64.5)	33(26.6)	11(8.9)	2.56±0.65	1st
Weak institutional support	38(30.6)	60(48.4)	26(21.0)	2.10±0.71	2nd
Lack of modern farming equipment	27(21.8)	71(57.3)	26(21.0)	2.01±0.66	3rd
Climate change and environmental challenges	24(19.4)	75(60.5)	25(20.2)	1.99±0.63	4th
Limited education and training	22(17.7)	59(47.6)	43(34.7)	1.83±0.71	5th
Limited access to land	22(17.7)	45(36.3)	57(46.0)	1.72±0.75	6th
Poor market access	16(12.9)	44(35.5)	64(51.6)	1.61±0.71	7th
Social and cultural change	10(8.1)	50(40.3)	64(51.6)	1.56±0.64	8th

Source: Field survey, 2025

Table 7: **Pearson Product Moment Correlation analysis of the relationship between socioeconomic characteristics of respondents and their participation in sustainable livelihood strategies**

	Correlation (r)	Sig. (p-value)
Age in years	-0.138	0.127
Marital status (married=1)	0.167	0.064
Years of formal education	0.004	0.965
Household size in persons	0.191*	0.033
Years of farming experience	-0.010	0.914
Size of farm in hectares	0.219*	0.014
Annual income in naira	-0.100	0.270
Membership of cooperative society (yes=1)	0.084	0.351

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

Conclusion and Recommendations

The study concluded that although rural women in Kwara State are actively engaged in farming, their overall participation in diverse livelihood strategies remains low, indicating limited livelihood diversification. Socio-economic factors such as household size and access to land were found to significantly influence their level of participation. Despite being aware of the benefits of engaging in sustainable livelihood activities, many rural women continue to face serious challenges, including inadequate financial resources, weak institutional support, and limited access to essential farming

inputs. Based on these findings, the study recommends that both government and non-governmental organizations (NGOs) should provide rural women with grants, credit facilities, and subsidized farm inputs to enhance their capacity for livelihood diversification. In addition, adequate sensitization and extension services should be offered to improve rural women's awareness and knowledge of sustainable livelihood options beyond farming. Furthermore, policies that promote equal access to land, regardless of gender, should be formulated and effectively implemented. Finally, rural women should be encouraged to diversify their livelihood strategies by engaging in non-farm activities such as trading, tailoring, and agro-processing, thereby reducing their heavy dependence on farming as the sole source of income.

References

Adams, O.K. (2017). Nigeria WIOSR Journal of Humanities and Social Science (IOSR-JHSS), 22 (1), 102-106

Adebayo, J. A., & Worth, S. H. (2024). Profile of women in African agriculture and access to extension services.Social Sciences & Humanities Open, 9, 100790–100790. https://doi.org/10.1016/j.ssaho.2023.100790

Ahmadu, J. &Edeoghon, C.O. (2018.) Effect of Maize Production on Poverty Alleviation of Farmers in Edo State, Nigeria Agrosearch, 18(1), 53 – 65

Aremu, A.O., A.A. Muhammad-Lawal and Omotesho, O.A. (2023). Assessment of the sustainability of agricultural livelihood activities among rural women in Kwara State, Nigeria. Agrosearch, 22(1), pp.29–40. doi:https://doi.org/10.4314/agrosh.v22i1.3.

Babatunde, R.O.and Qaim, M. (2010). Impact of off-farm income on food security and nutrition in Nigeria. Food Policy, 35: 303-311

Falola, A., Mukaila, R., Nafiu, G., Sanjo Olanrewaju, A., Oladipo, S.-U., Obetta, A. and Chidimma, A. (2023). Assessment of The Livelihoods Of The Rural Vulnerable Group In Nigeria. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, [online] 23(4), p.307-317.

Falola, Abraham; Fakayode, Segun B.; Kayode, Ajoke O.; and Amusa, Mujidat A. (2020). Rural Women in Kwara State (Nigeria) and their Contributions to the Welfare of their Households. Journal of International Women's Studies, 21(6), 167-180. Available at: https://vc.bridgew.edu/jiws/vol21/iss6/10

Mukaila, R., Falola, A., Egwue, L.O., 2021, Income diversification and drivers of rural smallholder farmers' income in Enugu State, Nigeria. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 21(3), 585-592.

Nnodim, A. U. (2019). Strategies for Sustainable Rural Livelihoods in Etche Local Government Area. International Journal of Agricultural Extension and Rural Development Studies 6(6), 18-26.

Omotesho, K. F., Adesiji, G. B., Kayode, O. A., Akinrinde, A. F., & Ariyo, F. O. (2019). Assessment of the Cultivation of Indigenous Leafy Vegetables in Kwara State, Nigeria

Popoola O. P., Yusuf A. O. T. J., Ishola S. O. D., Adara C. T., Yakubu S., Oyeyemi P. O., Nwankpa F. I. (2023). Assessment of Livelihood Activities of Beneficiaries of Village Alive Development Initiative, Kwara State, Nigeria; Vol-5, Iss- 3 pp- 47-60.

Reardon, T., Beregue, J., Barret, C.B. and Stamoulis, K. (2007). Household income diversification into rural nonfarm activities. John Hopkins University Press.

United NationsWomen (2015). Progress of the world's women 2015-2016: Transforming economics, realizing rights. New York. http:// progress. unwomen .org/

Rural Farming Youths' Behaviour towards Agricultural Entrepreneurship in Ilorin East Local Government Area, Kwara State, Nigeria

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Abstract

Despite the critical role that rural youths can play in agricultural development due to their population and physical strength, their level of involvement in agriculture remains low. The study therefore assessed the behaviour of rural farming youths towards agricultural entrepreneurship in Ilorin East Local Government Area of Kwara State. The specific objectives were to: describe the socio-economic characteristics of the rural farming youths; identify the drivers of agricultural entrepreneurship; assess the behaviour of rural farming youths towards agricultural entrepreneurship; identify the determinants of their behaviour; and identify the challenges faced by rural farming youths in agricultural entrepreneurship. A two-stage random sampling technique was used to select 148 rural youths on whom an interview schedule was administered. Data were analysed using descriptive statistics and the multiple regression analysis. Findings reveal that rural farming youths had mean age, years of schooling, household size, farming experience, and annual income of 30.18 years, 6.50 years, seven persons, 8.16 years and N322,297.29, respectively. About 53.4% were members of rural groups. The youths were mainly driven by the potential of agricultural entrepreneurship to generate income, provide resources and employment. Their behavour towards agricultural entrepreneurship was fairly favourable (Behavioural Index=0.77) and influenced by education (β=0.011), household size (β=0.017), farming experience (β=-0.028), and membership of rural groups (β=0.438). The major challenges limiting youths' involvement were inadequate capital (mean=3.47), poor access to credit (3.27), and climate change (3.12). The study concluded that rural farming youths generally exhibit fairly positive behaviour towards agricultural entrepreneurship. The study recommends regular training on agricultural entrepreneurship, linkage of youths with microfinance institutions, and other sources of funding, and incentives.

Keywords: Agricultural entrepreneurship, rural farming youths, behaviour, preferences

Introduction

Agricultural entrepreneurship is achievable when the associative concepts and ideas of entrepreneurship are applied in agriculture. Agricultural entrepreneurship activities are important for achieving Nigeria's development goals because of the various opportunities it provides, such as job creation (Vincent et al., 2021). Agricultural entrepreneurs initiate transformative agricultural changes that reduce real food prices, boost rural incomes, create jobs, and make financial profit from entrepreneurship. The ageing rural farmer population makes it very important to promote active participation of youths in agricultural entrepreneurship. The sustainability and effectiveness of youths as active actors therefore cannot be overemphasised (Adeyanju *et al*., 2021). According to Omotesho *et al.* (2022) youths are individuals between the ages of 18 to 35 years, this group is often characterised by ambition, inquisitiveness, energy and enthusiasm. These distinctive characteristics, together with the fact that they are, on average, more educated than the older generation and use more information and communication technology, help to justify the emphasis on youth as the face of commercial agriculture. Furthermore, compared to the older population, youth are the ideal catalysts for agricultural developmental change given their greater ability and willingness to adopt new ideas, concepts and technology (Proctor & Lucchesi, 2012).

A summary of different definitions refers to a person's behaviour as a measure of his/her knowledge and attitude towards another, an object, a concept, or an occasion. (Omotesho et al., 2022). Young people in rural areas continue to show little interest in agricultural entrepreneurship. This pattern seems to be evident in Kwara State, where young people's involvement in creative farming methods and agribusiness endeavors is minimal (Haruna et al., 2019) In many cases, rural farming youths seem to see agriculture as labour-intensive, unprofitable, and uninteresting in comparison to other industries. Rapid urbanization and the attractiveness of white-collar occupations have reinforced this impression, resulting in rural-urban migration and a diminishing agricultural workforce (Nnadi & Akwiwu, 2017). As a result, the agricultural sector suffers from an ageing farmer population, decreased productivity, and underutilisation of huge arable land. The main objective of the study, therefore, was to analyse the behaviour of rural farming youths towards agricultural entrepreneurship in Ilorin East Local Government Area, Kwara State. The specific objectives were to;

1. describe the socio-economic characteristics of the rural farming youths in Ilorin East Local Government Area;
2. examine the perception of rural youths towards agricultural entrepreneurship;
3. determine the drivers of youth's decision to participate in agricultural entrepreneurship;

4. assess the behaviour of rural farming youths towards agricultural entrepreneurship; and

5. identify the challenges faced by rural farming youth in agricultural entrepreneurship.

Methodology

The study was carried out in Ilorin East Local Government Area of Kwara State. The population for the study comprises all rural farming youths in Ilorin East Local Government Area of Kwara State. A two-stage random sampling procedure was used to select respondents for the study. A sample size of 148 was used for this study. The collection of data was done by using a structured interview schedule. The dependent variable for the study was the behaviour of rural farming youths toward agricultural entrepreneurship. Agricultural entrepreneurship behaviour was measured using a cumulative outcome of eight components namely; innovativeness, networking, achievement motivation, decision-making ability, technology orientation, risk orientation, decision making ability, management orientation and self-confidence. The scale developed by Chaudhari *et al.* (2007). The independent variables for the study were the socio-economic characteristics of the youths, the drivers of youth participation in agricultural entrepreneurship, and the challenges encountered by the youths in agricultural entrepreneurship. The data for the study were analysed using percentages, mean, frequency counts, standard deviation and the Multiple Regression Analysis. The OLS equation for the purpose of this study was represented as;

$Y = \beta_0 + \beta_1 + X_1 + \beta_2 + X_2 + \beta_3 X_3 + \ldots\ldots \beta_7 X_7 + \beta_8 D_1 + \beta_9 D_2 + \beta_{10} D_{10} + \mu$ .....(1)

β_0 = Intercept, $\beta_1 - \beta_{10}$ = Coefficients

Y = Rural Youths Agricultural Entreprenuership Behavior

X_1 = Age

X_2= Education

X_3= Income

X_4= Household size

X_5= Farming

X_6= Farming experience

d_1= Sex

d_2= Marital status

d_3= Primary occupation

Results and Discussion

Socio-economic Characteristics of Respondents

As shown in Table 1, the average age of respondents was 30.18 years, majority (61.5%) were males. The average number of years of formal education was approximately seven. Majority (90.1%) were married. The average household size was seven persons. The average annual income of respondents was ₦322,297 and 59.5% of the respondents were not members of rural associations. About 53.4% of the respondents had no extension contact in the immediate past six months period.

The Drivers of Youths' Decision to Participate in Agricultural Entrepreneurship

According to Table 2, the need to generate income and the availability of resources were identified as the most significant drivers of youth participation in agricultural entrepreneurship activities (Ranked 1st and 2nd).

Table 1: Socioeconomic Characteristics of Respondents (n=148)

Variables	Frequency	Percentages	Mean	Std. Dev
Age (years)				
≤ 25	36	24.3		
26-35	82	55.4	30.18	5.13
> 36	30	20.3		
Sex				
Male	91	61.5		
Female	57	38.5		
Years of Formal Education				
0	36	24.3		
1-6	64	43.2	6.50	4.60
7-12	43	29.1		
> 12	5	3.4		
Marital status				
Married	146	90.1		
Single	16	9.9		
Household Size				
≤ 3	9	6.1		
4-8	112	75.7	7.00	3.00
9-13	19	12.8		
>13	8	5.4		
Farming Experience (Years)	33	22.3		
≤ 3	50	33.8		
4-9	58	39.2	8.16	4.82
10-15	7	4.7		
> 15				
Annual Income (₦)				
≤ 150,000	33	22.3		
150,001-300,000	71	48.0		
300,001-450,000	14	9.5	322,297.29	223,953.63
> 450,001	30	20.3		
Membership of Association				
Yes	60	40.5		
No	88	59.5		
Extension Contact				
0	79	53.4		
1	59	39.9		
2	10	6.8		

Source: Field Survey, 2025

Youths also agreed that the need to stay out of unemployment, the need to contribute to local food, security and sustainable techniques are factors that drive their choice of agricultural entrepreneurship activities (3rd and 4th). Access to information and training along with a strong passion for agriculture were also identified as motivating factors (5th and 6th), these could also make them participate in agricultural activities.

Access to information and training could positively influence youths' choice to participate in agriculture, Adeyanju *et al.* (2021) reported that training in agribusiness has a substantial impact on the performance of young entrepreneurs in agricultural activities.

Table 2: Distribution of Respondents' Drivers of Participation in Agricultural Entrepreneurship (n=148)

Drivers	Strongly Agree F (%)	Agree F (%)	Disagree F (%)	Strongly Disagree F (%)	Mean	Rank
Income generation is a significant driver for my participation in agricultural entrepreneurship	2(1.4)	1(0.7)	67(45.3)	78(52.7)	3.49	**1st**
The availability of resources is crucial in facilitating agricultural ventures	4(2.7)	2(1.4)	105(70.9)	37(25.0)	3.18	**2nd**
Government incentives plays a crucial part in my participation in agriculture	28(18.9)	40(27.0)	53(35.8)	27(18.2)	2.53	**7th**
Employment generation is a key factor driving my interest in agricultural entrepreneurship	8(5.4)	9(6.1)	88(59.5)	43(29.1)	3.12	**3rd**
I participate in agricultural entrepreneurship because of the strong passion I have for it	14(9.5)	32(21.6)	66(44.6)	36(24.3)	2.83	**6th**
Access to information and training boosts my participation in agricultural entrepreneurship	12(8.1)	34(23.0)	64(43.2)	38(25.7)	2.86	**5th**
I am motivated by the chance to contribute to local food security and sustainable farming techniques	5(3.4)	16(10.8)	94(63.5)	33(22.3)	3.04	**4th**

Source: Field Survey 2025

The Behaviour of Rural Farming Youths towards Agricultural Entrepreneurship

The overall behaviour of respondents in agricultural entrepreneurship was fair (index=0.77). The reason for this might be because most of the respondents had high scores in key behavioural areas like innovativeness, achievement motivation and self-confidence. This finding is in conformity with Shivacharan (2014), who reported that rural youths exhibit positive entrepreneurial behaviour toward agricultural entrepreneurship, characterised by high levels of innovativeness, achievement motivation, and self-confidence.

Table 3: Behavioural Index

Score	Frequency	Percentage	Mean±S.D	Remarks
<0.50	5	3.4		Negative
0.51-0.90	135	91.2	0.77±0.09	Fair
> 0.90	8	5.4		Positive

Source: Field Survey 2025

The regression model with 10 predictors produced an R-squared value of 0.546 at a p<0.05. This implies that the significant variables explain 54.60% of the variations in the youths' behavior. As shown in Table 4, years of formal education (β =0.011), house size (β =0.017) and membership of rural association (β =0.438) were determinants of farming youths' behaviour towards agricultural entrepreneurship accordingly. The significant effect of education may be attributed to the need for an alternative employment after the long wait for a non-available white collar job. It could also be due to the role of education in accessing timely information about agricultural entrepreneurship activities, this confirmed the findings of Adeyanju *et al*. (2021).

Table 4: Determinants of Farming Youths' Behaviour towards Agricultural Entrepreneurship

	Unstandardised Coefficients			
Predictor	B	Std. Error	t	Sig.
(constant)	2.481	0.156	15.953	0.000
Age	0.009	0.007	1.372	0.172
Education	0.011**	0.005	2.302	0.023
Marital	0.033	0.062	0.530	0.597
Sex	-0.014	0.045	-0.312	0.755
Household size	0.017**	0.009	2.034	0.044
Average income	-7.743E-008	0.000	-0.675	0.501
Farming experience	-0.028**	0.007	-4.170	0.000
Primary occupation	-0.013	0.047	-0.269	0.789
Membership of rural association	0.438**	0.044	9.886	0.000
Extension contact	0.026	0.035	0.738	0.462

**Significant at the .05level (2-tailed), R Square=0.546, F value=14.8

Challenges to Participation in Agricultural Entrepreneurship

Table 5 below shows the challenges to participation in agricultural entrepreneurship**.** The most severe challenges to youths' participation in Agricultural Entrepreneurship were lack or inadequate capital, poor access to credit and weather change (ranked 1st, 2nd and 3rd respectively).

Table 5: Challenges to Participation in Agricultural Entrepreneurship (n=148)

Challenges	Not a challenge F (%)	Less Severe F (%)	Severe F (%)	Very Severe F (%)	Mean	Rank
Lack or inadequate start-up capital	0(0.0)	4(2.7)	69(46.6)	75(50.7)	3.47	1st
Climate change challenges	5(3.4)	13(8.8)	89(60.1)	41(27.7)	3.12	3rd
Poor access to credit	0(0.0)	12(8.1)	83(56.1)	53(35.8)	3.27	2nd
Limited access to markets	25(16.9)	66(44.6)	41(27.7)	16(10.8)	2.32	7th
Inadequate knowledge of agricultural enterprises	15(10.1)	42(28.4)	79(53.4)	12(8.1)	2.59	6th
Poor Infrastructure	6(4.1)	42(28.4)	73(49.3)	27(18.2)	2.81	5th
Limited access to agricultural inputs and technology	17(11.5)	12(8.1)	91(61.5)	28(18.9)	2.87	4th
Negative socio-cultural beliefs and perceptions about agricultural entrepreneurs	84(56.8)	40(27.0)	12(8.1)	12(8.1)	1.67	8th

Source: Field Survey 2025

Conclusion and Recommendations

The study concluded that the behaviour of rural farming youths towards agricultural entrepreneurship was fairly favourable, but the youths were constrained by inadequate capital, poor access to credit and climate change effects.

The following are recommendations

1. Stakeholder groups should explore a multidimensional approach to improve youth's access to credit facility for agricultural entrepreneurship.

2. Extension workers should support agricultural entrepreneurs, especially youths in the field by linking them to microfinance institutions, cooperative societies, and government support programs to help enhance their financial stability and investment capacity.

3. Extension agents should help in training, demonstrations, and providing technical support to agricultural entrepreneurs.

References

Adeyanju, D., Mburu, J., & Mignouna, D. (2021). Youth agricultural entrepreneurship: Assessing the impact of agricultural training programmes on performance. *Sustainability, 13*(4), 1697.

Chaudhari, R. R., Hirevenkanagoudar, L. V., Hanchinal, S. N., Mokashi, A. N., Katharki, P. A., & Banakar, B. (2007). A scale for measurement of entrepreneurial behaviour of dairy farmers.Nnadi, F. N., & Akwiwu, C. D. (2017). *Determinants of Youths' Participation in Rural Agriculture in Imo State, Nigeria*. Journal of Applied Sciences, 15(4), 798-805

Haruna, O. I., Asogwa, V. C., & Ezhim, I. A. (2019). Challenges and Enhancement of Youth Participation in Agricultural Education for Sustainable Food Security. *African Educational Research Journal*, *7*(4), 174-182.

Nnadi, F. N., & Akwiwu, C. D. (2017). *Determinants of Youths' Participation in Rural Agriculture in Imo State, Nigeria*. Journal of Applied Sciences, 15(4), 798-805.

Omotesho, K. F., Fatodu, P. A., & Ajibade, T. B. (2022). Farm record keeping behaviour of rural farming youths in Ekiti State, Nigeria. *Sarhad Journal of Agriculture*, *38*(1), 92-102.

Proctor, F.J. and V. Lucchesi (2012) Small-scale farming and youth in an era of rapid rural change, IIED/HIVOS, London/The Hague

Shivacharan, G. (2014). *A* study on entrepreneurial behaviour and attitude of rural youth towards agri entrepreneurship (Doctoral dissertation, ACharya Ng Ranga Agricultural University, Rajendranagar, Hyderabad).

Vincent. Segun, I. B., Loretta, N. N., & Abiola, A. (2021). Entrepreneurship, agricultural value-chain and exports in Nigeria. *United International Journal for Research and Technology*, *2*(08), 1-8.

Influence of Nutrition on Academic Achievement of Public Primary School Pupils in Ido Local Government Area of Oyo State

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Abstract

Numerous factors are known to affect the academic achievement of pupils, which include food type, food intake, pre-natal and birth conditions, parent social economic status and environmental factors. Nutrition is a vital component of human health, life, and brain development through the entire lifespan. Balanced nutrition is crucial for endurance, physical growth, cognitive development and productivity. This study therefore examined the influence of nutrition on academic achievement among public primary school pupils in Ido local government area of Oyo state. The study adopted a descriptive research design. Purposive and simple random sampling techniques were used to select three (3) public primary schools in Ido local government area of Oyo state. The population for the study comprised of fifty (50) male and female pupils from each school. A self-developed and validated questionnaire were used for data collection. Data were analyzed using frequency counts and percentages, while inferential statistics of Pearson product moment correlation and regression were used to test the hypotheses at 0.05 alpha level. Result from findings revealed that, type of food (r = 0.000) had positive relationship with academic achievement, while eating habits (r=0.186), parental social economic status (r= 0.058) and sex (r = 0.084) did not. It was recommended that parents should be educated that poor nutrition could influence children's learning habit. It is therefore essential that children daily diet include highly nutritious food(s).

Keywords: Academic, achievement, public, primary schools, and nutrition.

Introduction

More than one in four children under the age of fifteen are underweight, due to inadequate diets and persistent malnutrition. (Glewwe & Jacoby, 2018). The consequences are: weakened immunity, poor concentration in school etc. These challenges often start before birth. Mothers with under nutrition during pregnancy, do give birth to babies with low birth weight, which can hinder their healthy growth and development later in life (Glewwe & Jacoby, 2018). Nutrition is the body's way of absorbing essential nutrients. For children, the quality of nutrition during infancy, childhood, and adolescence is important (Cameron, 2012). Deficiencies at these stages' slow growth, increases susceptibility to disease etc. Food choices influence the brain works. Nutrients support the growth of brain cells, formation of connections, and development of protective myelin (Cameron, 2012). Malnutrition in children at early stage, can

reduce brain size, disrupt chemical messaging systems, and weaken memory and learning ability. Nutrient-rich diets build stronger foundations for learning (Second Harvest Heartland 2013). Malnutrition has impact on both health and education. Pupils with poor diets often suffer frequent illness, behavioral challenges, and weaker academic performance (Glewwe & Jacoby, 2018). "Brain foods", protects the brain and enhances cognitive function (Cameron, 2012).

Problem Statement and Objectives

Concerns over poor academic performance among primary school pupils have increasingly drawn the attention of teachers, parents, and policymakers. While many argue that government has the primary responsibility for tackling malnutrition, the roles of parents and teachers are equally important. This raises critical questions: How exactly does nutrition affect children's learning? What kinds of diets best support cognitive development? And why do some children thrive academically while others struggle, even within the same classrooms. This study seeks to explore the relationship between nutrition and academic achievement among public primary school pupils in Ido Local Government Area of Oyo State. Specifically, it aims to: Assess how the types of foods consumed influence pupils' academic achievement, examine the effects of eating habits on learning outcomes, investigate the role of sex in shaping academic performance and determine how parental socioeconomic status impacts pupils' achievement.

Methodology

Area of Study

Ido Local Government Area is one of the eleven local government areas in Ibadan, the capital city of Oyo State, Nigeria. It is largely semi-urban and agrarian, with farming as the predominant occupation, alongside petty trading and small-scale businesses. This study was conducted in Idioro-Elewa Primary School, Agelu Community Primary School, and Idiosan Community Primary School. These schools were selected using a proportionate sampling technique to ensure fair representation, taking into account the number of public primary schools available within the local government area.

Population, Sample Size, and Sampling Procedure

Primary data were collected using a well-structured questionnaire designed to capture information on pupils' nutrition, eating habits, socio-economic background, and academic achievement. A total sample size of 150 pupils was selected to provide adequate representation while ensuring that data collection remained manageable. The sample was drawn using a proportionate sampling technique to guarantee equal representation across the three selected schools. Consequently, 50 pupils were selected from each of the school (Cameron, 2012).

Method of Data Analysis

The data collected were analyzed using both descriptive and inferential statistical techniques. Descriptive statistics such as frequency counts, percentages, and charts were used to summarize and present the data clearly. Inferential statistics, including Pearson Product Moment Correlation and Chi-square tests, were applied to examine relationships between variables and test the study hypotheses. All hypotheses were tested at a 0.05 level of significance to ensure the validity and reliability of the results.

Results and Discussion

The demographic profile (Table 1) illustrates a representative cohort. The equitable distribution of pupils across the three schools supports the sample's validity. A modest female predominance (54.7%) was observed, consistent with regional enrollment trends. The age distribution, concentrated in the 10–11 year cohort, indicates instances of delayed enrollment or grade retention, as evidenced by older pupils in primary-level classes. Socioeconomically, the sample is characterized by a high prevalence of parental self-employment (62.0%) and moderate educational attainment, with the West African Senior School Certificate (WASC) being the most common qualification (39.3%). These demographic findings underscore the postulates of human capital theory, affirming the correlation between socioeconomic determinants and educational outcomes. This informs the necessity for targeted pedagogical interventions for children from socioeconomically disadvantaged households. Consequently, multifaceted policy initiatives are recommended. These should encompass strategies for economic empowerment to bolster household stability, programs to mitigate delayed school enrollment, and the reinforcement of institutional feeding schemes to function as socioeconomic safeguards, thereby enhancing scholastic performance.

The correlation analysis presented in Table 2 reveals a statistically significant positive relationship between dietary quality and academic achievement ($r = 0.410$, $p < 0.01$), establishing nutritional composition as a critical determinant of scholastic performance. This finding empirically validates the nutrition-education nexus, confirming that micronutrient and macronutrient adequacy directly supports cognitive function. In contrast, other variables demonstrated negligible predictive power. Eating habits ($r = 0.109$), biological sex ($r = -0.083$), and parental socioeconomic status ($r = 0.155$) all yielded non-significant correlations with academic outcomes. The minimal gender correlation indicates achieved equity in educational access, while the weak socioeconomic link partially corroborates human capital theory, albeit with limited effect size.

Table 1: Distribution of respondents using different variable

Variable	Category	Frequency	Percent (%)
School	Idioro-Elewa Primary School	50	33.3
	Agelu Community Primary School	51	34.0
	Idiosan Community Primary School	49	32.7
	Total	150	100.0
Sex	Male	68	45.3
	Female	82	54.7
	Total	150	100.0
Age	6–8 years	34	22.7
	10–11 years	70	46.7
	12–14 years	43	28.7
	15–17 years	3	2.0
	Total	150	100.0
Class	Primary 2	30	20.0
	Primary 3	27	18.0
	Primary 4	30	20.0
	Primary 5	30	20.0
	Primary 6	33	22.0
	Total	150	100.0
Parental Education Qualification	WASC	59	39.3
	NCE	26	17.3
	OND	17	11.3
	HND	10	6.7
	First Degree	7	4.7
	Master's Degree	22	14.7
	Above Master's	9	6.0
	Total	150	100.0
Nature of Parent's Job	Civil Servant	17	11.3
	Self-Employed	93	62.0
	Others	40	26.7
	Total	150	100.0

These results necessitate a strategic reorientation of intervention frameworks. Programmatic focus should prioritize nutrient density over meal frequency in school feeding initiatives. Concurrently, parallel policies addressing household economic viability may function as indirect mediators for improving educational outcomes through enhanced nutritional access. Wolfe et al. (2000) highlighted the negative impact of skipping meals. They concluded that children, who eat a good breakfast, have better performance scores as eating breakfast helps in improving attention, retrieving information more quickly and accurately, make few errors in problem-solving activities and concentrate better and also perform better when asked to do complex tasks. In addition, Pollitt and Mathews (1998) stated that children

skipping breakfast have low academic performance due to the failure in important areas such as alertness, attention, memory, processing of complex visual display and problem solving.

Table 2: Relationship between Selected Variables and Academic Achievement

Variable	Correlation Coefficient (r)	Significance
Type of Food	0.410**	$p < 0.01$
Eating Habit	0.109	Ns
Sex	-0.083	Ns
Parental Economic Status	0.155	Ns

Note: Correlation significant at the 0.01 level (2-tailed).ns = not significant.

Conclusion

Findings revealed that respondents were fairly distributed across schools, sex, age, and class categories, ensuring a representative sample. Most parents were self-employed and possessed WASSC as their highest qualification, highlighting the influence of socio-economic factors on pupils' schooling. Importantly, there was a significant positive relationship between the type of food consumed and pupils' academic achievement, underscoring the critical role of nutrition in educational outcomes. Although other variables such as eating habit, sex, and parental economic status showed weak or non-significant relationships with academic achievement, they still provide insights into the complex interplay of factors that shape learning performance.

Recommendations

Based on these findings, the study recommends that government and stakeholders strengthen school feeding programs to focus not only on meal provision but also on nutritional quality to enhance cognitive development and academic performance. Parents and guardians should be sensitized on the importance of providing balanced meals at home, regardless of income level, by using locally available and affordable nutritious foods. Furthermore, policies that promote household economic empowerment such as vocational training, access to microcredit, and support for self-employed parents should be prioritized, as they can indirectly improve children's educational outcomes. Lastly, community-based awareness campaigns should be implemented to encourage timely school enrollment and reduce grade repetition, thereby ensuring that pupils complete their education at the appropriate age.

References

Brown, J. L., Beardslee, W. H., & Pro-Throw-Stith, D. (2008). The impact of school breakfast on children's health and learning: An analysis of the scientific research. New York, NY.

Cameron, S. (2012). Education, urban poverty and migration: Evidence from Bangladesh and Vietnam (Working Paper No. 2012–2015). UNICEF Office of Research, Florence.

Glewwe, P., & Jacoby, H. G. (2018). An economic analysis of delayed primary school enrollment in a low-income country: The role of early childhood nutrition. The Review of Economics and Statistics, 77(1), 156– 178

Murphy, J. M., Drake, J. E., & Weineke, K. M. (2005). Academics and breakfast connection pilot: Final report on New York's classroom breakfast project. New York, NY.

Pollitt, E., & Mathews, R. (1998). Breakfast and cognition: An integrative summary. American Journal of Clinical Nutrition, 67(4), 804–813.

Second Harvest Heartland. (2013). Hunger facts. Retrieved from http://www.2harvest.org/pdf/hunger_facts_2013.pdf

Wolfe, P., Burkman, A., & Streng, K. (2000, March). The science of nutrition. Educational Leadership, 57(6), 54–59.

Digital Financial Inclusion and Innovation among Informal Food Vendors in Lagos, Nigeria: Bridging the Digital Gap

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Abstract

Despite the transformation of various economies locally and globally through leveraging on digital financial services, yet the informal sector remains an under-explored frontier in the digital financial inclusion (DFI) landscape. This study examined the impact of digital financial inclusion among informal food vendors in Lagos, Nigeria. Additionally, it investigates how this economically vital yet marginalized group is adopting and experiencing digital financial services amid systemic inequalities, assessed their digital financial status, and identified key constraints to digital financial inclusion. Using mixed-methods such as Descriptive statistics, Likert type scale and Multidimensional financial inclusion index (MFII), the research sampled 123 informal food vendors with the aid of a Kobo toolbox questionnaire. Findings revealed that 97.56% were female food vendors with 61.79% engaging in street food vending. Furthermore, the study revealed that 96.75% of food vendors are aware of digital financial services and 91.87% have access to the internet. Also, 99.19% and 91.87% of the respondents reported that the use of mobile banking and mobile money transfer are the most used digital financial services. The MFII index score of 0.6711 reveals that 61.79% of vendors are digitally included, driven primarily by financial capability and literacy. Major constraints to digital financial inclusion among informal food vendors include security concerns and also limited trust in the digital financial services platform. The study recommends that stakeholders should invest in improving internet infrastructure and accessibility, particularly in areas where vendors operate and that stakeholders should design a digital financial service with a focus on user-friendliness, simplicity and privacy.

Keywords: Digital Financial Inclusion, Informal Food Vendor, Digital Financial Services

Introduction

Digital literacy refers to the ability to effectively use digital tools and technologies to access, manage, and communicate information (Nikou et al., 2022). This skill set is increasingly critical for individuals and businesses, especially in informal sectors where traditional methods are being replaced by digital alternatives (Morris et al., 2020).

Financial inclusion refers to the availability and accessibility of financial services to all segments of the population, particularly marginalized and underserved groups (Lal, 2021). It involves providing affordable financial products such as savings accounts, credit, insurance, and digital payment systems to empower individuals and businesses. Financial inclusion contributes to the improvement and promotion of the well-being of the population (Eton et al., 2021). This ease of access to financial services is said to potentially affect household welfare through better production, higher income, and the possibility of increased consumption (Banerjee et al., 2015; Chakrabarty & Mukherjee 2021). The advent of digital tools has revolutionized financial inclusion by addressing traditional barriers, such as physical distance and high transaction costs (Ediagbonya & Tioluwani, 2023). Studies suggest that digital tools such as mobile apps and social media platforms enhance visibility, improve customer relationships, and streamline payment processes (Bagale et al., 2021). The informal food sector in Lagos State plays a critical role in providing affordable meals and employment opportunities to a significant portion of the urban population (Adeosun et al., 2023). The informal sector has always been in reliance on physical cash transactions, limited savings, and exposure to market fluctuations (Senyo et al., 2023). However, while digital financial platforms like mobile money and e-wallets offer promising solutions, the intersection of financial illiteracy and limited trust in digital systems often undermines adoption in the informal sector (Sikka & Bhayana, 2024). It is on this note, that this research tends to examine the level of involvement in informal food vending, awareness and usage of digital financial services, digital financial inclusion and digital literacy, and identify the constraints to digital financial inclusion among informal food vendors in the study area.

Material and Methods

Study area

It was carried out in Lagos State, Nigeria, which happens to be one of the fastest-growing urban centres in the world. As the country's commercial and financial hub, Lagos serves as a dynamic metropolis characterized by a robust economy, a diverse population, and substantial cultural influence (Busari & Princewill, 2023).

Sample techniques and sample size

Three-stage sampling technique was used for the selection of respondents who were informal food vendors within the state. The first stage involves the stratification of Lagos State into urban, semi-urban, and peri-urban areas The second stage involves the purposive selection of Two Local Government Areas (LGAs) with a high concentration of informal food vendors from each stratum making a total number of 6 communities and the third stage entails a random selection of 20 individual respondents within each

selected LGA leading to a total of one hundred and twenty (120) informal food vendors who were interviewed.

Analytical Techniques

Ordinary Least Squares (OLS) Regression was used to examine the effect of digital literacy on the level of financial inclusion. The equation is given as:

$Y=\beta0+\beta1(Age)+\beta2(Gender)+\beta3(Education)+\beta4(Income)+\beta5(Access\ to\ Credit)+\beta6(Access\ to\ Digital\ Tools)+\epsilon$.....(1)

Logistic Regression was used to analyse the relationship between Socioeconomic Characteristics and Digital Literacy. Independent variables such as age, education level, income, access to credit, and training opportunities were considered. This model is suitable for binary outcomes (e.g., whether a food vendor uses an innovation or not).

$Log\ (P(Y=1)/P(Y=0)) = \beta_0 + \beta_1 AGE + \beta_2 GENDER + \beta_3 EDUCATION + \beta_4 INCOME + \beta_5 ACCESS\ TO\ CREDIT + \beta_6 ACCESS\ TO\ DIGITAL\ TOOLS$..... (2)

Where the Dependent Variable (Y) = Digital Literacy (1 = literate, 0 = not literate)

Likert Scale was employed to assess respondents' perceptions of constraints limiting financial inclusion. Respondents rated various constraint items on a 5-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5).

Results and Discussion

The result of the level of participation in informal food vending by the respondents in the study area (Table 1) revealed that street food vending is the most prevalent among informal food activities (61.79%) with 95.93% very involved in the food activities. Also, more than half (53.66%) of the respondents have been involved in informal food vending for more than five years This is in support of a report by Ma et al, (2019) that argued, that high awareness in informal food vending indicates the pervasiveness and significance of informal food vending in urban livelihoods. The findings of digital financial inclusion awareness among respondents (Table 2) revealed that 96.75% of respondents are aware of digital financial services and also 91.87% have access to a smartphone or an internet-enabled device. Additionally, 91.87% of the respondents also confirmed that they have access to financial services through their devices, highlighting widespread connectivity. Majority (86.07%) revealed daily usage of digital financial services (DFS)

indicating a deep digital integration into business operations, while 99.19% indicated that mobile banking usage is majorly used among respondents, making it the most ubiquitous financial tool.

Table 1: Participation in Informal Food Vending

Variables	Frequency	Percentage
Type of informal food vending activities		
Street food vending	76	61.79
Market food vending	65	52.85
Mobile food vending (e.g., food trucks, carts)	38	30.89
Home-based food vending (e.g., selling food from home)	16	13.01
Online food vending (e.g., social media, online marketplaces)	34	27.64
Level of involvement in informal food vending		
Very involved	118	95.93
Moderately involved	5	4.07
Slightly involved		
Not involved at all		
Years of involvement in informal food vending		
Less than 1 year	6	4.88
1-2 years	13	10.57
3-5 years	38	30.89
5 years and above	66	53.66

Source: Field survey, 2025

This supports the findings by Sulistiyani et al (2024) who reported that the usage of mobile banking could be due to its integration with formal banking systems and user-friendly interfaces. Furthermore, among the reasons for the usage of DFS, 90.24% of the respondents indicated that they find the services convenient to use, while 77.24% revealed that digital services are easily accessible and 75.61% reported transaction efficiency of DFS. More than half of the respondents (55.28%) revealed that their rate of digital service usage is very good while 26.83% of respondents indicated that digital service usage is good showing strong satisfaction and perceived effectiveness. The above results corroborate the findings of Agwu (2021) confirming that mobile money has bridged financial service gaps in underserved communities.

The results of the digital financial status of the respondents were presented in Table 3a and 3b. The Multidimensional Financial Inclusion Index (MFII) (Table 3a) presents the financial inclusion status of informal food vendors through a composite score derived from three key dimensions: Financial Participation, Financial Capability, and Financial Wellbeing. Financial Capability domain is the strongest measuring dimension with a score of 0.7588. The result revealed that the majority of informal food vendors possess the knowledge, awareness, and skills necessary to make sound financial decisions.

Table 2: **Digital Financial Inclusion among Informal Food Vendors**

Variables	Frequency	Percentage
Awareness of digital financial inclusion		
Yes	119	96.75
No	4	3.25
Access to a smartphone or internet-enabled device		
Yes	113	91.87
No	10	8.13
Does your smartphone or internet-enabled device have access to financial services		
Yes	113	91.87
No	10	8.13
Frequency of digital financial services Usage		
Daily	105	86.07
Weekly	4	3.28
Rarely	8	6.56
Never	5	4.10
Types of digital financial services Used		
Mobile banking (e.g. GT Bank, First Bank etc.)	122	99.19
Mobile money transfer (e.g. Opay, Palmpay)	113	91.87
Digital payment platforms (e.g., PayPal, Paystack)	4	3.25
Reasons for usage of digital financial services		
Convenience	111	90.24
Accessibility	95	77.24
Cost-effectiveness	66	53.66
Security	60	48.78
Efficiency of transactions	93	75.61
Years of Usage of digital financial inclusion services		
1-2 years	43	36.44
3-5years	43	36.44
Rate of digital financial services Usage		
Very good	68	55.28
Good	33	26.83
Moderate	20	16.26

Source: Field survey, 2025

The composite MFI Index, calculated as 0.6711, exceeds the threshold value of 0.66, which was according to the classification adopted from Briguglio et al. (2009) and Chishimba & Wilson (2021) classifies the average informal food vendor as financially included (61.79%) and a small fraction (38.21%) as not financially inclined. This result is noteworthy, particularly for an informal sector often perceived as financially marginalized (Senyo et al, 2023). It demonstrates progress in efforts to extend financial services and literacy to underserved populations (Tay et al., 2022).

Table 3a: Multidimensional Financial Inclusion Index

Domain of Financial Inclusion	Indicator	Kendall Tau-b rank coefficient *fk* ≥ 0.66	Rank
Financial participation		0.5315	3rd
	Access	0.6341	
	Usage	0.6206	
	Barrier	0.3398	
Financial Capability		0.7588	1st
	Financial Literacy	0.8943	
	Financial Planning	0.6585	
	Consumer Protection	0.7236	
Financial Wellbeing		0.7231	2nd
	Control over Finance	0.7018	
	Financial Resilience	0.7561	
	Financial Situations	0.7113	
Multidimensional Financial Inclusion Index		0.6711	

Table 3b: **Level of Digital Financial Status of the Informal Food Vendors**

	Frequency	**Percentage**
Digital Financially included	76	61.79
Digital Financially excluded	47	38.21

Source: Field survey, 2025

The results of the major challenges informal food vendors face in accessing and using digital financial services was illustrated in Table 4. Security concerns ranked first as the extremely severe constraint affecting digital financial inclusion with a mean score of 3.122, trust issues with digital platforms ranked second with a mean score of 3.041, poor internet access ranked 3rd with a mean score of 2.837. This suggests that most informal vendors are already aware of digital financial tools, and that their challenges lie more in security, trust, access, and usability (Putrevu & Mertzanis, 2024).

Table 4: Constraints in Digital Financial Inclusion among Informal Food Vendors

CONSTRAINTS	NS	SS	MS	VS	ES	Mean	Rank
Lack of awareness or knowledge	14 (11.38)	26(21.14)	69(56.10)	14(11.38)	0(0.00)	2.674	5th
Poor internet access	3(2.44)	35(28.46)	64(52.03)	21(17.07)	0(0.00)	2.837	3rd
Security reasons	6(4.88)	23(18.70)	47(38.21)	44(35.77)	3(2.44)	3.122	1st
Trust issues with digital platforms	6(4.88)	27(21.95)	49(39.84)	38(30.89)	3(3.44)	3.041	2nd
Complexity of digital financial services	9(7.42)	26(21.14)	70(56.91)	17(13.82)	1(0.81)	2.797	4th

Source: Field survey, 2025

Conclusion

The study concludes that a significant proportion of vendors have access to smartphones or internet-enabled devices are being primarily driven by convenience, accessibility, and efficiency for the adoption of digital financial services. However, Security concerns and trust issues with digital platforms are the most significant constraints hindering digital financial inclusion.

Recommendation

- Government agencies and stakeholders should promote digital literacy initiatives that address not only basic usage but also build trust by covering security, data privacy, and consumer protection.
- Efforts should focus on improving the security of digital financial platforms in vendor areas through robust systems and transparent protocols.

References

Adeosun, K. P., Oosterveer, P., & Greene, M. (2023). Informal ready-to-eat food vending governance in urban Nigeria: Formal and informal lenses guiding the practice. *Plos one*, *18*(7), e0288499.

Bagale, G. S., Vandadi, V. R., Singh, D., Sharma, D. K., Garlapati, D. V. K., Bommisetti, R. K., Gupta, R. K., Setsiawan, R., Subramaniyaswamy, V & Sengan, S. (2021). *Small and medium-sized enterprises' contribution in digital technology Ann Oper Res* **326** (Suppl1), 3–4 (2023). https://doi.org/10.1007/s10479-021-04235-5

Banerjee, A., Duflo, E., Glennerster, R., & Kinnan, C. (2015). "The Miracle of Microfinance? Evidence from a Randomized Evaluation." *American Economic Journal: Applied Economics* 7 (1): 22–53.DOI: 10.1257/app.20130533

Chakrabarty, M., & Mukherjee, S. (2021). Financial inclusion and household welfare: An entropy-based consumption diversification approach. *The European Journal of Development Research, 34*(2), 1–22. https://doi.org/10.1057/s41287-021-00431-y

Ediagbonya, V., & Tioluwani, T. (2022). The role of fintech in driving financial inclusion in developing and emerging markets: Issues, challenges and prospects. *Technological Sustainability, 2*(1), 1–15. https://doi.org/10.1108/TECHS-10-2021-0017

Eton, M., Mwosi, F., Okello-Obura, C., Turyahebwa, A., & Uwonda, G. (2021). Financial inclusion and the growth of small medium enterprises in Uganda: Empirical evidence from selected districts in Lango sub-region. *Journal of Innovation and Entrepreneurship, 10*, 1–18. https://doi.org/10.1186/s13731-021-00168-2

Lal, T. (2021). Impact of financial inclusion on economic development of marginalized communities through the mediation of social and economic empowerment. *International Journal of Social Economics*, *48*(12), 1768-1793.

Viability of Homestead Fish Farming in Ado Local Government Area, Ekiti State, Nigeria

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Abstract

This research determined the feasibility and biotechnical factors of homestead fish farming in Ado-Ekiti, Nigeria. Data were collected from 75 homestead fish farmers through structured questionnaires and analyzed to determine demographic profiles, biotechnical factors, challenges, and enterprise viability. The study revealed that 36% of the respondents have between 6-10 years of experience, while 46.7% engaged in this practice on a full-time basis and another 53.3% engaged in the venture on a part-time basis, with 77.3% stocking only catfish. It was also observed that 44% of the respondents used concrete tanks for rearing fish, while 56% sourced water from borehole. Primary challenges faced included financial constraints (41.3%) and lack of quality fish feed (37.3%). Furthermore, the study revealed that homestead fish farming is viable with a significant portion of farmers (46.7%) achieving yields between 101-250kg per cycle, (at N4, 000.00/kg). Homestead fish farming in Ado- Ekiti can be further optimized, ensuring it remains a sustainable and profitable venture that contributes significantly to the socio-economic development of the region.

Keywords: Homestead, Fish farming, Biotechnical factors, Feasibility, Economic viability.

Introduction

Homestead fish farming is the rearing of fish on a small scale meant for subsistence use in controlled water body at home. This is an individual effort in increasing protein need of man, primarily for his family and a source of income. (Fapohunda, 2010). Fish farming, has gained significant attention as a viable and profitable venture globally, contributing to food security, economic development, and poverty alleviation (Mulokozi et al., 2020). Small scale rural aquaculture, has received significant attention in this respect, both in Sub-Saharan Africa (SSA) and abroad. In keeping with this, small-scale farms owned and managed by families account for more than 80% of worldwide aquaculture production (Mulokozi *et al*., 2020). Despite the vast potential of homestead fish farming, there is a lack of comprehensive studies and practical implementation strategies in Ado-Ekiti. Challenges such as limited access to technical knowledge, inadequate infrastructure, and insufficient financial resources may hinder the successful establishment and operation of homestead fish farms in the region (Alawode and Ajagbe, 2020). The findings of this

study can inform evidence-based policy decisions, guide local farmers in optimizing their practices, and contribute to the broader discourse on sustainable agriculture in Nigeria.

Materials and Methods

Study Area

This study was conducted in Ado-Ekiti, Ekiti State, Nigeria. Ado Ekiti is a cosmopolitan city in Ekiti State, it is the state capital of Ekiti State with population figures at 557,000 (Wikipedia, 2025) on Latitude 7.621111 and Longitude 5.221389. Fishing activities in the state is majorly artisanal fishery in small scale and aquaculture production which scholars defined as the rearing of aquatic organisms under controlled or semi-controlled environments for the social and economic benefits of mankind and livestock.

Data were collected from primary source using well-structured questionnaires that were arranged on a 5-point Likert scale with 5 being the highest rating which were administered on the sampled homestead fish farmers. Purposive sampling technique was used to pick 100 homestead fish farms in Ado-Ekiti, to assess the current status, identify the factors influencing the productivity and economic viability of homestead fish farming as a venture in Ado Ekiti. Due to incomplete supply of data, data from only 75 respondents were used. The analysis of the collected data was presented using descriptive methods: frequencies, tables and percentiles.

Results and Discussion

This study revealed that the majority of the fish farmers are male (74.7%), this indicates a higher participation rate of male in homestead fish farming in the area, Table 1. This result can be justified by the assertion of Brummett et al., (2010) that fisheries activities are mostly dominated by men. Educational attainment among the respondents showed that 61.3% have tertiary education, while no respondents reported having no formal education. This means that fish farming is dominated by the educated class as fish farming requires a lot of technical and scientific knowledge to translate into high output and efficiency. The biotechnical factors shown in Table 2 depicted that the largest group (41.3%) stocked 1001-2000 fingerlings, and the highest percentage of respondents (46.7%) achieved yields between 101-250kg, sold at N4, 000.00 per kg.

Table 1: Demographic Profile of Homestead Fish Farmers in Ado- Ekiti

Item		Frequency	Percentage (%)
Sex	Male	56	74.7
	Female	19	25.3
	Total	75	100.0
Age Range	18-35	18	24
	36-55	52	69.3
	56 and above	5	6.7
	Total	75	100.0
Religion	Christianity	51	68
	Islam	16	21.3
	Traditional	8	10.7
	Total	75	100.0
Level of Education	Primary	9	12
	Secondary	14	18.7
	Tertiary	46	61.3
	Adult	6	8
	Total	75	100.0

Source: Field Survey, 2024

Table 2 Biotechnical Factors of Homestead Fish Farmers in Ado-Ekiti

Item		Frequency	Percentage (%)
What type of fish farming	Full time	35	46.7
	Part time	40	53.3
	Total	75	100.0
What species of fish do you rear	Catfish	58	77.3
	Tilapia	7	9.4
	Both	10	13.3
	Total	75	100
Type of pond	Concrete pond	33	44
	Earthen pond	17	22.7
	Drum/Plastic	15	20
	Fibre/Tarpaulin	10	13.3
	Total	75	100.0
Source of water	Reservoir	42	56
	Well	19	25.3
	Borehole	14	18.7
	Total	75	100.0
Challenges faced	Financial problem	31	41.3
	Technical problem	6	8
	Environmental problem	5	6.7
	Fish feed problem	28	37.3
	Water quality problem	5	6.7
	Total	75	100

Fingerlings stocked/cycle	500-1000pcs	9	12
	1001-2000pcs	31	41.3
	2001-3500pcs	20	26.7
	3500pcs & above	15	20
	Total	75	100.0
Average yield/cycle	5kg-20kg	5	6.7
	21-50kg	5	6.7
	51-100kg	14	18.6
	101-250kg	35	46.7
	250kg & above	16	21.3
	Total	75	100.0

Source: Field Survey, 2024

Conclusion

The study concluded that homestead fish farming in Ado-Ekiti is a viable venture that can significantly contribute to food security and economic development. The demographic profile of the farmers indicated a predominance of educated individuals, suggesting a high potential for adopting advanced farming techniques. The primary challenges faced by farmers are financial constraints and feed-related issues, which need to be addressed to enhance productivity. Formulating and implementing supportive government policies that promote homestead fish farming, including tax incentives, grants, and technical support programs, is essential to enhance sustainable homestead fish farming in the study area.

References

Alawode, O.O. and Ajagbe, S.O. (2020). Profitability of Small-Scale Catfish Production in Southwest Nigeria: The Challenges. Scientific Papers Series "Management, Economic Engineering in Agriculture and Rural Development", 20(3), 77-88.

Brummett, R.E., Anne Marie, T., Youaleu, J.L.N. and Kenmegne, M.M. (2010). Women's Traditional Fishery and Alternative Aquatic Resource Livelihood Strategies in the Southern Cameroonian Rainforest. *Fisheries Management and Ecology* 17(3): 221-230.

Fapohunda, O.O. (2010). Exploitation of Homestead Fish Farming as a Profitable Venture in Ondo-State, Nigeria. *International Journal of Agriculture* 2(3): 33-37.

Mulokozi, D. P., Mmanda, F. P., Onyango, P., Lundh, T., Tamatamah, R. and Berg, H. (2020). Rural aquaculture: Assessment of its contribution to household income and farmers' perception in selected districts, Tanzania. *Aquaculture Economics & Management*, *24*(4), 387–405.

Haematology and Intestinal Health of Broiler Chickens Fed Dietary Fermented Mixture of Cassava Roots and Palm Kernel Cake

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Abstract

One hundred and fifty (150) day old Ross 305 chicks were used to evaluate the effect of fermented mixture of cassava roots and palm kernel cake (FCP) on the haematology and intestinal health of broiler chickens. The chickens were randomly assigned to three dietary treatments (A, B, C). Diet A (control) had maize as the principal energy source, while in diets B and C, the maize was replaced by the FCP at 50% and 100% respectively. Haematology, intestinal microbiology, and histology were evaluated at 49 days of age. The data generated were subjected to analysis of variance in a completely randomized design. The results showed that no differences were found in the microbial and haematological parameters except in the mean cell volume of the FCP treated birds. The broiler chickens fed diets containing 50% FCP based diets had a superior villi to crypt depth ratio. These results therefore suggest that the growth promoting potential of FCP is likely to be due to its modulatory effect on gut microbes and the superior crypt depth to villi ratio, which enhanced the absorptive capacity of the small intestines.

Keywords: Solid state fermentation, cassava, PKC, broilers, gut health, histology

Introduction

In recent years, solid state fermentation (SSF) has been increasingly used as a strategy for improving the nutritive value of low-quality feed materials, increasing the feed efficiency and hence the lower the cost of production of farm animals. Aladi et al, (2013) simulated maize, a major dietary energy source for poultry, from a 3:1 mixture of freshly grated cassava roots and palm kernel cake (PKC) and after solid state fermentation, the crude protein content of the fermented mixture (FCP) increased from 9 to 12 percent and the dustiness characteristic of cassava-based meals was removed. When FCP was fed as is, without further processing such as drying, to broiler chickens for 4 weeks, though the dry matter intake was reduced, the feed conversion ratio (FCR) increased (Aladi et al., 2021), resulting in comparable performance and superior economic returns. The physiological mechanism underlying the improved

performance is not yet clear. This experiment was therefore designed to better understand the physiological mechanisms involved in improved performance associated with the inclusion of FCP in broiler chickens' diets.

Materials and Methods

FCP was produced following the protocols previously described by Aladi (2013). Briefly, freshly grated cassava tubers were blended with PKC in a ratio of 3:1 and then fed into high density polythene bags. These were compressed to expel as much air as possible, sealed and allowed to ferment for 6 days before use. Three experimental broiler chickens' diets were formulated such that FCP replaced maize at 0, 50, and 100 % in Diets T1, T2 and T3, respectively. The feed composition is shown in Table 1. Diet 1 served as the control. One hundred and fifty (150) day old chicks were weighed on arrival and randomly assigned to three treatment groups with five replicates of 10 birds each in a Completely Randomized Design (CRD). Each group was fed its respective experimental diets for 49 days. Feed and water were given *ad-libitum*. At 49 days of age, 2 birds were randomly selected from each replicate and sacrificed. Blood samples were collected from the jugular vein and used to determine the haematological and lipid profile parameters. A section of the ileum was cut 3cm from the Meckel's Diverticulum and used for intestinal villus micrometry analysis according to procedures described by Asif et al. (2022). Luminal content of the ileum was aseptically collected into sterile sample bottles and use to enumerate microbes such as *Salmonella and E. coli.* was performed according to the method described by (Aladi et al., 2017).

Table 1: ingredient composition of experimental diets containing fermented mixture of cassava and palm kernel cake

Ingredients	**Broiler starter**			**Broiler finisher**		
	T1	T2	T3	T1	T2	T3
Maize	56.00	28.00	0.00	60.00	30.00	0.00
FCP	0.00	28.00	56.00	0.00	30.00	60.00
Soybean meal	28.00	28.00	28.00	24.00	24.00	24.00
Wheat offal	8.00	8.00	8.00	8.00	8.00	8.00
Fish meal	4.00	4.00	4.00	3.00	3.00	3.00
Bone meal	3.00	3.00	3.00	4.00	4.00	4.00
Lysine	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin and Min. Premix*	0.25	0.25	0.25	0.25	0.25	0.25
Common Salt	0.25	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutrient composition						
Crude protein	23.04	21.50	21.04	19.34	18.84	18.35
Crude fibre	4.11	5.56	6.28	4.29	5.28	6.47

Ether extract	2.83	2.87	2.90	2.81	2.84	2.89
Calcium	5.62	6.46	7.30	1.01	1.07	1.16
Phosphorus	1.04	1.21	1.16	1.14	1.93	1.19
Ash	1.32	1.26	1.19	1.62	1.46	1.30
Metabolizable energy (Kcal/Kg)	3200	2747	2587	2900	2698	2594

FCP – fermented mixture of cassava and palm kernel cake

* Formulated to supply per diet: Vit K3, 2mg; Vit B1 2.4mg; Vit B2 4.8mg; Vit B6 4.8, Niacin, 32mg; Pantothenic acid,8mg; Biotin 0.1mg, Vit B12, 0.02mg; Folic Acid, 0.8mg; Choline Chloride, 40mg; Manganese, 80mg; Iron, 40mg; Zinc, 36mg; Copper, 1.6mg; Iodine, 1.24mg; Cobalt,0.2mg; Selenium, 0.08mg

Results and Discussion

No significant differences were found in the haematological and lipid profile parameters except in the MCV of the experimental birds. The MCV of broiler chickens fed diets 1 and 2 were significantly higher ($P<0.05$) than those fed diet 3. The MCV values of chickens fed diets containing FCP (treatments B and C) fell within the normal range as seen in the results reported by Aladi et al., (2017). Birds fed diet C had better MCV values which suggests that they had the required folate and vitamin B_{12} levels. Fermentation has been reported to increase the content and bioavailability of cobalamin and folate in foods and vegetables (Ashagrie et al. 2025). Hence the experimental chickens fed diets containing FCP must have received higher levels of folate and vitamin B_{12}. Since vitamin B_{12} is crucial for several metabolic functions, diets containing FCP must have better supported animal health and welfare.

The crypt depth of birds fed diet A was significantly higher ($P<0.05$) than those fed diets containing FCP. Birds fed FCP-diets had superior villi to crypt depth ratio. Longer villi and shallower crypts provide larger surface area for absorption of nutrients. Fermentation of PKC releases mannan oligosaccharides (MOS) which have been reported to positively affects villi length and crypt depth in the small intestine of broilers (Asif et al., 2022) which encourage rapid growth. It is therefore likely the MOS released during SSF of FCP must have stimulated villi growth and thus increased absorptive capacity of their ileum in chickens fed the FCP. *E. coli* count decreased ($P>0.05$) at 100% replacement levels of maize in the diets of the poultry birds and was negligible in birds fed 50% inclusion levels of FCP which is in consonance with the results obtained by (Aladi et al., 2017) who reported that *E. coli* decreased in the small intestine at 75% and 100% replacement of maize with FCP in broiler chicken diets. This reduction was attributed to factors intrinsic to the process of fermentation.

Table 4: Haematological indices and lipid profile of broiler chickens fed diets containing FCP

	Replacement level for maize			
Parameters	10	50	100	SEM
White Blood Cell (x10^3/µl)	73.30	74.50	90.90	14.02
Lymph (%)	85.50	87.75	86.00	1.88
Neutrophil (%)	11.00	9.50	11.75	2.37
Monocytes (%)	1.50	1.50	1.50	0.53
Eosinophil (%)	2.00	1.25	0.75	0.55
Red Blood Cell (x10^6/µl)	1.55	1.65	2.07	0.36
Packed Cell Volume (%)	22.63	23.10	25.60	3.98
Haemoglobin (g/dl)	10.53	10.50	13.50	1.99
Mean cell volume (fl)	147.23[a]	143.3[a]	119.53[b]	10.14
Mean Corpuscular Haemoglobin (pg)	68.43	70.38	66.05	1.65
MCHC (g/dl)	46.53	49.18	52.38	2.62
Platelets (x10^3/µl)	20.00	16.00	32.75	7.36
Cholesterol (mg/dl)	95.50	115.75	99.00	10.65
Triglyceride (mg/dl)	44.25	44.25	47.25	6.34
HDL (mg/dl)	23.25	27.00	19.00	4.33
LDL (mg/dl)	63.50	79.25	69.75	10.36

MCHC - Mean Corpuscular Haemoglobin Concentration

[a,b]Means within the same row with different superscript are significantly different (P<0.05)

Table 5 Histological parameters and microbial counts of experimental broilers chickens (mm)

Parameter	Control	50%	100%	SEM
Villus length	20.4	18.58	18.15	4.09
Crypt depth	5.33[a]	4.1[b]	4.18[b]	0.32
Villus: Crypt depth ratio	3.93	4.5	4.29	0.92
E. coli (10^3cfu/ml)	14.38	-	7.38	7.20
Salmonella (10^3cfu/ml)	0.38	2.75	3.13	3.41

[a, b] Means in the same row with different superscript are significantly different (P<0.05)

Conclusion

Variations were not found (P>0.05) in haematology, lipid profile, ileal *E. coli* and *salmonella* counts of the broiler chickens fed the three experimental diets. The crypt depth of birds fed the control diets, and the two FCP-based diets differed significantly. The chickens fed 50% FCP based diets had superior crypt to depth ratio. It is therefore concluded that the growth promoting potential of FCP is likely to be due to its

modulatory effect on gut microbes and the superior crypt depth to villi ratio which enhanced absorptive capacity of the small intestine. FCP-based diets do not support the growth of harmful microorganisms in the gut of broiler chickens.

References

Aladi, N.O., Chukwukaelo, A.A., Okeudo, N. J., Ogbuewu, I.P., Ugwu, C.C., Etuk, E.B., & Okoli, I.C. (2017). Blood chemistry, haematology and ileal bacterial counts of broilers fed fermented mixture of cassava root meal and palm kernel cake. *Comparative Clininical Pathology*, (5). https://doi.org/10.1007/s00580-017-2519-y

Aladi, N.O., Isinguzo, C., Okorondu, S., Okoli, I.C., & Okeudo, N.J. (2013). Improvement on the physicochemical characteristics of cassava root pulp and palm kernel mixtures under solid state fungal fermentation. *Journal of Agricultural Technology*, *9*(5), 1111–1124.

Aladi, N. O., Nwafor, E.J., Odoemelam, V.U., Emenalom, O.O., Okoli, I.C., & Okeudo, N.J. (2021). Performance, carcass , and organoleptic scores of broiler chickens fed diets containing wet or sun-dried fermented mixture of grated cassava roots and palm kernel cake as replacements for maize. *Tropical Animal Health Production*, *53*(255). https://doi.org/https://doi.org/10.1007/s11250-021-02687-2

Asif, M., Hayat, Z., Rahman, A., Qamar, M. F., Nawaz, S., M., …& Yar, M.K. (2022). Effects of mannan-oligosaccharide supplementation on gut health, immunity, and production performance of broilers. *Brazilian Journal of Biology*, 84, e250132

Ashagrie, H., Baye, K., Guibert, B., Rochette, I., Tisseyre, P., & Humblot, C. (2025). The use of propionic acid and lactic acid bacteria to produce cobalamin and folate and injera, an Ethiopian cereal-based fermented food. *International Journal of Food Microbiology*, 426, 110909

The Effects of Flooding on Fish Pond Farming in Kwara State, Nigeria

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Abstract

This study examined the impact of flooding on fish pond farming in Kwara State, Nigeria, highlighting the socio-economic characteristics of the respondent, assessed the perceived effects of flooding on fish pond and their coping strategies. A Purposive sampling was used to select participants for qualitative interviews. Fish farmers were identified through collaboration with local fish farmers' associations. A sample of 160 fish farmers from various locations within Kwara State was chosen to ensure a representation of different perspectives. The semi-structured question served as the instrument for collecting data from the respondents. Results were analyzed using both descriptive (frequency, percentage, mean, and ranking) and inferential (Linear regression) statistics. Key findings reveal that he perceived effects of flooding primarily include financial losses (90.0%) and emotional distress, with 86.9% reporting high impacts. Linear regression analysis revealed that socio-economic factors, including sex, household size, and farming experience, significantly influenced the perceived flood effects, with male farmers and those with higher education experiencing a lesser impact (B = -3.545 for sex, B = -0.937). In conclusion, flooding occurs in the study area, and it has a great negative impact on the fish ponds, which in turn affects the farmers and their income level. The study therefore recommends that the state government /NGOs should compensate the affected farmers during flooding. This can reduce the pain of losses; possible preventive strategies should be provided on time by the Nigeria Hydrological Services Agency (NIHSA), and sensitization on proper sanitation should be done regularly.

Keywords: Fish Farming, Flooding, Climate Change, Sustainability, Flood Control.

Introduction

Flooding significantly impacts fish farming, threatening human lives and infrastructure while disrupting vital ecosystems and agricultural activities. It leads to increased fish mortality in ponds and rivers and can exacerbate humanitarian crises, as highlighted by Week and Wizor (2020). Long-term effects include water contamination, disease outbreaks, and disruptions to community structures (Echendu A.J., 2020). Fish farming, or aquaculture, is crucial for global food security and economic growth, serving as a key

protein source and creating jobs, especially in developing countries (FAO, 2020; Almeida et al., 2020). However, its sustainability is threatened by environmental challenges such as flooding.

Flooding, caused by factors like heavy rainfall, poor drainage systems, and environmental degradation, significantly impacts agriculture and ecosystems (Adeyemo et al., 2020). In Nigeria, flooding results from inadequate urban drainage systems due to rapid urbanization (Adekunle & Adejobi, 2020), illegal waste dumping that blocks waterways (Adeniji & Adesina, 2021), and deforestation, which reduces the land's capacity to absorb water (Onwuka et al., 2022). Understanding the link between flooding and fish farming is essential for developing adaptive strategies to enhance aquaculture resilience amid climate change. Flooding has become a recurring issue in Kwara State, severely impacting fish farming activities. The floods cause physical damage to fish ponds, leading to high mortality rates among fish stocks, and degrade water quality. These effects not only reduce productivity but also threaten the income and food security of local fish farmers and the nation at large. Despite the growing frequency of floods, there is limited research on how flooding specifically affects fish farming in Kwara State and what coping measures can be implemented. This study aims to fill this knowledge gap by examining the effects of flooding on fish farming operations and the livelihood of the farmers and proposing sustainable solutions under the following research questions. What are the perceived effects of flooding on fish pond and their livelihood in the study area and their coping strategies? The specific objectives of the study were to: Examine the perceived effect of flooding on fish pond. One null hypothesis was tested. Ho1: There is no significant relationship between socioeconomic characteristics of the fish farmers and perceived effects of flooding.

Methodology

The study was conducted in Kwara State, located in the north-central region of Nigeria. Kwara State is bordered by several neighboring states. A purposive sampling was used to select participants for qualitative interviews. Fish farmers were identified through collaboration with local fish farmers' associations. A sample of 160 fish farmers from various locations within Kwara State was chosen to ensure a representation of different perspectives. The questionnaire as designed as an instrument of data collection and subjected to close examination by experts in the field of Agricultural Extension service in Kwara State University Malate to ensure both face and content validity. Descriptive statistics (frequency, percentage, mean, and ranking) and inferential (Linear regression) statistics. Perceived effect of flooding on pond fish farming, using a five-point Likert-type scale, 5 = strongly agree, 4 = agree, 3 = undecided, 2 = disagree, 1 = strongly disagree. Coping Strategies to Mitigate the Impact of Flood on Fish Farming using a four–point Likert-type scale, 4=always used, 3=sometime used, 2 = rarely used = 1, never used.

Results and Discussion

Perceived Effects of Flood on Fish Farming

The effects of flooding on fish farming, as reported by respondents, are summarized in Table 1. The most significant impact was financial loss due to damage to ponds and infrastructure; this led to emotional and psychological stress/instability for farmers because all their investments had gone down the drain. this also led to a decrease in fish availability, reducing the market supply and food security at large. As a result of this production costs increased and farmers had to reduce their production because of lack of funds. Respondents were grouped based on the aggregate scores obtained regarding the effects of floods on pond fish.

The results presented in Table 2 indicate that 5.6% experienced low effects, 15.6% experienced moderate effects, and 78.8% experienced high effects. This suggests that the incidence of floods has significantly impacted pond fish farming in the study area.

The findings in Table 3 revealed that fish farmers, in an attempt to reduce the severe effects of flooding, have introduced the early harvesting of fish to avoid losing all while waiting, Constructing raised ponds to a higher level to prevent the water from entering ponds and seeking financial assistance from the government and other stakeholders for flood recovery efforts or obtaining insurance. this is in line with (Areola, 2020), who state that in order to ameliorate the loss of fish, incomes, investment, and livelihoods, the fish farmers and fishermen developed local grassroots strategies to cope with the annual escalating effects of flooding.

Ho_1: There is no significant relationship between socioeconomic characteristics and the perceived effects of flood on the fish pond.

As shown in Table 4 the analysis revealed that the following variables sex (B = -3.545), household size (B = -0.937), farming experience (B = -0.0856), and formal education attainment (B = -1.941) showed a significant negative relationship. This indicates that being a male farmer, having a larger household, more years of fish farming experience, and higher levels of formal education are associated with a decreased perception of the effects of flooding among fish farmers.

Table 1: Perceived Effects of Flood on Fish Pond Farming

Effects	SA	A	U	D	SD	Mean ± SD	Rank
Financial loss due to damage to fish pondsandinfrastructure	144(90.0)	16(10.0)	0	0	0	4.90±.30	1
Emotional and psychological impact on fish farmers	139(86.9)	18(11.3)	3(1.9)	0	0	4.85±.40	2
Flooding leads to a decrease in the availability of fish for consumers.	114(90.0)	39(24.4)	7(4.4)			4.69±.58	3
Increased cost of fish production and management.	116(72.5)	32(20.0)	6(3.8)	6(3.8)	0	4.61±.73	4
Leads to a decrease in the number of fish produced by farmers.	112(70.0)	35(21.9)	10(6.3)	0	1(1.9)	4.58±.77	5
Increased stress and workload for fish farmers.	106(66.3)	29(18.1)	16(10.0)	9(5.6)	0	4.45±.88	6
Increased vulnerability to other natural disasters and climate-related risks.	96(60.0)	37(23.1)	18(11.3)	9(5.6)	0	4.38±.89	7
Disruption of fish feeding patterns and reduced feeding efficiency due to Altered water conditions caused by flooding.	80(50.0)	57(35.6)	16(10.0)	7(4.4)	0	4.31±.82	8

Table 1 Continued: Perceived Effects of Flood on Fish Pond Farming

Industry in Kwara State.	SA	A	U	D	SD	Mean ± SD	Rank
Changes in fish species composition and diversity as some species may be more resilient to flooding than others.	70(43.8)	75(46.9)	9(5.6)	6(3.8)	0	4.31±.74	9
Challenges in accessing financial resources and insurance coverage for flood-related damages.	75(46.9)	60(37.5)	19(11.9)	6(3.8)	0	4.28±.81	10
Disruption of fish reproductive cycles and reduced breeding success.	69(43.1)	59(36.9)	23(14.4)	9(5.6)	0	4.18±.88	11
Flooding increases the mortality rate of fish in farms.	77(48.1)	42(26.3)	20(12.5)	21(13.1)	0	4.09±1.06	12
Displacement or loss of fish farmers' households and communities.	50(31.3)	77(48.1)	29(18.1)	4(2.5)	0	4.08±.78	13
Changes in water temperature and dissolved oxygen levels affecting fish physiology and growth.	62(38.8)	54(33.8)	28(17.5)	16(10.0)	0	4.01±.98	14
Flooding affects the nutritional value of fish Produced by farmers.	49(30.6)	67(41.9)	19(11.9)	25(15.6)	0	3.88±1.02	15

Table 2: Level of Effects of Flood on Fish Pond Farming

Obtained score Range	Level	Frequency	Percentage	Mean±SD
15 – 35	Low	9	5.6	
36 – 55	Moderate	24	15.6	65.6±5.45
56 – 75	High	126	78.8	
Possible score range = 15 – 75				

Table 3: Coping Strategies to Mitigate the Impact of Flood on Fish Farming

Coping strategies	Always Used	Sometimes Used	Rarely Used	Never Used	Mean	Rank
Practicing early harvesting to avoid loss of fish	129(80.6)	24(15.0)	7(4.4)	0	2.76±0.52	1
Constructing raised ponds.	115(71.9)	35(21.9)	10(6.3)	0	2.66±0.59	2
Seeking financial assistance from government and other stakeholders to aid in flood recovery efforts or an insurance plan.	98(61.3)	49(30.6)	13(8.1)	0	2.53±0.64	3
Implementing good farm management practices to reduce the risk of disease outbreak and mortality during flood.	92(57.5)	55(34.4)	13(8.1)	0	2.49±0.64	4
Adopting improved water management techniques to control water level during flood.	87(54.4)	53(33.1)	20(12.5)	0	2.42±0.70	5
Developing emergency response plans to address flood-related challenges	89(55.6)	45(28.1)	26(16.3)	0	2.39±0.75	6
Improving feed management practices to minimize the effect of flood on fish feeding.	78(48.8)	70(43.8)	6(3.8)	6(3.8)	2.38±0.73	7
Diversifying income sources to reduce dependence on fish farming income during flood.	63(39.4)	73(45.6)	24(15.0)	0	2.24±0.70	8
Using of floating cages	67(41.9)	70(43.8)	14(8.8)	9(5.6)	2.22±0.83	9
Ensure proper sanitation	58(36.3)	75(46.9)	19(11.9)	8(5.0)	2.14±0.82	10

Source: Field survey, 2023

Table 4: Linear regression showing the influence of socioeconomic characteristics on the perceived effects of flood on fish pond among respondents

Perceived effects	Coef. (β)	Std. Error	T	Sig.
Age (years)	0.077	0.064	1.206	0.230
Sex (male 1, female 0)	-3.545**	1.485	-2.388	0.018
Marital status (married 1, others 0)	2.142*	0.924	2.319	0.022
Household size (persons)	-0.937**	0.315	-2.974	0.003
Farming experience (years)	0.0856**	0.237	-3.610	0.000
Education (formal 1, no formal 0	1.941**	0.590	-3.292	0.001
Farm size (ha)	-0.026	0.176	-0.148	0.882
(Constant)	75.865	3.350	22.643	0.000

R square 0.511, Adj. R square 0.469

Conclusion and Recommendations

This study concluded that floods have hurt fish pond farming in the area. The main effects identified include financial losses, emotional and psychological distress, and a decrease in the number of fish in the

ponds. The main coping strategies employed by fish farmers to prevent and mitigate the impact of floods include early harvesting of fish, constructing raised ponds, and implementing effective farm management practices. The study recommendations were as follows: Training programs should focus on preventing financial losses, reducing emotional and psychological impacts, and decreasing the number of fish lost due to flooding in ponds.

References

Adeyemo, J. T., & Adesina, M. A. (2020). Urban flooding in Lagos: Causes, effects, and management strategies. Journal of Environmental Science and Technology, 13(5), 456-472. https://doi.org/10.1080/09768801.2020.1783456.

Adekunle, A. O., & Adejobi, B. K. (2020). Drainage system inadequacies as a contributor to urban flooding in Nigeria. International Journal of Civil Engineering and Technology, 11(4), 234-245. https://www.arcjournals.org/pdfs/ijcet/v11-i4/24.pdf.

Adeniji, A. S., & Adesina, M. A. (2021). Waste management and its role in flood mitigation in Nigerian cities. Environmental Research Journal, 15(3), 123-132. https://doi.org/10.3923/erj.2021.123.132.

Alemenda, A.G., Moreno, Y.M.F., & Carciofi, B.A.M. (2020) Plant proteins as high–quality nutritional source for human diet. Trend and Science technology. Vol 97, 170-184.

Areola Foluke (2020) Local Adaptation Strategies in Combating Flooding in Fisheries and Aquaculture in Nigeria. https://link.springer.com/rwe/10.1007/978-3-030-22759-3-18-1

Onwuka, C. I., et al. (2022). Land-use changes and their influence on flooding in Nigeria. *Geography and Natural Disasters,* 12(2), 123-134. https://doi.org/10.4018/IJGND.2022040108

Week & Wizor (2020) Effects of Flood on Food Security, Livelihood and Socio-economic Characteristics in the Flood-prone Areas of the Core Niger Delta, Nigeria. Asian Journal of Geographical Research. Vole 3 (1) DOI: 10.10.973/ajgr/2020/v

Assessing Farm-level Competitiveness through Profit Efficiency: The Case of Catfish Farming Systems in Ogun State, Nigeria

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Abstract

Catfish farming has become increasingly important for enhancing livelihoods and improving profitability in Ogun State; however, little is known about how profit efficiency reflects farm-level competitiveness within catfish farming systems. This study examines the determinants of profit efficiency among sole catfish farmers (SCF) and diversified catfish farmers (DCF) in Ogun State, using profit efficiency as a proxy for farm-level competitiveness. Data was collected from 177 catfish farmers in Ogun State using a structured questionnaire, comprising 102 sole catfish farmers (SCF) and 75 diversified catfish farmers (DCF). Stochastic Profit Frontier Function (SPFF) was employed to analyze the determinants of profit efficiency. The SPFF analysis showed that the mean profit efficiencies of SCF and DCF were 82.0% and 87.0%, respectively. For SCF, the cost of feed ($\beta = 0.5795$) and cost of fingerlings ($\beta = 0.1827$) positively influenced profit efficiency ($p < 0.01$), while for DCF, the cost of feed ($\beta = 0.4125$) and cost of capital ($\beta = 0.2782$) significantly increased profit efficiency ($p < 0.01$). Farming experience ($\beta = -0.1749$) and extension visits ($\beta = -0.1010$) also enhanced SCF profit efficiency ($p < 0.05$). A Student's t-test revealed a significant difference between the profit efficiencies of SCF and DCF ($t = 2.550$, $p < 0.05$). Enhancing key production inputs, farmer expertise, and extension support boosts profit efficiency, offering a practical reflection of farm-level competitiveness.

Keywords: Competitiveness, Profit Efficiency, Production, Catfish

Introduction

Catfish farming occupies a vital position within Nigeria's agricultural sector, with the fisheries sub-sector showing sustained growth in its contribution to the national Gross Domestic Product (GDP) (Oladoyin et al., 2025). Aquaculture entails the cultivation of aquatic animals and plants in freshwater, brackish, or marine environments and encompasses practices such as stocking ponds with fingerlings, applying fertilizers and feed, and regulating water quality to promote healthy growth and development (Ajao & Galadima, 2017). The production of fish as an economic resource is undertaken by a large number of small-scale farmers in Nigeria (Aloysius et al., 2020), making fish farming an important livelihood and

income-generating activity. Numerous institutions have identified fish importation as a major factor depleting Nigeria's foreign reserves (Oyewole et al., 2023). Furthermore, global demand for protein-based foods increased by approximately 58% between 1995 and 2020 and is expected to continue rising in the coming years. The growing demand for protein underscores the urgency of expanding investment and research in catfish production to ensure a sustainable animal protein supply. However, financial viability and production sustainability remain persistent concerns in the aquaculture sector (Oyewole et al., 2023). Efficiency in the use of financial resources in farming is a key determinant of farm performance, which can be expanded by emphasizing the need to market outputs in a manner that maximizes returns (Ajao & Galadima, 2017).

Estimating profit efficiency provides a means of assessing farm-level production specialization, enabling farms to secure higher incomes through differentiated outputs that offset elevated production costs (Setsoafia et al., 2017). The stochastic profit frontier model, which integrates both technical and allocative efficiency concepts, assumes that any deviations from the optimal production process translate into lower profits. Profit efficiency, therefore, reflects the ability of a fish farmer to achieve the highest possible benefit given input prices and fixed resource constraints (Setsoafia et al., 2017). Usually, the competitiveness of agricultural production systems is not well defined and is often assessed using indicators such as technical efficiency, productivity, and profitability (Bachev, 2021).

Farm-level competitiveness can be inferred when a farm's productivity and profitability indices significantly exceed the sectoral benchmark (Bachev, 2021). Conceptually, competitiveness refers to the ability to offer goods and services that meet market demand at prices superior to those of potential competitors while maximizing profits by minimizing resource use (Farah & Gómez-Ramos, 2014). In agriculture, where outputs and inputs are largely homogeneous, price is the main determinant of competitiveness. Since prices are directly tied to production costs and input efficiency, a farm's competitiveness level is ultimately shaped by its ability to operate above the profitability threshold that is, the point at which production begins to yield profit. In this regard, profitability reflects the relationship between profit and the resources used to generate it. While Farah and Gómez-Ramos (2014) highlight profitability in enhancing farm competitiveness, this study focuses on profit efficiency as a more precise measure of farm-level performance, linking it to empirical evidence from catfish farming systems in Ogun State.

Methodology

The Study Area

This study was conducted in Ogun State, one of the six states in Southwestern Nigeria, comprising 20 Local Government Areas and four major agricultural zones; the state has a predominantly agrarian economy and serves as a major hub for farming and agro-based industries in the region.

Sampling Procedure and Sampling Size

A structured questionnaire was administered to sole and diversified catfish farmers in Ogun State to collect data on their socio-economic characteristics, input use, and output during the 2017 farming season. A four-stage random sampling procedure was employed to select respondents. Two ADP zones (Abeokuta and Ijebu) were purposively selected, followed by the random selection of two blocks from each zone. In the third stage, 15 cells were chosen through simple random sampling proportionate to size across the blocks. In the final stage, 12 farmers were randomly selected from each cell, giving a total of 180 respondents, of which 177 (102 sole and 75 diversified) provided valid responses for analysis.

Method of Data Analysis

The Cobb-Douglas Stochastic Profit Frontier model was used in this study to analyze profit efficiency of SCF and is specified as:

$$\ln\Pi_i = \beta_0 + \beta_1 \ln P_1 + \beta_2 \ln P_2 + \beta_3 \ln P_3 + \beta_4 \ln P_4 + V_i + U_i \ldots\ldots\ldots \text{(i)}$$

Where:

P_1 = cost of feed (₦), P_2 = cost of labour (₦), P_3 = cost of fingerling (₦), P_4 = depreciated value of the contribution of fixed assets to production (i = 1, 2), β_0 = constant parameter, $\beta_{1\text{-}4}$ = coefficient of parameters to be estimated, V_i = error term , U_i = disturbance term

The Cobb-Douglas Stochastic Profit Frontier model used in this study to analyze profit efficiency of DCF and is specified as:

$$\ln\Pi_i = \beta_0 + \beta_1 \ln P_1 + \beta_2 \ln P_2 + \beta_3 \ln P_3 + \beta_4 \ln P_4 + \beta_5 \ln P_5 + \beta_6 \ln P_6 + \beta_7 \ln P_7 + \beta_8 \ln P_8 + V_i + U_i \ldots\text{(ii)}$$

Where:

Π_i = normalized profit computed as (total revenue less total variable cost)/output price (₦/kg), P_1 = cost of feed (₦), P_2 = cost of labour for fish (₦), P_3 = cost of fingerling (₦), P_4 = depreciated value of the contribution of fixed assets to production (i = 1, 2), P_5 = cost of maize seed (₦), P_6 = cost of cassava cuttings

(₦), P_7= cost of labour for crop (₦), P_8 = cost of fertilizer (₦), β_0 = constant parameter, β_{1-8}= coefficient of parameters to be estimated, V_i = error term

U_i = disturbance term

The inefficiency model (U_i) is defined by:

$U_i = \delta_0 + \delta_1 D_1 + \delta_2 D_2 + \delta_3 D_3 + \delta_4 D_4$ . . . . . (iii)

Where:

U_i = Inefficiency effect, D_1= Age (years), D_2= Education of fish farmer (years of formal education), D_3 = Farming experience (years), D_4 = Extension visit (number of visits), δ_{1-4} = Parameters to be estimated

The straight-line depreciation method was used to calculate the depreciation cost of the fixed assets

$AD = \frac{P-S}{n}$ ..... (iv)

Results and Discussion

The Student's t-test of equal means for profit efficiency between SCF and DCF (t = 2.550, p<0.05), as shown in Table 1, indicates a significant difference between the two groups. Specifically, the average profit efficiency of DCF is significantly higher than that of SCF. This aligns with findings by Adedigba & Dipeolu (2024) who reported higher profitability for diversified catfish farming, suggesting that diversification may support both greater returns and more efficient resource use.

Table 1: Test of Difference in Profit Efficiency of SCF and DCF

Variable	Mean Profit Efficiency	Standard Deviation	N	Degree of freedom	T-value	P-value
SCF	0.82	0.12	102	175	2.5500**	0.0180
DCF	0.87	0.10	75			

***Significant at 1%, ** Significant at 5% and * Significant at 10%

In Table 2, for SCF feed (β = 0.5795, p<0.01) and fingerling costs (β = 0.1827, p<0.01) positively affected profit, while labour (β = -0.1585, p<0.05) and capital costs (β = -0.0925, p<0.1) reduced it. Profit efficiency improved with experience (β = -0.1749, p<0.05) and extension visits (β = -0.1010, p<0.05), indicating that knowledge and advisory support enhance performance. Among DCF, feed (β = 0.4125, p<0.1) and capital costs (β = 0.2782, p<0.01) increased profit, whereas labour (β = -0.2252, p<0.05) reduced it. Inefficiency was significantly associated with age (β = 0.0322, p<0.01), education (β = 0.0579, p<0.01), and extension

visits (β = 0.0776, p<0.01), suggesting that resource allocation and diversification challenges can affect performance. Diagnostic tests confirmed that farm-specific practices, rather than random shocks, accounted for most variations in profit. Overall, optimizing key inputs and leveraging experience and extension services are crucial for enhancing both profit and profit efficiency in SCF systems.

Table 2: Determinants of SCF and DCF Profit Efficiencies in Ogun State

Variables	Coefficient		Standard error		t-value	
	SCF	DCF	SCF	DCF	SCF	DCF
Constant	3.4915***	1.9360*	0.8606	1.1188	4.0569	1.7305
Cost of feed	0.5795***	0.4125*	0.0814	0.1587	7.1138	2.5994
Cost of fish labour	-0.1585**	-0.2252**	0.0757	0.1102	-2.0930	-2.0444
Cost of fingerling	0.1827***	0.0593	0.0618	0.1196	2.9524	0.5072
Cost of capital	-0.0925*	0.2782***	0.0521	0.0931	-1.7742	2.9895
Cost of maize seed	-	0.0178	-	0.2281	-	0.0779
Cost of cassava a cutting	-	0.0040	-	0.1374	-	0.0294
Cost of crop labour	-	0.1522	-	0.1294	-	1.1761
Cost of fertilizer	-	0.1013	-	0.0800	-	1.2664
Inefficiency Model						
Constant	0.7443	-2.9144***	0.7787	0.8342	0.9558	-3.4936
Age	0.0009	0.0322***	0.0107	0.0080	0.0871	4.0152
Education	-0.0246	0.0579***	0.0452	0.0153	-0.5444	3.7753
Experience	-0.1749**	0.0238	0.0855	0.0154	-2.0454	1.5501
Extension visit	-0.1010**	0.0776***	0.0505	0.0164	-2.0006	4.7242
Diagnostic Statistics						
Sigma-Squared (σ^2)	0.2505***	0.1505***	0.0923	0.0223	2.7120	6.7554
Gamma(γ)	0.8120***	0.1384***	0.0969	0.0059	8.3773	23.6419
Log Likehood Function (LLF)	-14.5700	-31.4065	-	-	-	-

***Significant at 1%, ** Significant at 5% and * Significant at 10%

Conclusion

Catfish farming in Nigeria is profitable, whether practiced as a diversified or sole enterprise. Both DCF and SCF generate positive returns; however, they do not operate on the profit frontier, indicating room for efficiency improvement. The major sources of inefficiency among DCF are age, education, and farming experience, while inefficiency among SCF is primarily influenced by farming experience and frequency of extension visit.

Recommendation

This study recommends that catfish farmer education and training should be strengthened, frequency of extension visits increased, and youth participation in catfish farming actively promoted to enhance efficiency.

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References

Adedigba, M. Y., & Dipeolu, A. O. (2024). Assessing the Economic Performance of Sole and Diversified Catfish Farming Enterprise in Ogun State, Nigeria. In K. T. Kareem, O. A. Akinbode, & O. A. Kolade (Eds.), Food Security in Nigeria: Innovations and Sustainable Agriculture (pp. 358–366). Nigerian Women in Agricultural Research for Development (NiWARD) in collaboration with the Institute of Agricultural Research and Training (IAR&T).

Ajao, A. M., & Galadima, A. (2017). Profit Efficiency of Concrete and Earthen Pond Systems in Kwara State, Nigeria: A path towards Protein Self-Sufficiency in Fish farming. Nigerian Journal of Fisheries and Aquaculture, 5(2), 104–113. https://www.researchgate.net/publication/320022088

Aloysius, O. C., Matthew, N. C., Odinaka, A. O., & Johnpaul, O. C. (2020). Analysis of the Resource Management Ability by Catfish Farmers in Nigeria: A Case of Ogbaru Local Government Area, Anambra State. International Journal of Agricultural Economics, 5(5), 156. edhttps://doi.org/10.11648/j.ijae.20200505.12

Bachev, H. I. (2021). Unpacking competitiveness of agricultural farms in Bulgaria. Journal of Economics Bibliography, 8(1), 56–86. www.kspjournals.org

Farah, A. B., & Gómez-Ramos, A. (2014). Competitiveness vs. sustainability: An assessment of profitability as a component of an approach on “sustainable competitiveness” in extensive farming systems of central Spain. Sustainability (Switzerland), 6(11), 8029–8055. https://doi.org/10.3390/su6118029

Oladoyin, O., Bello, T. O., Ijigbade, J. O., Adaba, O. E., & Ilesanmi, J. O. (2025). Analysing Resource Use Efficiency and Determinants of Catfish Output in Ondo State, Nigeria. Pancasila International Journal of Applied Social Science, 3(02), 348–363. https://doi.org/10.59653/pancasila.v3i02.1728

Oyewole, B. O. O., Ibitoye, S. J., Adejo, P. E., & Oyibo, F. O. (2023). Resource Use Efficiency and Profitability Analysis of Catfish (Clarias gariepinus) Production in Kogi State, Nigeria. Asian Journal of Agricultural Extension, Economics & Sociology, 41(9), 103–116. https://doi.org/10.9734/ajaees/2023/v41i92021

Setsoafia, E. D., Owusu, P., & Danso-Abbeam, G. (2017). Estimating Profit Efficiency of Artisanal Fishing in the Pru District of the Brong-Ahafo Region, Ghana. Advances in Agriculture, 2017. https://doi.org/10.1155/2017/5878725

Hematological Response and Protective Efficacy of African Locust Bean (*Parkia biglobosa*) Flower extract against *Aeromonas hydrophila* Infection in *Clarias gariepinus*

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Abstract

The global criticism against the utilization of synthetic antibiotics for the production of food fish, due to the emergence of bacterial resistance to drugs, calls for suitable eco-friendly alternatives. Hence, this study evaluated the hematological response and protective effect of dietary *Parkia biglobosa* flower (PBF) extract against *Aeromonas hydrophila* infection in *Clarias gariepinus*. A total number of 180 *C. gariepinus* juveniles were randomly stocked into aquaria at the rate of 15 per replicate and fed diets containing 0.0, 0.5, 1.0 or 1.5 g PBF/kg diet for eight weeks. At the end of the feeding trial, blood samples were analyzed for hematological indices and fish were challenged intraperitoneally with *A. hydrophila* (5×10^6 CFU/mL) and observed for 14 days. The results showed significant ($P < 0.05$) increases in hemoglobin, red blood cells, white blood cells (WBCs), and lymphocytes in fish fed 1.0-1.5 g PBF/kg diet, while platelets, heterophil, monocytes, eosinophils, and basophils were not significantly affected. The highest relative protection level (80%) was obtained in fish fed 1.0 g PBF/kg diet. Therefore, 1.0 g PBF extract/kg diet is recommended as an effective inclusion level for improving hematological parameters and resistance to *A. hydrophila* infection in *C. gariepinus*.

Keywords: African catfish, *Aeromonas hydrophila,* Hematological parameters, *Parkia biglobosa* flower

Introduction

Aquaculture is the fastest growing food producing industry in the world, accounting for about 51% of the global fish production for the continually growing human population. Nigeria is the highest producer of African catfish, *Clarias gariepinus*, globally. The fish is widely distributed in Africa, India, and Asia due to its ability to thrive in variety of environmental conditions, high consumer acceptance and market value (Adeniyi et al., 2023). Adequate nutrient balance and fish health management are important for profitability and sustainability of intensive aquaculture venture.

African catfish, like other aquaculture species, is reared intensively with high stocking density, which make it prone to stress, alteration of physiological functions and suppression of immune system against pathogenic organisms, especially bacteria. Infectious diseases, like bacterial diseases, represent a bottleneck for the development and sustainability of the aquaculture industry. One of such infectious bacteria is *Aeromonas hydrophila,* which poses a major challenge in the production of freshwater, brackish, and marine tropical and sub-tropical finfishes, resulting to hemorrhagic septicemia, morbidity, mass mortality, and drastic economic losses (Adeniyi et al., 2025).

The conventional method of controlling bacterial infection is the application of synthetic antibiotics, which has been largely criticized and discouraged due to the related emergence of bacterial resistance, environmental degradation, and residual effects in fish's tissue and consequential risk on consumers' health (Adeniyi et al., 2025). Therefore, the need for natural and eco-friendly alternatives to synthetic antibiotic is a necessity. One of such alternatives to synthetic antibiotics is *Parkia biglobosa* (African locust bean), a widely available perennial tree in the family Leguminoseae. The flower of *P. biglobosa* has low concentration of anti-nutritive factors (Hassan et al., 2011), naturally fall from the tree, and underutilized. Earlier researchers utilized the seed of *P. biglobosa* as protein ingredient (Babalola et al., 2019), while the pulp from the seed was used as feed additive (Adeniyi et al., 2023) for fishes. There is limited information on the utilization of *P. biglobosa* flower in aquaculture. Therefore, the current study was conducted to evaluate the effect of dietary *P. biglobosa* flower (PBF) extract on hematological profile and resistance of *C. gariepinus* against *A. hydrophila* infection.

Materials and Methods

Source of plant and preparation

The mature and fresh PBFs which fell naturally overnight were obtained from the Faculty of Agriculture Teaching and Research Farm, Kwara State University, Malete, cleaned, air-dried at ambient temperature for five days and grinded to fine powder using an electric blender. The blend sample was mixed with ethanol at the ratio of 1:10 [plant material (g)/solvent (mL)], placed on electrical orbital shaker for 48 hours at 250 rpm for proper homogenization and extraction. The filtrate was concentrated using a rotary evaporator to obtain PBF extract, which was kept in a freezer at -20°C till when used.

Experimental diet and fish culture

Four isonitrogenous [40% crude protein (CP)] diets were formulated to include fish meal (72% CP), soybean meal, groundnut cake, maize, fish oil, and other additives while PBF extract was added to the ingredients at 0.0, 0.5, 1.0, or 1.5 g/kg diet. The ingredients were milled, mixed and pelletized to 2 mm

diameter size. A total of 180 juveniles of *C. gariepinus* of similar weights were randomly stocked into 12 rectangular plastic (80 × 60 × 45 cm^3) tanks at the rate of 15 juveniles per replicate and fed with the assigned diets twice daily to apparent satiation for 8 weeks. The water in the tanks were renewed 3 times weekly in order to maintain good water quality. The values of dissolved oxygen, pH and temperature were within 4.3 - 4.7 mg/L, 6.9 -7.2, and 25.2 - 27.5 °C, respectively, which were within the recommended range for tropical farmed fishes.

Blood collection and analysis

Blood samples were obtained from three fish per replicate from the caudal vein at about 1 cm from the anus, using sterilized 2 mL hypodermal plastic syringe. The blood samples collected were put into Ethylenediaminetetraacetic Acid tubes to prevent clotting and used for hematological analysis.

Bacterial Challenge Test

After the feeding trial, 10 fish from each experimental tank were randomly sampled and each fish was intraperitoneally challenged with a 0.1-mL dose of *A. hydrophila* (5 × 10^6 CFU/mL). The fish were fed the assigned diets for 14 days, during which the effect of dietary PBF extract on their level of resistance against the experimental infection was observed. The cumulative mortality (CM), survival rate and relative level of protection (RLP) were calculated using the formulas below:

$CM = Dt_1 + Dt_2 + Dt_3 +---------- Dt_n$

(D is the number of dead fish at the given time (days), t_1, t_2, t_3. ---------- t_n)

Survival rate (%) = (Number of survived fish on day t_1---- tn) / Number of fish stocked) × 100

RLP (%) = 1 – (% mortality in treatment / % mortality in control) × 100

Statistical analysis

The data obtained were analyzed using descriptive statistics and one-way analysis of variance while Duncan multiple range test was used to compare differences among means at $P < 0.05$, using SPSS (Version 23, Armonk, NY) software.

Results and Discussion

Hematological profile

The results (Table 1) showed that dietary supplementation with 1.0-1.5 g PBF/kg diet significantly ($P < 0.05$) enhanced hemoglobin, red blood cell, white blood cells (WBCs) and lymphocytes in *C. gariepinus*, while the packed cell volume and other WBCs differential cells were not affected ($P > 0.05$). Hematological parameters are useful tools for evaluation of physiological status of fish exposed to different text ingredients (Seibel et al., 2021; Adeniyi et al., 2023).

Post-challenge fish survival

The mortality in the experimentally *A. hydrophila*-infected fish fed the control and 0.5 g PBF/kg diets were higher and continued till day 10 (Figure 1). On the other hand, dietary supplementation with 1.0-1.5 g PBF/kg diet enhanced the survival and the highest survival rate occurred in the fish fed 1.0 g PBF/kg diet. Also, the fish fed 1.0-1.5 g PBF/kg diet had lower CM and higher ($P < 0.05$) RLP during the 14-day post-challenge than those fed the control and 0.5 g PBF/kg diets (Table 2). The study demonstrated the prophylactic or therapeutic role of PBF as natural alterative to synthetic antibiotic. The protective effect of PBF observed in this study might be related with the presence of polyphenols in the plant (Saleh et al., 2021).

This study aligns with previous authors on the antimicrobial activities of plant extracts in fishes against *A. hydrophila* infection (Saleh et al., 2021; Adeniyi et al., 2025).The WBCs and lymphocytes enhance immunity of fish to develop resistance against infectious diseases and could have contributed to the higher survival of the *A. hydrophila*-challenged *C. gariepinus* obtained in the current study. Herbal extracts containing polyphenolic compounds have been reported to enhance the physiological and immune functions of aquatic species (Abdul-Qadir *et al*., 2020; Seibel et al., 2021; Adeniyi et al., 2023, 2025).

Table 1: Hematological profile of *Clarias gariepinus* fed experimental diets supplemented with different levels of *P. biglobosa* flower (PBF) extract for eight weeks

Parameters	PBF extract levels (g/kg diet)			
	0.0	0.5	1.0	1.5
PCV (%)	36.01 ± 0.58	36.01 ± 0.58	37.01 ± 0.58	36.00 ± 0.58
HB (g/dL)	11.53 ± 0.15^{b}	11.53 ± 0.88^{b}	12.08 ± 0.24^{a}	12.43 ± 0.88^{a}
RBC (x 10^6/µL)	3.27 ± 0.02^{bc}	3.23 ± 0.02^{c}	3.32 ± 0.01^{a}	3.29 ± 0.01^{ab}
PLT (x 10^9/µL)	135.67 ± 0.73	137.00 ± 0.57	136.67 ± 0.87	136.00 ± 0.46
WBC (x 10^9/µL)	18.35 ± 0.13^{b}	19.33 ± 0.37^{b}	19.73 ± 0.73^{a}	19.48 ± 0.32^{a}
LYM (%)	61.00 ± 0.58^{b}	62.00 ± 1.15^{ab}	65.00 ± 1.53^{a}	64.67 ± 0.67^{a}
HET (%)	33.00 ± 1.52	30.67 ± 0.88	29.33 ± 2.03	29.00 ± 2.31
MON (%)	3.00 ± 0.33	2.67 ± 0.30	2.67 ± 0.33	2.67 ± 0.57
EO (%)	3.0 ± 0.67	4.33 ± 0.67	3.0 ± 0.67	3.0 ± 1.52
BA (%)	0.0 ± 0.00	0.33 ± 0.33	0.0 ± 00	0.33 ± 0.33

Mean ± standard error having different superscripts in the same row are significantly different at $P < 0.05$. PVC, Packed cell volume; HB, Hemoglobin; RBC, Red blood cells; WBC, White blood cells; LYM, Lymphocytes; HET, Heterophils; MON, Monocytes; EO, Eosinophils; BA, Basophils.

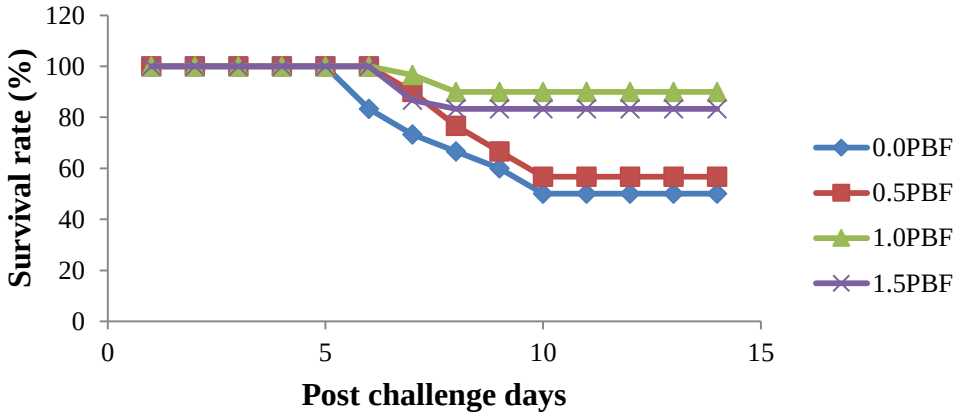


Figure 1: Post challenge survival rate of *Clarias gariepinus* experimentally infected with *Aeromonas hydrophila* and fed with diets supplemented with *Parkia biglobosa* flower (PBF) extract (g/kg diet) for 14 days

Table 2: Cumulative mortality and relative level of protection of *Clarias gariepinus* experimentally infected with *Aeromonas hydrophila* and fed with diets supplemented with *Parkia biglobosa* flower (PBF) extract for 14 days

Dietary levels of PBF (g/kg diets)	Cumulative mortality (%)	Relative level of protection (%)
0.0	50.00 ± 5.77^{a}	0.00 ± 0.00^{b}
0.5	43.33 ± 3.33^{a}	13.33 ± 6.67^{b}
1.0	10.00 ± 3.77^{b}	80.00 ± 11.67^{a}
1.5	16.67 ± 3.33^{b}	66.67 ± 6.67^{a}

Means ± standard error with different superscripts along the column are statistically different at $P < 0.05$.

Conclusion

Dietary supplementation with 1.0-1.5 g PBF extract/kg diet enhanced the hemoglobin, WBCs and lymphocytes counts as well as the survival of the *A. hydrophila*-challenged *C. gariepinus*. The highest survival was obtained at 1.0 g PBF/kg diet. Therefore, 1.0 g PBF extract/kg diet is recommended as an effective inclusion level for improving hematological parameters and resistance to *A. hydrophila* infection in *C. gariepinus*.

References

Abdul-Qadir, A., Mohammed, A., Adamu, K. M., & Abdulraheem, A. (2020). Inclusion of *Sargassum muticum* and *Parkia biglobosa* in diets for African catfish (*Clarias gariepinus*) elevates feed utilization, growth and immune parameters. *African Journal of Agricultural Research,* 15(1), 134-139. https://doi.org/10.5897/AJAR2019.14189

Adeniyi, O. V., Norman, A. S., & Onojobi, S. (2023). Effects of dietary supplementation of *Parkia biglobosa* pulp on growth performance and physiological status of *Clarias gariepinus* fingerlings. *The Journal of Basic and Applied Zoology,* 84,19. https://doi.org/10.1186/s41936-023-00340-y

Adeniyi, O. V., Pourmozaffar, S., Setufe, S. B., & Adeshina, I. (2025). Effects of dietary supplementation of *Euphorbia hirta* on the growth performance, serum biochemistry, antioxidative status, and immune response of *Clarias gariepinus*. *Aquaculture Research*, 5208865, https://doi.org/10.1155/are/5208865

Babalola, O. A., Odu-Onikosi, S. G., Adam, O. B., & Ogunyomi, O. R. (2019). Effects of replacing soya bean meal with fermented African locust bean (*Parkia biglobosa*) meal on the growth performance and condition factor of *Tilapia zilli* fingerlings. *Global Journal of Fisheries*, 1(1), 9-14. https://doi.org/10.31248/GJFS2019.005.

Hassan, L., Bagudo, B., Aliero, A., Umar, K., & Sani, N. (2011). Evaluation of nutrient and anti-nutrient contents of *Parkia biglobosa* (L.) flower. *Nigerian Journal of Basic and Applied Sciences*, 19(1), 76-80. https://doi.org/10.4314/njbas.v19i1.69347

Saleh, M. S. M., Jalil, J., Zainalabidin, S., Asmadi, A. Y., Mustafa, N. H., & Kamisah, Y. (2021). Genus *Parkia*: Phytochemical, medicinal uses, and pharmacological properties. *International Journal of Molecular Sciences*, 22, 618. https://doi.org/10.3390/ijms22020618.

Seibel H., Babmann, B., & Rebl, A. (2021). Blood will tell: What hematological analyses can reveal about fish welfare. *Frontiers in Veterinary Science,* 8. https://doi.org/10.3389/fvets.2021.616955

Gender Issues in Agricultural Research for Development: Advancing Women's Leadership in Postharvest Innovation

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Abstract

Women play a vital role in agricultural production and postharvest systems, yet they remain underrepresented in research and leadership roles. This study examined gender issues in agricultural research for development (AR4D), with a focus on postharvest innovation in Nigeria. Drawing on literature, institutional reports, and case examples/studies from the Nigerian Stored Products Research Institute (NSPRI), the study explored barriers to women's leadership and highlighted opportunities for gender-responsive change. Findings revealed that socio-cultural constraints, unequal access to resources, and institutional barriers continue to hinder women's career progression. However, supportive leadership within NSPRI particularly initiatives championed by the Executive Director (ED) to empower women researchers and farmers offers a sustainable model for inclusive innovation. The study recommends institutionalizing gender policies, expanding leadership mentorship programs, and scaling gender-inclusive outreach to strengthen women's visibility and influence in postharvest research. Advancing women's leadership will not only promote equity but also drive postharvest innovation, reduce losses, and enhance food security.

Keywords: Gender equity, agricultural research, postharvest innovation, women's leadership, NSPRI, AR4D.

Introduction

Agricultural Research for Development (AR4D) plays a critical role in advancing food security, poverty reduction, and innovation in sub-Saharan Africa. Women have historically played active and indispensable roles in agricultural production and postharvest management. However, gender disparities persist, with women often underrepresented in leadership and decision-making roles despite their central contributions to the sector (FAO, 2011). Globally, women constitute nearly half of the agricultural labour force, yet their participation in research leadership remains significantly lower than that of men, thereby limiting the inclusivity and impact of agricultural innovations (Meinzen-Dick et al., 2020).

In Nigeria, women contribute substantially to agricultural activities, particularly in processing and postharvest value addition, but face systemic barriers such as limited access to education, research funding, and decision-making platforms (Adams, 2017; Abebe et al., 2024). Postharvest losses estimated at 30–50% of fresh produce; disproportionately affect women who dominate processing and storage roles, yet their voices remain marginal in research leadership (Aulakh & Regmi, 2013).

The Nigerian Stored Products Research Institute (NSPRI) has made notable efforts to address these gaps. Under the leadership of its current Executive Director, NSPRI has promoted gender-responsive outreach, supported women farmers' groups with improved storage facilities, and encouraged the advancement of women researchers into visible roles. Such institutional commitment highlights the potential of leadership support in advancing gender equity and postharvest innovation. This study examines the barriers and opportunities for women's leadership in AR4D, with NSPRI as a case example/study, and makes recommendations for strengthening women's roles in postharvest research and innovation.

Materials and Methods

This study adopted a qualitative review approach, combining institutional case analysis with secondary data. Peer-reviewed articles, FAO and IFPRI reports, and policy documents were reviewed to identify key gender issues in AR4D. Institutional data were drawn from NSPRI, including staff records and program reports highlighting women's participation in research and farmer outreach. The analysis also incorporated regional statistics on women in agricultural research to situate NSPRI within the broader Nigerian context.

Following Tranfield et al. (2003), the review followed a structured process: planning, data collection, analysis, and synthesis. Gender frameworks, including FAO's Gender and Agricultural Research Assessment Guidelines (FAO, 2018), were used to interpret institutional practices. Case examples were selected from NSPRI's outreach to women farmers' groups and internal initiatives to promote women researchers. The analysis (descriptive) focused on barriers, leadership opportunities, and institutional practices relevant to postharvest innovation.

Results and Discussion

The analysis revealed that women remain underrepresented in agricultural research for development (AR4D) leadership, despite their critical contributions to agricultural production and postharvest systems. Nationally, women account for less than 25% of agricultural researchers and fewer than 15% in senior management roles (ASTI, 2021). This underrepresentation constrains inclusivity and reduces the

transformative impact of research outputs, as women's perspectives are often excluded from decision-making (FAO, 2011).

In postharvest systems, women perform 60–80% of processing and storage activities, yet their involvement in decision-making remains limited (Adams, 2017). Consequently, many technologies and innovations do not fully address the practical challenges faced by women users. Gender gaps in education, access to research grants, and promotion opportunities further restrict women's advancement, with studies indicating that women in Nigeria receive less than 20% of agricultural research funding (Abebe et al., 2024).

Institutional Inclusion of Women Researchers within NSPRI

At the institutional level, the Nigerian Stored Products Research Institute (NSPRI) provides a compelling case study. The institute maintains a substantive research workforce and has implemented initiatives aimed at enhancing women's participation in postharvest systems. For example, NSPRI recently distributed modern storage facilities to eleven women farmer groups in Yobe State, helping them reduce postharvest losses and improve household food security (Independent, 2023). This gender-responsive outreach exemplifies the institute's broader commitment to inclusivity.

A significant factor driving this progress has been the supportive leadership of NSPRI's Executive Director (ED), who has championed mentorship for women scientists, promoted their inclusion in research programs, and expanded outreach to women farmers. Notably, the institute currently has three female and two male zonal coordinators; an uncommon gender balance among research institutions in Nigeria; reflecting a deliberate effort to enhance women's representation in leadership. Furthermore, in the Ibadan Zonal Office, all heads of department, including that of Engineering, are female, underscoring NSPRI's commitment to gender equity within its internal research structure. Such leadership demonstrates how institutions can model gender-sensitive practices in Agricultural Research for Development (AR4D). However, to ensure sustainability, these gains must be institutionalized through formal gender policies, structured mentorship programs, and increased resource allocation to women researchers.

While specific data on gender representation in research committees and grant allocation are being consolidated, existing evidence (such as the predominance of women in zonal and departmental leadership) illustrates a strong institutional shift toward inclusivity. Strengthening data systems to monitor

women's participation in leadership and research funding would further institutionalize these gains and serve as a replicable framework for other national research agencies.

These developments highlight NSPRI's emerging institutional framework for advancing women in AR4D. By combining gender-responsive leadership with opportunities for professional growth, the institute is setting a precedent for how agricultural research organizations can operationalize gender equity not only through outreach programs but also within their internal governance and research systems.

To further contextualize the discussion on gender inclusion within NSPRI and the broader Agricultural Research for Development (AR4D) landscape, key findings from relevant literature and institutional records are summarized in Table 1. The table highlights the persistent gender gaps in representation, leadership, and access to resources, alongside emerging institutional responses (such as those demonstrated by NSPRI) that promote women's participation in research and postharvest innovation. These insights provide a foundation for assessing progress, identifying remaining challenges, and formulating strategies for more gender-responsive AR4D systems in Nigeria.

Table 1: Summary of Key Findings on Gender Issues in AR4D

Theme	Findings	Evidence/Example	Implication
Representation of Women in AR4D	Women remain underrepresented in research and leadership roles. Nationally, women make up less than 25% of agricultural researchers and under 15% in senior management.	ASTI (2021); FAO (2011).	Gender imbalance limits inclusivity and reduces the transformative impact of research outputs.
Role in Postharvest Systems	Women dominate processing and storage activities (≈60-80%), but their role in decision-making is minimal.	FAO (2011); Adams (2017).	Postharvest technologies may not fully address the needs of women users.
Institutional Barriers	Socio-cultural norms, limited access to higher education and research grants (women receive <20% in Nigeria), and gender bias in promotion.	Abebe et al. (2024).	Constrains women's career progression and slows innovation.
NSPRI Initiatives	NSPRI has implemented gender-responsive outreach and internal inclusion measures. For instance, the institute coordinated the distribution of modern storage facilities to eleven women farmer groups in Yobe State and maintains notable female representation	Independent (2023); NSPRI reports.	Expands women's participation in postharvest systems and provides a replicable model for institutional

	across leadership roles—including three female zonal coordinators and all-female departmental heads in the Ibadan Zonal Office.		gender inclusivity in AR4D.
Leadership Support	NSPRI's Executive Director has actively promoted women's empowerment, mentorship for female researchers, and inclusivity in research design.	NSPRI internal reports.	Provides a model of gender-sensitive leadership in AR4D.
Opportunities for Advancement	Institutionalizing gender policy, mentorship programs, increasing women's share in leadership >30%, and scaling outreach across Nigeria.	Study findings.	Can transform NSPRI into a model for women's leadership in AR4D and postharvest innovation.

The findings presented in Table 1 underscore both the progress and the persisting disparities in gender participation within Agricultural Research for Development (AR4D). While national trends reveal continued underrepresentation of women in research and leadership, the NSPRI case demonstrates how deliberate institutional actions can begin to reverse these patterns. Building on such evidence, the subsequent section discusses the policy implications and strategic pathways for strengthening gender mainstreaming within AR4D institutions, ensuring that inclusion becomes a sustained organizational norm rather than an isolated achievement.

Policy Implications

The analysis of gender dynamics in AR4D and the NSPRI case study highlights the need for policies that move beyond program-level interventions toward systemic institutional change. To sustain gains made through leadership initiatives and outreach, research organizations should adopt gender policies that clearly define equity targets, provide accountability frameworks, and allocate dedicated funding for gender-responsive programs. National agencies such as the Agricultural Research Council of Nigeria (ARCN) can strengthen this process by incorporating gender performance indicators into institutional evaluations and grant assessments. Furthermore, capacity-building programs that support women scientists through mentorship, research funding, and leadership development; will ensure a steady pipeline of female professionals equipped to drive innovation across Nigeria's agricultural research system.

Conclusion and Recommendations

Gender disparities continue to persist in Agricultural Research for Development (AR4D) in Nigeria. Women remain underrepresented in research and leadership roles, face limited access to funding, and play secondary roles in decision-making; especially within postharvest systems where they constitute the majority of the labor force. Institutional barriers, including socio-cultural norms and unequal access to research grants, further constrain their professional advancement.

The Nigerian Stored Products Research Institute (NSPRI) offers a compelling example of progress. The institute's gender-responsive initiatives (such as the distribution of modern storage facilities to women farmer groups), and the promotion of women into zonal and departmental leadership positions, reflect a growing institutional commitment to inclusivity. The Executive Director's supportive leadership has also advanced mentorship for women scientists and fostered gender mainstreaming across research programs.

Gender responsiveness in agricultural research and development is not only a question of equity but also a driver of innovation and impact. This study concludes that while gender disparities in AR4D remain a challenge, NSPRI's experience demonstrates that transformative leadership and institutional support can open viable pathways for women's inclusion and empowerment in research and innovation.

To sustain and expand these gains, the following recommendations are proposed:

Institutionalize Gender Policies: Embed gender equity principles into recruitment, promotion, and leadership processes to ensure sustainability.

Expand Leadership Support: Formalize mentorship and capacity-building programs to prepare women researchers for leadership roles.

Strengthen Capacity Building: Provide targeted research grants, leadership training, and professional networking opportunities for women.

Promote Gender-Responsive Research: Involve women farmers and processors in the design, testing, and evaluation of postharvest technologies.

Scale Outreach Programs: Expand NSPRI's women-focused interventions nationwide to reduce postharvest losses and enhance food security.

By embedding these strategies, NSPRI can serve as a national model for gender-inclusive agricultural research and innovation. Strengthening women's representation and leadership will not only advance equity but also accelerate technological innovation and contribute to sustainable food security in Nigeria and beyond.

References

Abebe, H., Jaslin, K., & Mavisakalyan, A. (2024). Gender gaps in the adoption of climate-smart agricultural practices: Evidence from sub-Saharan Africa. *Journal of Agricultural Economics*, 75(2), 764-793. https://onlinelibrary.wiley.com/doi/10.1111/1477-9552.12583?af=R

ASTI (2021). *Agricultural Science and Technology Indicators: Nigeria*. International Food Policy Research Institute. Available at: https://asti.cgiar.org/nigeria

Aulakh, J., & Regmi, A. (2013). *Post-harvest food losses estimation—development of consistent methodology*. Food and Agriculture Organization of the United Nations. Available at: https://www.fao.org/fileadmin/templates/ess/documents/meetings_and_workshops/GS_SAC_2013/Improving_methods_for_estimating_post_harvest_losses/Final_PHLs_Estimation_6-13-13.pdf

FAO (2011). The State of Food and Agriculture. Women in Agriculture-Closing the gender gap for development. https://www.fao.org/4/i2050e/i2050e00.htm

FAO (2018). Guidance note on gender-sensitive vulnerability assessments in agriculture. https://openknowledge.fao.org/server/api/core/bitstreams/3bea6d4d-691d-4377-87e7-5b894567a0b5/content

Adams, O. K. (2017). Nigeria Women in Agriculture: Challenges and Way Forward IOSR Journal of Humanities And Social Science (IOSR-JHSS) Volume 22, Issue 1, Ver. 3 (January 2017) PP 102-106 e-ISSN: 2279-0837, p-ISSN: 2279-0845. https://www.iosrjournals.org/iosr-jhss/papers/Vol.%2022%20Issue1/Version-3/P220103102106.pdf

Independent. (2021). 11 Women Farmers Group Get NSPRI Storage Facilities to Tackle Post-Harvest Losses written by Oluseyi Taiwo-Oguntuase. Available at https://independent.ng/11-women-farmers-group-get-nspri-storage-facilities-to-tackle-post-harvest-losses/

Meinzen-Dick, R., Quisumbing, A., Behrman, J., Biermayr-Jenzano, P., Wilde, V., Noordeloos, M., Ragasa, C., & Beintema, N. (2011). Engendering Agricultural Research, Development, and Extension Priority Setting Research & Development Extension Adoption Evaluation.

NSPRI (2023). Report on Distribution of Improved Storage Facilities to Women Farmer Groups in Yobe State. Ilorin, Nigeria: Nigerian Stored Products Research Institute.

Tranfield, D., Denyer, D., Smart., & P. (2023). Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. *British Journal of Management*, 14(3), 207-222. https://onlinelibrary.wiley.com/doi/abs/10.1111/1467-8551.00375

Gender Issues and Implications for Agricultural Advisory Service Delivery in Nigeria

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Abstract

This paper examined gender issues and the implications for agricultural extension service delivery in Nigeria. Specifically, the nature and extent of gender disparities in access to agricultural extension services, the socio-cultural and institutional factors influencing gender differences in the delivery and access to extension services were identified. The study was conducted through a systematic review of scholarly journal articles, institutional reports, and policy documents published between 2010 and 2025. Findings revealed that agricultural extension systems in Nigeria remain largely male-dominated, with women farmers facing limited access to information, training, and productive resources due to socio-cultural norms, mobility constraints, and institutional biases. These inequalities contribute to lower productivity and slower adoption of agricultural innovations among women compared to men. To achieve equitable and efficient service delivery, gender mainstreaming across all extension activities, recruitment and training of more female extension agents, adoption of gender-responsive approaches, policies and monitoring frameworks become imperative for sustainable agricultural development in Nigeria.

Keywords: Advisory services, Agricultural innovation, Gender-responsive, Gender disparity, Inequality

Introduction

Agriculture is underperforming in many developing countries due to several reasons, with gender-related inequalities being one of the most significant (Clark et al., 2023). The global community is increasingly committed to sustainable agricultural growth by tackling gender issues through national, regional, and global initiatives and partnerships. Thus, gender equality is a global concern and the fifth subject of the Sustainable Development Goals (SDG) which is to achieve gender equality and empower all women and girls by focusing on eliminating gender disparities in education, economic participation, decision-making, and access to resources across all sectors.

Agriculture is crucial as it directly and indirectly contributes to achieving 12 of the 17 Sustainable Development Goals (SDGs). However, these goals cannot be fully realized without addressing gender concerns within the sector, particularly the gender issues in agricultural advisory services delivery. Gender

issues in the dissemination of agricultural innovation have been observed to contribute to global hunger and food insecurity (Ragasa et al*.,* 2013; FAO 2020) and this has been known to influence differences in technology adoption and agricultural productivity.

Agricultural extension services serve as a vital link between research institutions and farmers by facilitating the transfer of knowledge, innovations, and improved practices. In Nigeria, where agriculture employs over 70% of the rural population, extension systems play a central role in enhancing productivity, food security, and livelihood diversification. However, the delivery of extension services has often been unevenly distributed between male and female farmers (Obayelu et al. 2024). Gender issues in extension service delivery are not only about participation but also about equity and inclusivity.

Gender imbalance among agricultural advisory providers, socio-cultural constraints, and policy gaps contribute to disparities in access to extension services. This imbalance limits the productivity and potential of a large number of the agricultural workforce (Obayelu et al. 2024). FAO (2021), Fawole and Tijani (2019), Agbamu (2015) and Odebode (2012) emphasized that addressing gender concerns is critical to achieving effective agricultural transformation. This paper, therefore, reviewed articles on gender issues in Nigeria's agricultural advisory system and the implications for agricultural development, while recommending practical steps toward gender-responsive service delivery.

Methodology

This study employed the Integrative Review Framework by Whittemore and Knafl (2005**)** to synthesize evidence on gender issues and their implications for agricultural extension service delivery in Nigeria. This approach enabled the integration of diverse qualitative and conceptual studies. Literature was retrieved from Scopus, Web of Science, Google Scholar, and ScienceDirect**,** using Keywords such as *"gender and agricultural extension," "women in agricultural innovation,"* and *"gender mainstreaming in Nigeria."* Grey literature from Food and Agriculture Organization (FAO), Global Forum for Rural Advisory Services (GFRAS), African Forum for Agricultural Advisory Services (AFAAS) and World Bank reports supplemented the review.

Inclusion criteria covered peer-reviewed and technical publications (2010–2025) focused on Nigeria addressing gender issues in extension advisory service delivery. Studies unrelated to gender or limited to production practices were excluded. A total of 56 articles meeting the inclusion criteria were analysed to ascertain gender issues in agricultural extension. Data were extracted using a structured matrix and analyzed through data reduction, display, comparison, and conclusion drawing as outlined by Whittemore and Knafl. Four themes emerged: gender participation and access, socio-cultural and institutional barriers,

gender responsiveness in extension, and policy implications. Credibility was ensured through triangulation of multiple data sources and transparent documentation of the review process.

Results and Discussion

Gender Participation and Access to Agricultural Advisory Services

Gender issues refer to differences in the roles, responsibilities, access, and opportunities available based on gender differences. These differences are shaped by social norms, cultural beliefs, and institutional practices that often inhibits gender inclusivity. In agricultural extension, gender issues manifest in how information, technologies, and training are disseminated in relation to gender differences. When these differences are not taken into cognizance, then gender biases become evidence. Men typically have greater access to extension information due to their control over land, mobility, and leadership roles in farmer groups (Akeredolu et al., 2017). Women, on the other hand, often face restrictions due to domestic responsibilities, limited education, and social expectations (FAO (2018).

Gender-based marginalisation in agricultural extension service delivery often varies across contexts. Although literature frequently portrays women farmers as the most marginalised group, patterns of exclusion are not uniform. In some cases, agricultural advisory services are deliberately targeted at the gender perceived to be more involved at specific nodes of the agricultural value chain, thereby marginalising the other group considered less active. For instance, women are often associated with the cultivation of certain crops commonly referred to as “women’s crops.” Consequently, innovations and advisory interventions directed at these crops may focus primarily on women while neglecting male farmers who also engage in their production. Similarly, because women are generally perceived to be more active in postharvest activities particularly in processing, extension interventions in these areas may prioritise women’s participation, inadvertently excluding men. This context specific differences underscores the need for a balanced and inclusive approach to agricultural extension and advisory services that recognises the diverse roles of all gender groups across the value chain.

Arokoyo (2019) and Davis & Sulaiman (2014) reported that poor and small-scale male farmers are often overlooked in extension programmes while priority is often given to large scale producers who are perceived as more capable of adopting innovations, however attention is often given to small scale women farmers often considered as the vulnerable group. Similarly, institutional structures that rely on farmer associations or cooperative networks tend to favour wealthier or more influential male farmers, excluding poorer men without the social capital to engage effectively (Rivera & Alex, 2008). These institutional requirements are often waived for the women. Younger men, especially those without land

or collateral, also encounter barriers to participation in extension programmes designed around land ownership and household headship.

Despite women's substantial contribution to agricultural production especially in food processing, marketing, and subsistence farming, they continually face systemic barriers that limit their access to agricultural information and resources. Women farmers are widely recognised as being marginalised in access to agricultural extension and advisory services. Their exclusion is shaped by a combination of socio-cultural, institutional, and economic factors. Culturally, gender norms often restrict women's mobility, discourage interaction with male extension agents, and limit their participation in farmer groups or field demonstrations (FAO, 2021).

Extension systems are frequently male-dominated, with few female extension officers and little consideration for women's schedules, literacy levels, or farming roles. Similarly, women's limited ownership of land and productive assets reduces their eligibility for formal training, credit, and input support, which are often prerequisites for inclusion in extension programmes. Also, information channels and technologies such as radio or mobile platforms are sometimes less accessible to women due to lower income and limited decision-making power within households. These disparities have broader implications for agricultural productivity and consequently, widens gender gap in extension service delivery perpetuating rural poverty and constraints national food security. However, recognizing and addressing these differences is essential to designing inclusive agricultural programs.

Socio-Cultural Institutional Barriers to Gender-sensitive Extension Services Delivery

In Nigeria, the agricultural extension system is predominantly male-dominated, with the number of male extension agents far exceeding that of their female counterparts (Obayelu et al. 2024). However, there are situations in which female extension personnel are responsible for disseminating innovations to farmers. In such contexts, cultural perceptions about women's roles may influence the extent to which farmers especially male accept or adopt the technologies being promoted. In some communities, it is considered inappropriate for male extension officers to interact closely with female farmers, just as certain cultural and religious norms restrict women from engaging freely with men and because female agents are fewer, women receive little to no advisory support. These gendered cultural dynamics can hinder effective communication and limit the reach and impact of extension programmes, underscoring the need for more gender-sensitive staffing and culturally adaptive extension approaches.

In northern Nigeria, religious and cultural practices often restrict women's mobility, further reducing their participation in on-farm demonstrations and training (FAO, 2021, Auta & Dafwang, 2023). In contrast,

studies in southwestern and southeastern Nigeria indicate that women's participation improves when extension programs are community-based and when female agents are involved (Nnadi & Akwiwu, 2018). Women bear the burden of domestic work and childcare, therefor trainings scheduled during the day may clash with their household responsibilities. Advisory materials are often produced in formal languages or technical terms, which many rural women especially those with limited schooling cannot easily understand. Extension agents sometimes assume men already know enough about farming and focus their training on women.

Gender Responsiveness in Extension Service Delivery and policy Implications

Gender responsiveness in agricultural extension service delivery refers to the extent in which extension systems recognize and address the distinct needs, priorities, and constraints of different gender groups in accessing agricultural knowledge, inputs, and opportunities. A gender-responsive extension system ensures equitable participation, decision-making, and benefits for both men and women across the agricultural value chain (FAO, 2011). However, in many developing countries, including Nigeria, extension structures have historically been designed around male farming models, overlooking women's critical contributions to production, processing, and marketing (Ragasa et al., 2013; Adisa, 2019).

The limited representation of women among extension personnel and decision-makers further undermines gender responsiveness. Female extension agents are often few and unevenly distributed, reducing the system's capacity to effectively reach women farmers especially in culturally conservative areas where gender norms restrict male-female interaction (Arokoyo, 2019). Moreover, extension content and delivery methods frequently fail to consider women's time burdens, literacy levels, and mobility constraints, thereby limiting their participation in training and capacity-building activities (Doss & SOFA Team, 2011).

To enhance gender responsiveness, policy frameworks must move beyond gender-neutral approaches toward gender-transformative strategies that challenge structural inequalities within agricultural institutions. This requires strengthening the recruitment and capacity-building of female extension agents, promoting participatory and inclusive advisory methods, and integrating gender analysis into programme design and evaluation (GFRAS, 2020). Additionally, policies should ensure that both men and women farmers have equal access to productive resources, digital advisory platforms, and decision-making spaces.

Ultimately, a gender-responsive extension system is not only an issue of equity but also of agricultural efficiency and sustainability, as it leverages the full potential of all farmer groups. Policies that

institutionalize gender mainstreaming within extension services will contribute to more inclusive innovation systems and improved agricultural productivity at the household and community levels (Meinzen-Dick et al., 2014; FAO, 2018).

Conclusion

Gender issues in agricultural extension service delivery continue to undermine Nigeria's agricultural potential. The literature consistently shows that addressing these disparities is key to achieving inclusive agricultural growth. A shift toward gender-responsive extension systems through inclusive policies, equitable staffing, and participatory communication is necessary to ensure that both men and women benefit equally from agricultural innovations.

Recommendation

Policy makers must be gender sensitive and responsive in formulating agricultural extension policies and programs at all levels. Increase recruitment and capacity building of female extension agents by both public and private providing agricultural advisory services. Provision of regular gender-sensitivity training for all extension staff and field agents.

References

Adisa, R. S. (2019). *Rural women's access to agricultural extension services in Nigeria: Constraints and policy implications*. *Journal of Agricultural Extension*, 23(2), 45-58.

Agbamu, J. U. (2015). Agricultural Extension in Nigeria. Agricultural Society of Nigeria Press.

Akeredolu, M., Okonkwo, I., & Adebayo, A. (2017). Gender and Agricultural Information Dissemination in Nigeria. *Journal of Agricultural Extension, 21*(2), 45-59.

Arokoyo, T. (2019). *Restructuring agricultural extension for improved service delivery in Nigeria*. *Nigerian Journal of Agricultural Extension*, 33(2), 1–9.

Auta, S. J., & Dafwang, I. I. (2023). *Socio-cultural constraints to women's participation in agricultural extension activities in northern Nigeria. Asian Journal of Agricultural Extension, Economics & Sociology, 41*(11), 75–86. https://doi.org/10.9734/ajaees/2023/v41i112238

Clark, M., Bandara, S., Bialous, S., Rice, K., & Lencucha, R. (2023). Gendering the political economy of smallholder agriculture: A scoping review. *Social Sciences*, 12(5), 306. https://doi.org/10.3390/socsci12050306

Davis, K., & Sulaiman, R. (2014). *The new extensionist: Roles and capacities to strengthen extension and advisory services*. *Global Forum for Rural Advisory Services (GFRAS)*.

Doss, C., & SOFA Team. (2011). The Role of Women in Agriculture. *FAO Agricultural Development Economics Working Paper No. 11-02*. Rome: FAO.

FAO. (2011). *The State of Food and Agriculture 2010–2011: Women in Agriculture—Closing the Gender Gap for Development*. Rome: FAO.

FAO. (2018) Developing gender-sensitive value chains – Guidelines for practitioners. Rome, FAO available at http://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1140290/

FAO. (2021). *Gender and Agricultural Extension in Africa: Bridging the Gap.* Rome: FAO.

FAO. 2020. FAO Policy on Gender Equality 2020–2030. Rome, FAO. (also available at https://www.fao.org/3/cb1583en/cb1583en.pdf)

Fawole, O. P., & Tijani, A. A. (2019). Gender Dimensions in Agricultural Extension Services in Nigeria. *Nigerian Journal of Rural Sociology, 19*(1), 32–45.

GFRAS. (2020). *Youth engagement in rural advisory services: Policy brief*. Lindau: Global Forum for Rural Advisory Services.

Meinzen-Dick, R., Quisumbing, A., Behrman, J., Biermayr-Jenzano, P., Wilde, V., Noordeloos, M., ... & Beintema, N. (2014). *Engendering agricultural research, development and extension*. Washington, DC: IFPRI.

Nnadi, F. N., & Akwiwu, C. D. (2018). Determinants of women's participation in agricultural production: Implication for rural development in Imo State, Nigeria. *International Journal of Agricultural and Rural Development, 21*(1), 3558–3564.

Obayelu, O., Jimmy, M., & Ojo, A. O. (2024). Women's empowerment in agriculture and household food insecurity in Nigeria. *Malaysian Journal of Agricultural Economics, 31*(1). https://doi.org/10.36877/mjae.a0000541

Odebode, S. O. (2012). Gender participation in agricultural extension services in Nigeria. *Journal of Rural Sociology and Development, 10*(2), 45–58.

Ragasa, C., Berhane, G., Tadesse, F., & Taffesse, A. S. (2013). *Gender differences in access to extension services and agricultural productivity*. *Journal of Agricultural Education and Extension*, 19(5), 437–468.

Rivera, W. M., & Alex, G. (2008). *Human resource development for modernizing the agricultural workforce*. *Human Resource Development Quarterly*, 19(3), 311–323.

Whittemore, R., & Knafl, K. (2005). *The integrative review: Updated methodology. Journal of Advanced Nursing*, 52(5), 546–553.

Effect of Storage Containers on Chemical Stability of Palm Oil

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Abstract

This study examines the effect of storage containers on the chemical stability of palm oil. Palm oil samples were stored in glass, tin and plastic containers for 12-month period at 25±2°C. Analytical methods by AOAC were employed to monitor changes in key chemical parameters of the oil on quarterly basis and the average effect statistically analyzed. Results showed that glass containers resulted in the lowest values for key degradation indicators and were as follows: free fatty acids (3.76%), peroxide value (6.14mEq/kg) and iodine value (51.86 g/100g). Oil stored in tin had the highest value for free fatty acid, peroxide value and iodine value and were 0.82 %, 6.48mEq/kg and 55.68g/100g, respectively. Oil stored in tin had the highest value for acid value (13.41mgKOH/g) while the one stored in glass had the least value (5.62 KOH/g). Generally, with the exception of peroxide values, the values of chemical compositions of the oil stored in different containers were significantly ($p<0.05$) different from each other. These findings emphasize the importance of container type in maintaining the stability of palm oil during storage, with glass, followed by plastic containers offering superior protection against rancidity and quality degradation.

Keywords: Chemical properties, Palm oil, Storage containers, Rancidity, Degradation

Introduction

Palm (*Elaeis guineensis*) is a “wonder tree”, being very useful to humans and the oil is among its most useful products, which finds application in cooking, manufacturing of paints, cloth, linoleum, printing ink, insecticides, pharmaceuticals, cosmetics, leather making, production of animal feeds, baking products and confectioneries. Palm oil, extracted from the fresh mesocarp of oil palm fruits (*Elaeis guineensis*) of the Palmae family, has seen a substantial production increase over recent decades due to its extensive industrial uses. It has surpassed soybean oil to become the world's most significant vegetable oil, with global production reaching 80 million tons in 2024–2025, making up 40 % of the total 230 million tons of vegetable oil produced worldwide. Globally, 80% of palm oil is consumed as food, with the remaining 20% used in soap and oleo-chemical manufacturing (Shapiro, 2013).

The main components of palm oil are triacylglycerols (TAG), with crude palm oil containing about 1% of minor constituents such as carotenoids, tocopherols and tocotrienols, phytosterols, phospholipids, glycolipids, terpenic and aliphatic hydrocarbons which not only enhance the stability and quality of palm oil but also offer notable biological benefits, including antioxidant, anti-cancer, anti-inflammatory, anti-atherosclerotic and cholesterol- lowering properties. The increasing interest in the health benefits of these minor components has spurred the creation of functional foods or nutraceuticals that incorporate phytosterols, tocopherols, and tocotrienols (Ekwenye, 2006).

The chemical properties of palm oil which are critical in determining its quality, shelf life and suitability for various applications in the food, cosmetic, and biofuel industries could be significantly influenced by the type of storage vessels used. Palm oil is traditionally stored in varying containers such as glass, plastic and tin containers and over time, become un-palatable to consumers because of rancidity. Variations in temperature, light exposure and chemical interactions between the oil and storage vessel materials can lead to changes in the physiochemical properties of palm oil over time (Shapiro, 2013). The storing of large volumes of oil for long periods under diverse conditions is not an easy task, since many of its characteristics which are necessary to be maintained, deteriorate. In order to maintain stability of palm oil for a long period for consumption and industrial usage, without the loss of quality, there is need for adequate storage. This study evaluates how different storage containers: glass, tin and plastic affect the chemical properties of palm oil over a 12-month period at 25±2^{o}C.

Methodology

The freshly extracted palm oil used for the study was obtained from oil mill in Amuzi, Obowo, Imo State, Nigeria. Plastic bottles, glass bottles, metal cans were purchased from Relief Market, Owerri, Imo state and were heat-treated in boiling water for 10 min, before use. Uniform volume (250 ml) were poured into the different packaging materials (plastics, glass and metal) and stored on dark elevated platform at 25±2^{o}C for subsequent analysis. Samples were analyzed prior to storage (zero months) and further analyzed after 3, 6, 8 and 12 months.

Experimental Design

A complete Randomized, destructive sampling Design (CRD) was used. For each container type, 2 replicate samples were taken at 0 (baseline),3,6,9 and 12 weeks making the total number of experimental units = 3 containers x 5 storage duration x 2 replicates = 30 samples.

Analysis of Samples

Chemical properties (free fatty acids, peroxide value, iodine value, acid value and saponification value) of oil samples were determined according to the method of AOAC (2012) with the following method numbers: 969.33, 965.33, 996.06, 950.49 and 920.160, respectively. All analyses were done in duplicates. Data generated were statistically analyzed using computer software, Statistical Package for Social Sciences (SPSS) version 21 to obtain the Analysis of Variance (ANOVA). A comparison test (LSD) was used to separate means where significant differences exist.

Results and Discussion

Effect of Storage Materials on the Chemical Properties of Palm Oil after Twelve Weeks

Table 1 shows the average results on the effect of storage containers on the chemical properties of palm oil after twelve weeks. From the results of the chemical properties of palm oil, glass stored oil had the lowest values for all the parameters examined while the oil stored in tin container had the highest values. The results were in the following ranges: 3.76% to 6.82% (free fatty acid), 6.14 mEq/kg to 6.48mEq/kg (peroxide value), 51.86g/100g to 55.68g/100g (iodine value), 0.5mgKOH/g to 1.41mgKOH/g (acid value) and 194.21 mgKOH/g to199.01 mgKOH/g (saponification value). With the exception of the peroxide values, the compositions of all the chemical parameters of oil stored in various containers were significantly ($p<0.05$) different from each other.

Free fatty acids are components of triacylglycerol molecules that indicate poor oil quality. It is a very important quality index of oil and should not exceed 5 %,(expressed as palmitic acid) (Codex Alimentarius/FAO/OMS, 2005). The high FFA level (6.82%) reported in this study for oil stored in tin containers could be attributed to the reaction with the composition of the tin container used for the oil storage (Ohimain & Izah, 2013).

Peroxide value according to Ekwenye (2006) is a function of storage environment and packaging. This implies that there was no significant effect of the different storage containers on the peroxide value, though its value of oil stored in tin container had the highest value (6.48mEq /kg) when compared to oil stored in the other containers.

Iodine value is an index of unsaturation and susceptibility of oil to oxidation and rancidity and determines the stability and shelf life of the oil. It is used to identify adulteration of palm oil with any other vegetable or animal fat (Ekwenye, 2006). High iodine value makes the oil to be unstable thereby affecting other downstream application beside food (Ohimain and Izah, 2013). The range (51.86 to 55 48) g/100g of

iodine values of oil samples from different storage containers in this research were within the standard range of 45-53g/100g fat as recommended by SON (2000).

Acid value is the amount of Potassium hydroxide required to neutralize free fatty acid in oil. It is a critical parameter in measuring oil quality. A high acid value reflects an increased concentration of free fatty acids in the oil, resulting from hydrolytic rancidity. Ohimain & Izah (2013) stated that a high acid value might probably be as a result of improper storage and could affect the quality of oil for both domestic and industrial applications. The maximum allowable acid value for edible vegetable oil by SON (2000) is 0.6mgKOH/g. This implies that the acid (0.5mgKOH/g) of the oil stored in glass was within the acceptable limit

Saponification value is indirectly related to the molecular weights of triglycerides. It is inversely proportional to the average molecular weight of fatty acids (Ashoro *et al*., 2024). The saponification value gives information about the solubility in water and soap formation (Ohimain and Izah, 2013). Codex standard requirements specify that the saponification value of unblended palm oil should be within the range 194-202 mg KOH/g oil. The saponification values showed that the palm oil samples under different storage containers are within the range of specified standard requirements.

Table 1: Average Effect of Storage Containers on Chemical Properties of Palm Oil after 12 Weeks

Parameters	Storage Materials			
	Plastic	Tin	Glass	LSD
Free fatty acids (%)	4.78^{b}+0.12	6.82^{a}+0.11	3.76^{c}+0.11	0.07
Peroxide value (mEq/kg)	6.27^{a}+1.37	6.48^{a}+1.33	6.14^{a}+1.20	0.82
Iodine value (g/100g)	55.48^{b}+4.90	55.68^{a}+4.10	51.86^{a}+3.35	2.61
Acid value (mgKOH/g)	1.00^{b}+4.83	1.41^{a}+10.9	0.5^{b}+9.32	5.54
Saponification value (mgKOH/g)	194.21^{c}+0.70	197.88^{b}+0.31	199.01^{a}+0.50	0.33

Values represent means ± standard deviation of ten replicates. Means on the same row with different superscript are significantly ($p<0.05$) different from each other

Conclusion

From the findings, palm oil stored in glass containers exhibited better overall stability compared to the samples stored in plastics and tin. Glass storage maintained lower peroxide values and free fatty acid content, suggesting reduced oxidative degradation over time. Oil stored in tins containers showed higher levels of rancidity and degradation, especially in terms of peroxide and free fatty acid development. From

the results of this study, it can be inferred that deterioration in the chemical parameters in the containers was in the following order: tin container > plastic container > glass containers.

References

Ashoro, C.O., Emaziya, P.O. & Ovharhe, O.J. (2024).Efficiency of Oil Palm Production in Nigeria: A review-Pathway,World Journal of Advanced Research and Reviews, 2(1):2558-2568. https.//doi org/10.30574/wjarr.2024.21.1.2736

A.O.A.C (2012). Official Methods of Analysis of the Association of Official Analytical Chemists International 17th edition, Maryland, U.S.A.

Codex Alimentarius/ FAO/OMS, (2005). Normes alimentaires pour huiles et graises. CODEXSTAN 210, FAO/OMS.

Ekwenye, U. N. (2006). Chemical characteristics of palm oil biodeterioration. *BIOKEMISTRI*,18 (2): 141-149 (December 2006) http://www.bioline.org.br/bk

Ohimain, E. I.& Izah, S. C. (2013). Energy self sufficiency of small holder oil palm processing in Nigeria. Renewable Energy, 63: 426 – 431.

Standard Organization of Nigeria (S.O.N) (2000). Standards for edible refined palm oil and its processed form. pp. 2-5.

Yusuf, M. O. L. & Ayanlade, A. (2015). "The role of smallholders in oil palm production inNigeria: A case study of smallholders in Edo State, Nigeria." *Agriculture and Food Security*, 4(1): 1-12.

Cassava Value Chain: An Instrumental Factor for Economic Growth and Profitability in Nigeria

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Abstract

Cassava is a staple crop widely consumed across African households, with the majority of tubers produced used locally in traditional meals, underscoring its importance in both production and consumption. This study examined the value chain of cassava in Nigeria, focusing on producers, processors, and marketers. Using a multistage sampling technique, data were collected from these key actors and analyzed through descriptive statistics, mean rating analysis, and gross margin calculations. Findings revealed that 75% of cassava farmers were males, while 95% of both processors and marketers were females. Most respondents (53%) possess formal education, predominantly at the secondary level. Among producers, mechanization is limited primarily to tractor usage, with minimal adoption of other technologies such as planters and harvesters. Processors commonly use traditional tools like graters, pressers, cutters, and pounders, but few have integrated modern equipment like fryers and peelers. However, marketers further behind in technology adoption; only a small fraction utilize the internet for information access and advertisement, and most do not employ packaging logos or improved transportation methods. Economic analysis indicates gross margins of ₦1,020,000 for producers, ₦60,000 for processors, and ₦20,000 for marketers, highlighting cassava farming as the most profitable segment within the value chain. The percentage of 77%, 40%, and 22.22% of the revenue are available to cover fixed costs and contribute to net profit, which are strong signs of profitability. This suggests that the production, processing and marketing are highly profitable on a variable cost basis. However, respondents face significant challenges including limited access to credit, high labor, input costs, and inadequate extension services. In conclusion, while cassava farming is profitable, processors and marketers require enhanced financial and technical support to increase their profitability. The study recommends targeted education on adopting improved technologies, access to financial facilities, and strengthened government extension services to provide technical assistance.

Keywords: Cassava, Economic growth, Profitability, Value chain.

Introduction

The cassava value chain typically starts with small-scale farmers who cultivate cassava, followed by harvesting and transport to processing facilities where roots are cleaned, peeled, and grated. Processors then convert grated cassava into products like flour, starch, and chips, which are distributed by marketers

to wholesalers, retailers, and ultimately to end-users (such as food manufacturers, households, and animal feed producers) (Amelework et al., 2021). Value chain analysis for cassava enhances understanding of marketing operations from production through to consumption, helping farmers select efficient marketing channels and distribution networks to maximize profitability. This study determined the level of traditional and improved technologies utilized by farmers, processors, and marketers in the value chain of cassava, analyzed the costs and returns on activities involving farming, processing, and marketing in the value chain of cassava and described the constraints faced by respondents along the value chain of cassava in the study area.

Methodology

The study was conducted in Kwara State, located in Western Nigeria. Kwara shares borders with Kogi State to the east, Niger State to the north, Ekiti, Osun, and Oyo states to the south, and its western boundary forms part of the international border with Benin Republic. The state's capital city is Ilorin, and it is divided into 16 local government areas.

Sampling Techniques and Method of Data Collection

A multi-stage sampling technique was used for collecting the data. Stage one involved the purposive selection of Zone C out of the four agricultural Zones in Kwara State based on the rate of cassava production in the area. Second stage also involves the random selection of three (3) local government areas from Zone C. The third stage involves the random selection of four (4) villages each from the three local government areas selected, while the fourth stage involve random selection of 40 cassava farmers, 40 cassava processors (*lafun, fufu, garri*), and 40 marketers of cassava in all the villages. A total number of one hundred and twenty (120) actors were randomly selected.

Method of Data Analysis

The data obtained was analyzed using a number of econometric tools based on the objectives stated. The analytical tools used include descriptive statistics, gross margin analysis, percentage distribution, mean rating analysis, and a Likert-type scale.

Results and Discussions

The study reveals significant gender disparities in the cassava value chain: Table 1 shows that about 75% of farmers were male, while 95% of processors and marketers were female, reflecting traditional gender roles with men dominating cultivation and women leading processing and marketing. Most farmers (75%) are aged 41 and above, this implies that they were still in their active and producing stage to handle the farming rigorous activities, whereas processors and marketers are mostly younger adults aged 26-30. All

farmers surveyed were married, with processors and marketers mostly married as well, reflecting cassava activities as family-centered. Household sizes vary, with farmers having larger households (6-10 members) and processors and marketers having smaller ones (5 or fewer members). Education levels differ: many farmers have non-formal or secondary education, processors mainly primary or secondary, and marketers mostly secondary education, influencing their adoption of technologies and business approaches.

Membership in associations varies: 35% of farmers, 92.5% of processors, and 72.5% of marketers belong to groups, mainly to access inputs, credit, or support. Profitability satisfaction is highest among processors (95%), followed by marketers (67.5%), and lowest among farmers (52.5%), with challenges like transportation and market access affecting returns. Capital sources differ, with farmers relying more on savings, processors mainly on bank loans, and marketers using a mix of savings and loans. Experience is mostly moderate, with 4-6 years common across all groups, which enhances management and decision-making in cassava activities.

Level of Traditional or Improved Technologies Adopted by Respondents

Figure 1 shows that 72.5% of farmers rely on traditional cassava farming technologies, with only 27.5% adopting improved practices, mainly tractors. Adoption of other modern equipment is low due to high costs, lack of knowledge, and availability issues. Similarly, 67.5% of processors use traditional methods, while 32.5% adopt improved technologies like graters and pressers. Low adoption of equipment such as peelers and fryers is linked to cost, technical knowledge gaps, and limited extension services. In marketing, 75% of marketers use traditional methods, with only 25% adopting improved technologies, mostly internet use. Innovations like branded packaging and advanced transport remain uncommon, likely due to limited awareness and access, reflecting marketers' limited influence on production and processing technologies.

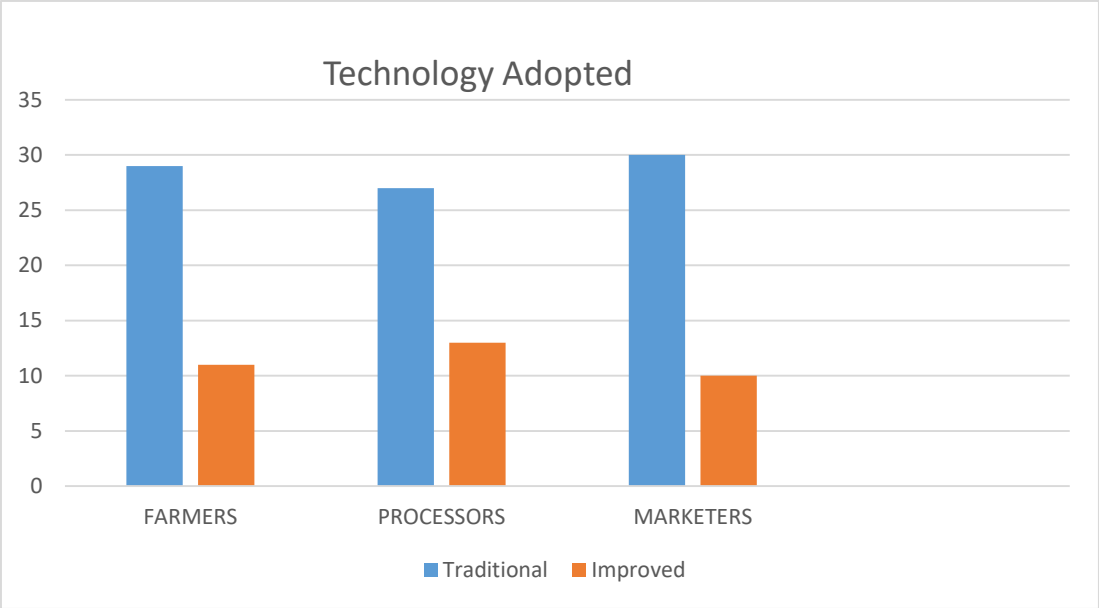


Figure 1: Level of Traditional or Improved Technologies Adopted by Respondents

Number of Technologies Adopted

Among cassava farmers, 11 have adopted tractor technology, while no adoption of planters or harvesters was reported, likely due to cost, accessibility, or suitability issues. Among processors, 13 adopted graters and pressers each, 7 adopted cutters, and 12 adopted pounders, but none have adopted fryer or peeler technologies. For marketers, 10 have adopted internet use for marketing, 2 use transportation technology, and none have adopted package logo technology, showing a preference for digital tools over packaging innovations.

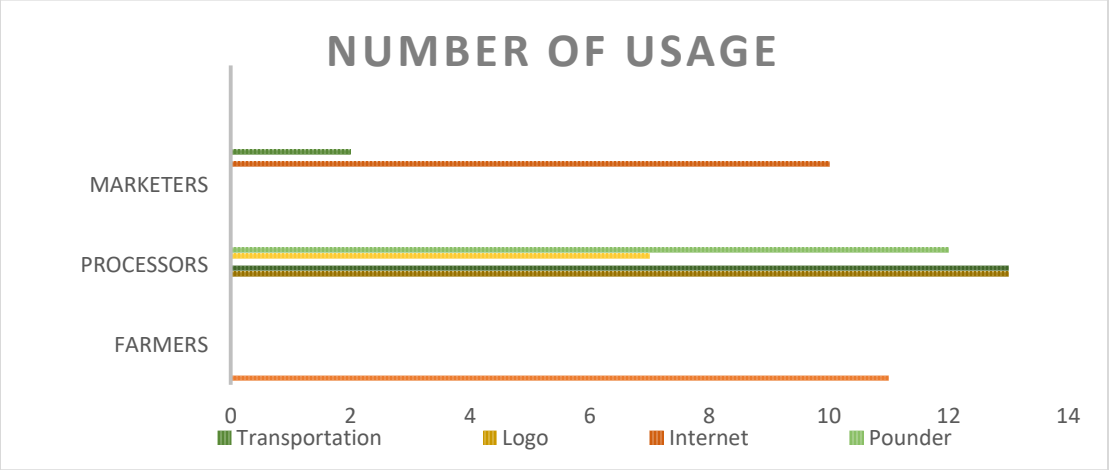


Figure 2: Number of Technologies Adopted.

Costs and Returns of Respondents

- Farmers in the study area earn an average gross margin of ₦1,020,000 per production season, with revenue covering their variable costs, indicating profitable cassava farming. Processors generate a gross margin of ₦60,000, also profitable but lower than farmers, while marketers earn the least with a gross margin of ₦20,000. This pattern differs from Donkor et al. (2022), where processors and marketers had higher profits. The difference is attributed to the small-scale nature of processors and marketers in this study, who lack economies of scale and rely on manual production, limiting their profitability. A gross margin of ₦1,020,000 means farmers retains this amount after covering variable costs associated with production. This suggests that the production is highly profitable on a variable cost basis.

- The gross margin ratio, expressed as a percentage of total revenue, can be calculated as:

Gross Margin Ratio = $\frac{₦1,020,000}{₦1,320,000} \times 100 = 77.27\%$

This indicates that about 77% of the revenue is available to cover fixed costs and contribute to net profit, which is a strong sign of profitability.

In summary, the farmers demonstrate strong profitability potential as the gross margin of ₦1,020,000 (77.27%) indicates efficient operations and good financial performance at the production and variable cost level. This positive margin is crucial for overall sustainability and growth in farming enterprises.

PRODUCTION

Net Return = GM-TFC

NR= 1,020,000 - 300,000

NR= 720000

Benefit Cost Ratio (BCR)= TR/TC

BCR=1320000 /300000

BCR=4.4

Table 1: Costs and Returns of Respondents

FARMERS		PROCESSORS		MARKETERS	
Variables	Amount(₦/ha)	Variables	Amount (₦)	Variables	Amount (₦)
Total revenue	1,320,000	Total revenue	150,000	Total revenue	90,000
Variable costs		Variable costs		Variable costs	
Cost of cassava cuttings	50,000	Cost of cassava	60,000	Cost of produce	41,500
Fertilizer	65,000	Cost of jacking/pressing	10,000	Cost of transportation	16,500
Herbicide	40,000	Cost of labour	15,000	Cost of packaging	5,000
Equipment	50,000	Transportation	5,000	Cost of labour	7,000
Transportation	45,000				
Cost of labour	50,000				
Total variable costs	300,000	Total variable costs	90,000	Total variable costs	70,000
Gross margin (GM) = TR – TVC					
GM =1,020,000		GM =60,000		GM =20,000	

Constraints Faced by Respondents along the Value Chain of Cassava

The study identified key constraints in the cassava value chain affecting farmers, processors, and marketers. Farmers face serious challenges with land availability or high rent, costly inputs, and lack of quality planting materials, along with poor storage, limited credit access, pests, low product prices, and high labor costs. For processors, major issues include high input and labor costs, poor storage, and limited credit, while land and pests are less problematic. Marketers mainly struggle with limited credit access, input and labor costs, and inadequate marketing facilities, with other constraints being less significant.

In conclusion, the value chain analysis reveals cassava farming is currently more profitable than processing and marketing, despite low adoption of improved technologies. Enhancing technology use among all actors could boost profitability, especially if farmers adopt improved practices more widely.

Recommendations include providing credit at lower interest rates to enable access to machinery and inputs, expanding agricultural extension services for training and technical support, and government-led programs to educate farmers on improved technologies. Processors should receive inputs at lower costs, while marketers should be encouraged to improve advertising, packaging, and online marketing. Additionally, government support is needed to improve infrastructure like roads and water supply and to implement policies favoring all cassava value chain stakeholders.

References

Amelework, A. B., Bairu, M. W., Maema, O., Venter, S. L., & Laing, M. (2021). Adoption and promotion of resilient crops for climate risk mitigation and import substitution: A case analysis of cassava for South African agriculture. *Frontiers in Sustainable Food Systems* 3(5), 617-783.

Donkor, E., Onakuse, S., Bogue, J., & de los Rios Carmenado, I. (2022). Income inequality and distribution patterns in the cassava value chain in the Oyo State, Nigeria: a gender perspective. *British Food Journal*, 124(13), 254-273.

Impact of Climate Change on Livestock Production, Animal Products Quality and Supply

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Abstract

The livestock industry is crucial to both food security and supply. Even though it plays an important role for humans, it is prone to climate variability and change. Climate change indicators, including global land and ocean temperature increases, rising sea levels, changes in the frequency and severity of extreme weather events such as hurricanes, heat waves, wildfires, droughts, floods, and precipitation, and vegetation cover changes, have a significant adverse impact on animal agriculture. For all categories of livestock, the most significant direct impact of climate change on livestock production comes from heat stress. Heat stress results in reduced production performance of animals, such as a decrease in milk production and composition, a decline in meat production and quality, a reduction in both external and internal qualities of eggs, impaired reproductive efficiency, and animal health risks. Climate change also indirectly affects livestock production by decreasing feedstuff and water availability. Climate change can also cause disruptions along the supply chain of animal products. Processing, storage, transport, retailing, consumption, labour, and pricing of livestock products can be negatively impacted by climate variability. These impacts threaten the ability of current livestock systems to support livelihoods and meet the increasing demand for livestock products.

Keywords: Climate change, Livestock production, Product quality, Supply

Introduction

The importance of livestock production cannot be overemphasized. Currently, the livestock industry is crucial to both food security and supply. With regional variations, livestock products such as meat, milk, and eggs account for 15% and 31% of the world's per capita supply of calories and protein, respectively (FAOSTAT, 2020). Livestock also offers a number of other benefits, such as draught power, transportation, nutrient provision for deficient soils, income generation and diversification, and financial capital, all of which enhance the general resilience and well-being of numerous communities (CIRAD, 2016). Climate change, which refers to any change in climate over time, due to natural variability or as a result of human activity (IPCC, 2007), can have a serious impact on animal agriculture. It is the most serious environmental threat that adversely affects agricultural productivity (Yohannes, 2016). Climate change will have an

impact on livestock's contributions to food security and other sustainability aspects, while it is unclear how much of an impact they will have overall (Godde et al., 2021). Climate change is very likely to affect food security at the global, regional, and local levels and can disrupt food availability, reduce access to food, and affect food quality (US EPA, 2023). High temperatures and climate variability adversely affect general health, feed intake and production performance of livestock. Livestock production systems, on the other hand significantly contribute to climate change through greenhouse gas emissions. Climate change has also been shown to play a role in the spatial and temporal distribution of pathogens and is expected to increase the risk of emerging zoonotic diseases (Owino et al., 2022). The distribution of food of animal origin can potentially be disrupted by an increase in the frequency and intensity of extreme weather events. As a result, food costs are predicted to rise in the future. Temperature increases also have the potential to cause contamination and spoilage. Any disruption in food distribution and transportation caused by climate change, whether it be domestically or internationally, might have a major effect on food access as well as safety and quality.

Causes and Effects of Climate Change

Climate change, can occur naturally, such as changes in the sun's activity or large volcanic eruptions or as a result of human activities which include burning of fossil fuels, deforestation and livestock production (Jackson, 2023). However, the influence of natural processes is too small or occurs too slowly to explain the rapid warming seen in recent decades (Turrentine, 2022). Changes observed in Earth's climate since the mid-20th century are known to be driven by human activities, particularly fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere, raising Earth's average surface temperature (NASA, 2023). Human-induced global warming is presently increasing at a rate of 0.2°C per decade (European Commission, 2023). It has been observed that the 20th century was the warmest of the past 10 centuries, and the decade 2011-2020 was the warmest decade recorded, with global average temperature reaching 1.1°C above pre-industrial levels in 2019 (European Commission, 2023; Jackson, 2023). Climate change has both direct and indirect effects on humans and the environment. Key indicators of climate change include global land and ocean temperature increases; rising sea levels; ice loss at Earth's poles and in mountain glaciers; frequency and severity changes in extreme weather such as hurricanes, heat waves, wildfires, droughts, floods, and precipitation; and cloud and vegetation cover changes (NASA, 2023). Indirectly, climate change causes an increase in hunger and water crises, especially in developing countries, threat to livelihoods from floods and forest fires, health risk due to increase in frequency and intensity of heat extremes, increased spread of pests and pathogens, loss of biodiversity due to limited

adaptability, and economic implications of dealing with secondary damage related to climate change (Myclimate, 2023)

Impact of Livestock Production on Climate Change

Over time, the Food and Agriculture Organization has observed a rise in the consumption of meat worldwide. In 2021, it was estimated that we consumed more meat than ever before. It is estimated that by 2050, this will result in a 60% rise in greenhouse gas emissions (GHG) from the animal food production sector (Giovetti, 2022). GHG emissions from livestock production contribute more GHG to the atmosphere than the entire global transportation sector (Chitra, 2021). According to Cheng et al. (2022), FAO Global Livestock Environmental Assessment Model (GLEAM) results indicate that emissions from livestock supply chains consist of 50% methane (CH_4), 24% nitrous oxide (N_2O), and 26% carbon dioxide (CO_2). In terms of species, cattle are the major contributor, with about 62% of total livestock emissions. Other species (hogs, poultry, buffaloes, and small ruminants) each represent between 7 and 11% of the sector's emissions. 39% of the emissions from the livestock industry come from enteric fermentation, which is a normal part of the digestive process for many ruminant animals (Chitra, 2021). Manure storage (10%), and feed production and processing (45%) are two more major sources of emissions. Processing and transportation of livestock products is responsible for the remaining 6% of greenhouse gas emissions. 9.2% of all livestock greenhouse gas emissions are attributable to changes in land use, of which 6% and 3.2% are attributable to the expansion of pastures and feed crops, respectively (Cheng et al., 2022; Chitra, 2021). Elevated levels of these gases may be attributed to reduced livestock system productivity and efficiency as a result of excessive loss of energy, nutrients and organic matter (Gerber *et al*., 2013). Deforestation, cultivated soils, and land degradation due to livestock production are the main sources of CO_2 emissions (Chitra, 2021). Methane and nitrous oxide are released by livestock manure. Methane is released during the anaerobic breakdown of the organic materials in manure. Nitrous oxide emissions are typically increased by the use of fertilizer, atmospheric nitrogen deposition, and agricultural nitrogen fixation. Giovetti (2022) noted that even though methane has a shorter shelf-life than carbon dioxide, it's much more damaging when it comes to warming the atmosphere.

Impact of Climate Change on Animal Production and Product Quality

Climate change is regarded as a major threat to the sustainability of livestock systems globally (Sejian et al., 2016). The difficulty facing livestock is weather extremes such as intense heat waves, floods and droughts. In addition to production losses, extreme events also result in livestock death (Gaughan & Cawsell-Smith, 2015). Climate change is also known to influence water demand, availability and quality of water (Sejian et al., 2016). Climate change can result in a higher intensity precipitation that leads to

greater peak run-offs and less groundwater recharge. Longer dry periods may reduce groundwater recharge, reduce river flow and ultimately affect water availability, agriculture and drinking water supply. The deprivation of water affects animal physiological homeostasis, leading to loss of body weight, low reproductive rates and decreased resistance to diseases (Naqvi et al., 2015). Climate impacts directly or indirectly on livestock production (Cheng et al., 2022). Direct effects refer to climate change impacts on livestock thermoregulation, metabolism, immune system function, and production. Indirect effects derive from the influence of climate on feed production, water availability, and pest/pathogen populations. Wells (2021) observed that African poultry production is at risk of indirect climate change aspects that will impact feed ingredient availability and quality for poultry, particularly for the commercial poultry industry, since arid and semi-arid regions experiencing increasing temperatures, low rainfall, and irregular rainfall patterns cannot produce the bountiful harvests needed to stave off rising feed prices.

Nwosu and Ogbu (2011) affirmed that poor performance of tropical breeds is an adaptation to the harsh environmental conditions such as scarce feed resources, poor forage quality, the challenge of pests and diseases, hot, humid and dry conditions, variable rainfall pattern, poor soil quality and land degradation. Various factors of the environment, such as the average temperature, humidity and air velocity all play an important role in the physiology and metabolism of farm animals (Babinszky et al., 2011). However, heat stress caused by exposure to high ambient temperature have negative effects on livestock. Heat stress occurs when animals are not able to dissipate sufficient heat to keep homeothermy (Daramola et al., 2012) and limits the capacity of livestock to shed heat to their environment, on farm or during transportation (Godde et al*.,* 2021). It has been found to lead to increased respiration, pulse, and heart rate, along with increased body temperatures (Rashamol et al., 2018). In turn, this can result in reduced feed intake, production performance and reproduction efficiency, as well as changes in mortality and immune system functions. Vulnerability to heat stress varies according to species, breed, life stage, genetic potential, nutritional status, size, level of insulation (hide thickness or distribution of feathers) and previous exposure of the animal, with animals with high energy demands (high-yielding individuals and breeds) most susceptible (Godde et al., 2021).

In beef cattle production, heat stress causes slower growth and lower slaughter weights, which have an impact on the quality of the meat, as animals with similar age but smaller body weights have lower muscle fat and poor sensory attributes such as juiciness and tenderness (Babinszky et al., 2011). Heat stress has been found to impact the quality of animal products which include reduction in the size of eggs and thickness of eggshells (Mashaly et al., 2004), decreasing milk yield, fat and protein content of milk in cattle, sheep and goats (Babinszky et al.,2011; Biswal et al., 2021), reduced carcass fatness in pigs (Noblet et al.,

2001) and changing the colour and water-holding capacity of both red and white meat (Gonzalez-Rivas et al., 2020). These deviations can make livestock products less appealing to customers, increase wastage, and reduce the price that producers receive for their products.

Effect of Climate Change on the Supply of Animal Products

According to Godde et al. (2021), the supply chain for livestock products is highly concentrated and coordinated, and disruptions anywhere along the supply chain can have impacts throughout the chain. Under climate change, processing, storage, transport, retailing, consumption, labour and pricing of livestock products can be negatively impacted. Climate change, in particular temperature increases and disruptions caused by the climate to the transportation network, may increase the risk of heat stress during livestock transportation, which can lead to poor animal welfare and animal deaths (Caulfield et al., 2014; Collins et al., 2018). Built-up capital such as machinery, transportation infrastructure, electricity networks, and telecommunications, is subjected to additional stress due to rising temperatures, increased humidity, and an increase in the frequency of extreme weather events (Godde et al., 2021). Degradation and damage of vital transportation infrastructure, such as ports, railroads, and roadways (Markolf et al., 2019) can have adverse effect on livestock industry. The supply of animal products may be seriously threatened if excessive flooding destroys roads. Furthermore**,** a rise in temperature deteriorates storage conditions, leading to food quality and shelf-life degradation, increased food waste, and a higher chance of microbial and fungal growth, particularly in humid environments (van der Spiegel et al., 2012). Also, energy usage and costs will increase if climate control measures like refrigeration and air-conditioning are used to maintain the necessary shelf life of animal products. Globally, the use of refrigeration is low, especially in low and middle income countries (LMIC) situated in hot environments which has witnessed high increases in consumption of livestock products recently. This has led to wastage of perishable food (Godde et al., 2021).

Climate change can reduce the availability of livestock products, as well as their quality and safety through contamination with pathogens or pesticides and reduced nutritional quality and sensory appeal. Prices may increase and be more volatile (Godde et al., 2021). In terms of labour, climate change is expected to have a negative effect on labour availability and productivity because of heat stress, an increased risk of disease outbreaks, and extreme weather events like heat waves, floods, and severe storms (Caminade et al., 2019; International Labour Organization, 2019; Walsh et al., 2018). According to McIntyre et al. (2017), populations that have close contact with livestock and wildlife are more vulnerable to zoonotic pathogens. The risk of zoonosis is also increased by climate change. Along the supply chain, commodity price and price volatility are likely to increase under climate change. The impacts of climate change on animal

product prices could be felt mainly through changes in costs and availability of feed (Godde et al., 2021). All these have adverse effect on availability and consumption of animal products.

Conclusion

Climate change poses significant challenges to global livestock production and the supply of animal products, contributing to harsh environmental condition and poor animal welfare. The resulting effect manifests as low productivity and economic losses. Improving feed quality, implementing climate-resilient breeding programs, improving livestock management, and supporting smallholder farmers can help mitigate these impacts. Policy makers, farmers, and stakeholders must work together to develop and implement effective adaptation and mitigation strategies, ensuring the long-term sustainability of livestock production and food security in a changing climate. Further research on GHG emissions from livestock production industries and vulnerability of animal product supply chain to climate change is necessary.

References

Babinszky, L., Halas, V. & Verstegen, M.W.A. (2011). Impacts of climate change on animal production and quality of animal food products. In: climate change – socioeconomic effects. Editor: Dr Houshan Kheradmand. In Tech., pp 165-190.

Biswal, J., Vijayalakshmy, K. & Rahman.H. (2021). Impact of climate change on small ruminants' production: A Review. *Approaches in Poultry, Dairy & Veterinary Sciences*, 8(1), 751-756. DOI: 10.31031/APDV.2021.08.000680

Caminade, C., McIntyre, K.M. & Jones, A.E. (2019). Impact of recent and future climate change on vector-borne diseases. *Annals of the New York Academy of Sciences*, 1436, 157–173. https://doi.org/10.1111/nyas.13950.

Caulfield, M.P., Cambridge, H., Foster, S.F. & McGreevy, P.D. (2014). Heat stress: a major contributor to poor animal welfare associated with long-haul live export voyages. *Veterinary Journal*, 199, 223–228. https://doi.org/10.1016/j.tvjl.2013.09.018.

Cheng, M., McCarl, B. & Fei, C. (2022). Climate change and livestock production: a literature review. *Atmosphere,* 13, 140. https://doi.org/10.3390/atmos13010140

Chitra, P. (2021). Impact of climate change on livestock farming. *E-pashupalan,* (7)2, 34-37

CIRAD (2016). Livestock farming & local development. CIRAD, Montpellier.

Collins, T., Hampton, J.O. & Barnes A.L. (2018). A systematic review of heat load in Australian livestock transported by sea. *Animals,* 8, 164. https://doi.org/10.3390/ ani8100164.

Daramola, J.O.; Abioja, M.O. & Onagbesan, O.M. (2012). Heat stress impact on livestock production. In environmental stress and amelioration in livestock production; Sejian, V., Naqvi, S.M.K., Ezeji, T., Lakritz, J., Lal, R., Eds.; Springer: Berlin/Heidelberg, Germany; pp. 53–73.

European Commission (2023). https://climate.ec.europa.eu/climate-change/causes-climate-change_en

FAOSTAT (2020). Statistical yearbook, world food and agriculture 2020. http://www.fao.org/faostat/en/.

Gaughan, J. B & Cawsell-Smith, A. J. (2015). Impact of climate change on livestock production and reproduction. In: climate change impact on livestock: adaptation and mitigation. Sejian, V., Gaughan, J., Baumgard, L., Prasad, C.S (Eds), Springer-Verlag GMbH Publisher, New Delhi, India, pp 51-60.

Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G. (2013).Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities. https://www.cabdirect.org/cabdirect/abstract/20133417883

Giovetti, O. (2022). The human activities that cause climate change and the human necessities climate change affects. *Concern Worldwide.* https://www.concern.net/news/human-activities-that-cause-climate-change

Godde, C.M., Mason-D'Croz, D., Mayberry,D.E., Thornton,P.A. & Herrero, M. (2021). Impacts of climate change on the livestock food supply chain; a review of the evidence. *Global Food Security 28, 100488.* Doi:10.1016/j.gfs.2020.100488.

Gonzalez-Rivas, P.A., Chauhan, S.S., Ha, M., Fegan, N., Dunshea, F.R. & Warner, R.D. (2020). Effects of heat stress on animal physiology, metabolism, and meat quality: a review. *Meat Sci*ence, 162, 108025. https://doi.org/10.1016/j.meatsci.2019.108025.

International Labour Organization (2019). Working on a warmer planet: the impact of heat stress on labour productivity and decent work. Geneva. https://www.ilo.org/ global/publications/books/WCMS_711919/lang–en/index.htm.

IPCC (2007). Climate Change 2007, the fourth assessment report. Impacts, Adaptation and Vulnerability. Intergovernmental Panel for Climate Change. https://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_ report_impacts_adaptation_and_vulnerability.htm

Jackson, S.T. (2023). Climate change. Britannica. https://www.britannica.com/science/climate-change

Markolf, S.A., Hoehne, C., Fraser, A., Chester, M.V. & Underwood, B.S. (2019). Transportation resilience to climate change and extreme weather events – beyond risk and robustness. *Transport Policy*, 74: 174–186. https://doi.org/10.1016/j. tranpol.2018.11.003.

Mashaly, M.M., Hendricks, G.L., Kalama, M.A., Gehad, A.E., Abbas, A.O. & Patterson, P.H., (2004). Effect of heat stress on production parameters and immune responses of commercial laying hens. *Poultry Science*, 83: 889–894. https://doi.org/10.1093/ps/ 83.6.889.

McIntyre, K.M., Setzkorn, C., Hepworth, P.J., Morand, S., Morse, A.P. & Baylis, M. (2017). Systematic assessment of the climate sensitivity of important human and domestic animals' pathogens in Europe. *Scientific Reports,* 7: 1–10. https://doi.org/10.1038/s41598- 017-06948-9.

Myclimate.org (2023). https://www.myclimate.org/en/information/faq/faq-detail/what-are-the-effects-of-climate-change/

NASA (2023). What is climate change? National Aeronautics and Space Administration. https://climate.nasa.gov/what-is-climate-change

Noblet, J., Le Dividich, J. & van Milgen, J. (2001). Thermal environment and swine nutrition, In: *Swine Nutrition*, A.J. Lewis & L.L. Southern (Eds), pp. 519-544, CRC Press, ISBN: 0-8493-0696-5, Boca Raton, Florida, US.

Nwosu, C.C & Ogbu, C. C. (2011). Climate change and livestock concern in Nigeria: issues and concerns. *Journal of Tropical Agriculture, Food, Environment and Extension,* 10(1), 41-60.

Owino, V., Kumwenda, C., Ekesa, B., Parker, M.E., Ewoldt, L.,Roos, N., Lee, W.T. & Tome, D. (2022). The impact of climate change on food systems, diet quality, nutrition, and health outcomes: a narrative review. https://www.frontiersin.org/articles/10.3389/fclim.2022.941842/full

Rashamol, V.P.; Sejian, V.; Bagath, M.; Krishnan, G.; Archana, P.R. & Bhatta, R. (2018). Physiological adaptability of livestock to heat stress: An updated review. *Periodikos.* http://www.jabbnet.com/journal/jabbnet/article/doi/10.31893/2318-1265jabb.v6n3p62-71

Sejian, V., Gaughan, J. B., Raghavendra Bhatta & Naqvi, S. M. K. (2016). Impact of climate change on livestock productivity. Feedipedia. https://www.feedipedia.org/content/impact-climate-change-livestock-productivity

Turrentine, J. (2022). What are the causes of climate change? https://www.nrdc.org/stories/what-are-causes-climate-change#natural

US EPA (2023). Climate impacts on agriculture and food supply. United States Environmental Protection Agency. https://climatechange.chicago.gov/climate-impacts/climate-impacts-agriculture-and-food-supply#main-content

van der Spiegel, M., van der Fels-Klerx, H.J. & Marvin, H.J.P.(2012). Effects of climate change on food safety hazards in the dairy production chain. *Food Research Int*ernational 46, 201–208. https://doi.org/10.1016/j.foodres.2011.12.011

Walsh, M.G., De Smalen, A.W. & Mor, S.M. (2018). Climatic influence on anthrax suitability in warming northern latitudes. *Scientific Reports*, 8: 9269. https://doi.org/10.1038/s41598- 018-27604-w.

Wells, J. (2021). Poultry production in Africa, impacts of climate change. http://extension.msstate.edu/publications/poultry-production-africa-impacts-climate-change

Yohannes, H. (2016). A review on relationship between climate change and agriculture. *Journal of Earth Science and Climate Change,* 7(2)

The Evaluation of some Selected Sweet Potato Varieties Grown at National Root Crops Research Institute Umudike, for Cooking Time and Colour.

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Abstract

Sweet potato, botanically known as *Ipomoea batatas,* is a tuberous vegetable with diverse varieties, including white-fleshed, orange-fleshed, cream-fleshed, and purple-fleshed. Twelve samples of sweet potato, including orange-fleshed, purple-coloured, and white-coloured varieties, were sourced from the National Root Crops Research Institute's sweet potato farm in Umudike. They were peeled, washed, and prepared for colour evaluation and cooking time. The samples were diced uniformly, and a known weight of each was boiled. The fresh tubers were used for colour determination using a chromameter to assess the colour range. Results indicated that cooking times ranged from 10 to 25 minutes, with the sample Po3/11, Cri-dadajue, and others having the lowest, highest, and intermediate cooking times, respectively. This suggests variations in nutrient retention. The L, a, and b values ranged from 44.20 to 85.14, -24.00 to 25.50, and -5.51 to 46.22, respectively. Differences in cooking times and colour ranges may provide better options for selection in various food formulations.

Keywords: sweet potato, cooking time, colour, production, food processing.

Introduction

Sweet potatoes (*Ipomoea batatas*) play a vital role in global food security, valued for their resilience, nutritional content, and versatility. As a staple crop in many developing regions, including Nigeria, breeding programmes at institutions like the National Root Crops Research Institute (NRCRI) focus on developing improved varieties that not only deliver high yields and resistance to diseases but also feature desirable culinary qualities. Among these qualities, cooking time and flesh colour are particularly important for both consumer acceptance and food processing. A sweet potato's culinary attractiveness is greatly influenced by how long it takes to cook. It has an impact on residential energy use and plays a crucial role in industrial processing Truong et al., 2018.

Research has demonstrated that cooking time depends on the variety and the tuber's physicochemical properties, especially dry matter content and the composition and structure of starch granules (Bhandari & Kaur, 2020). For example, varieties with higher amylose content tend to have a firmer texture and may

require longer cooking times. Adeyemo et al. (2022) stated that the cooking characteristics of new sweet potato genotypes are vital for their acceptance by local communities. The nutritional profile of the tuber is reflected in; energy content, the flesh color which is more than just an attractive characteristic contains other nutrients such as protein, vitamins etc.

High quantities of beta-carotene, a precursor to vitamin A that is vital for immune and visual health, give many sweet potato cultivars their vibrant orange color. (Kim et al., 2021). Similarly, purple-fleshed varieties are rich in anthocyanins, potent antioxidants associated with reduced inflammation and protection against chronic illnesses (Li *et al*., 2023). A comprehensive assessment of flesh colour, therefore, offers valuable insights into the potential health benefits of different cultivars.

This research aims to systematically evaluate a selection of sweet potato varieties developed and grown at NRCRI, focusing on the interconnected traits of cooking time and flesh colour. The objective of this study is to provide crucial data for sweet potato breeders, assisting them in selecting parent lines for future crosses that combine optimal nutritional value with consumer-friendly cooking qualities. Furthermore, this work aims to inform farmers about the characteristics of available varieties and enable consumers to make informed choices that align with their culinary preferences and health objectives.

Methodology

Sweet potato was collected from the sweet potato farm of the National Root Crops Research Institute Umudike. The colorimeter was used to check the colour range using the fresh root, while the cooking time of the samples was checked by boiling a known weight of diced in a uniform shape.

Result and Discussion

Table 1 shows the color parameters (L*, a*, b*) of some selected sweet potato varieties. The L* (lightness) values range from 44.20 (TU PURPLE) to 85.14 (TIS87/100). Cri dadanjuie (83.40), PG17/305-14 (82.95) and POS/11 (75.20) are significantly different from the rest of the genotypes. Lighter L* values indicate lighter colour, while lower values show darker shades. TIS87/100 has the highest value, making it the variety with the lightest colour, while TU PURPLE has the lowest L* value. This implies that it is the darkest in terms of lightness.

Table 1: Colour of Newly Bred Sweet Potato Harvested at Pyt

Samples	L	A	B
Alisha	71.96^{de} ±1.47	7.44^{c}±2.04	36.69cd ± 0.95
Benjamin	64.34^{g} ±0.18	25.50^{a} ±1.24	47.16^{a} ±0.83
Cri dadanjuie	83.40^{ab}±0.71	0.00^{d} ±1.75	14.39^{ef}±0.99
Victoria	64.54^{f}±2.78	24.71^{ab}±1.04	46.22^{ab}±0.77
Bita	78.23^{bc}±5.58	0.38^{d}±3.58	15.99^{ef}±4.04
PG17/305-NI	82.95^{ab}±0.87	-24.00^{e}±0.00	13.55^{ef}±3.71
PO3/87	75.17^{cd}±0.63	1.16^{d}±0.98	18.13^{e}±3.71
IRENE	75.20^{cd}±0.53	5.53^{c}±0.73	43.37^{bc}±0.33
POS/11	75.20^{ab}±0.53	8.66^{c}±0.00	39.46^{cd}±2.93
UMUSPO1	66.52^{ef}±4.07	21.01^{b}±2.56	34.21^{d}±5.18
TIS87/100	85.14^{a}±3.04	-0.03^{d}±0.13	10.01^{f}±0.83
TU PURPLE	44.20^{h}±2.61	22.94^{ab}±2.71	-5.51^{g}±3.58

The a* values, which represent the positive red hue and negative green hue, range from 25.50 (Benjamin) to -24.00 (PG17/305-14). The highest positive value indicates a strong reddish tone, while the lowest negative value indicates a strong green value. There is no significant difference between genotypes Alisha, Irene and POS/11. The same applies to genotypes Cri dadanjuie, Bita, PO3/87 and TIS87/100.

Positive b* values represent yellow tones and negative values represent blue tones. Benjamin (47.16) has the highest positive b* value, signifying a strong yellow tone, while TU PURPLE (-5.51) is the only genotype with a negative value, signifying a blue tone. There are significant differences among the genotypes except for Cri dadanjuie, Bita, PG17/305-14 and Alisha, POS/11.

Generally, genotypes like Cri dadanjuie, TIS87/100, PO3/87 and Bita have very high L*, low a*, and moderate b* values. This balanced colouration may enhance their visual appeal and marketability. Variations in color parameters among the varieties shows breeding programs' success in establishing potato cultivars that cater for various consumer preferences and market demands.

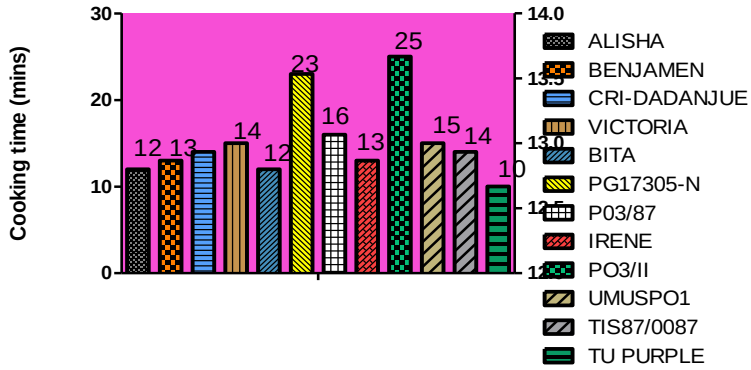


Fig 1: Cooking time of sweet potato at PYT

Figure 1 presents the cooking time of different sweet potato (*Ipomoea batatas*) varieties. Cooking time is an essential trait for both consumer preference and industrial processing efficiency. The cooking time, measured in minutes, varied significantly among the varieties, indicating differences in their physicochemical properties such as texture composition, etc.). The values range from 10 minutes to 25 minutes. Sample Tu purple had the shortest cooking time, at 10 minutes, making it a potentially desirable variety for quick cooking. The longest cooking time is observed in BITA (25 minutes), and PG17305-N (23 minutes), suggesting higher dry matter content, which affects the cooking duration in that it takes a longer time for the heat to penetrate the sample. Other parameters that can affect cooking time are starch composition, fiber content, and cellular structure (Low et al., 2009). The amylose-to-amylopectin ratio affects the cooking time. Varieties with higher amylose content require longer cooking due to slower starch gelatinisation (Zhang et al., 2020). Varieties like BITA and PG17305-N (long cooking times) may contain more amylose, while TU PURPLE and ALISHA (shorter cooking times) may have more amylopectin, which makes them to soften faster. Consumers prefer varieties that cook faster for convenience, to save time and fuel (Bovell-Benjamin, 2007). Short-cooking varieties like TU PURPLE and ALISHA may be ideal for direct boiling and steaming. These factors determine the suitability of each variety for different culinary and industrial applications. Short-cooking varieties like TU PURPLE may be ideal for household consumption, while longer-cooking varieties like PG17305-N may be better for industrial processing. Also, research shows that cooking time influences the retention of some Nutrients such as Vitamin C and beta

carotene, and extended boiling, can cause greater nutrient loss, making quick-cooking varieties potentially more nutritious when boiled (Tian et al., 2016). Understanding the differences in cooking time will assist breeders, food industries, and consumers in choosing the most suitable varieties for various uses.

Conclusion

In conclusion, the study may indicate that the sweet potatoes evaluated have a short cooking time, except for the varieties PG17305-N and Bita, which have longer cooking times. Shorter cooking time is an important quality for nutrient retention, and the colour variation observed among the evaluated varieties adds to the diversification of value-added products.

References

Adeyemo, T. E., Alamu, O. F., & Popoola, A. A. (2022). Evaluation of cooking characteristics and sensory properties of new sweet potato genotypes in Nigeria. Nigerian Journal of Food Science and Technology, 40(1), 1-10.

Bhandari, S., & Kaur, P. (2020). Impact of cooking on the textural properties and starch digestibility of different sweet potato varieties. Journal of Food Science and Technology, 57(9), 3327-3335.

Kim, S., Kwak, C. S., & Lee, M. S. (2021). Orange-fleshed sweet potatoes as a source of provitamin A carotenoids: A review of their nutritional composition and health benefits. Journal of Functional Foods, 87, 104770.

Li, Y., Wu, B., Li, X., et al. (2023). Anthocyanin composition and antioxidant activity of purple sweet potato varieties: A comparative study. Food Chemistry, 404, 134661.

Low, J., Lynam, J., Lemaga, B., Crissman, C., Barker, I., Thiele, G., & Ortiz, O. (2009). Sweet potato in sub-Saharan Africa. *African Journal of Food, Agriculture, Nutrition and Development, 9(2)*, 1-12.

Truong, V. D., Avula, R. Y., Pecota, K. V., & Yencho, G. C. (2018). Sweetpotato production, processing, and nutritional quality. *Handbook of vegetables and vegetable processing*, 811-838.

Zhang, P., Whistler, R. L., BeMiller, J. N., & Hamaker, B. R. (2020). Banana starch: Composition, structure, properties, and digestibility: a review. *Carbohydrate Polymers, 247*, 116578.

Efficacy of *Dennettia tripetala* and Carbonized Coconut Endocarp Powders as Grain Protectants against *Sitophilus zeamais i*n Stored Maize

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Abstract

Postharvest losses due to insect infestations remain a major constraint to maize storage in sub-Saharan Africa. Synthetic insecticides, though effective, are increasingly associated with environmental hazards, resistance development, and food safety concerns, hence necessitating the use of botanicals against synthetic insecticides. This study investigated the insecticidal efficacy of *Dennettia tripetala* (pepper fruit) powder and carbonized coconut endocarp powders individually, against *Sitophilus zeamais* Motschulsky in stored maize. Maize grains were treated with different concentrations of the powders at a dosage rate of 0.5,1.0, and 1.5g/50g of undamaged, clean and insect susceptible maize grains with three replicates for each dosage corresponding to 1%, 2% and 3% w/w respectively. Parameters such as adult mortality, and F_1 progeny emergence were assessed. The dosage-mortality effect of *D. tripetala* and carbonized coconut endocarp powders were investigated using Statistical Analysis System software. Results showed significant mortality rates in treatments compared to the control, with 90% weevil mortality for *D. tripetala* and 100% weevil mortality for carbonized coconut endocarp powders at dosage level of 0.5g/50g of maize grain at day seven (7) and fourteen (14) respectively. Mortality of adult insect increases in *D. tripetala* as the exposure period to the powders and concentration of the powders increased but not same with carbonized coconut endocarp powders. Adult emergence was also considerably suppressed in treated grains, indicating a strong potential for these natural materials as grain protectants. The findings highlight the promise of eco-friendly, locally available botanical and organic residues in integrated pest management strategies for sustainable maize storage.

Keywords: Emergence, Insecticidal, Maize grains, Mortality, Weevil.

Introduction

Maize (*Zea mays* L.) is a vital staple crop in sub-Saharan Africa, serving as a primary source of food and income for millions. However, its post-harvest preservation is severely threatened by insect pests, particularly the maize weevil *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) which causes significant quantitative and qualitative losses during storage (FAO, 2021). This insect pest is notorious for its destructive activities during storage, leading to reduced grain weight, germination ability, and market value. Reliance on synthetic insecticides has been widely used for pest control; however, issues such as insect resistance, chemical residues, high cost, and environmental hazards have prompted increased interest in alternative pest management strategies (Lale & Mustapha, 2000)

Consequently, there is a growing interest in exploring eco-friendly, biodegradable alternatives derived from plant-based materials. Among the promising botanical candidates are *Denettia tripetala*, commonly known as pepper fruit, is traditionally used in Nigeria for medicinal and culinary purposes, and has been found to possess insecticidal, repellent, antimicrobial, anti-ovipositional and antioxidant properties (Udo & Epidi, 2009; Emeasor *et al.*, 2017, Okonkwo & Okoye, 2020). Its efficacy against storage pests is attributed to bioactive compounds such as alkaloids, flavonoids, and essential oils (Ogunleye et al., 2017).

Similarly, carbonized agricultural waste like endocarp of coconut, is gaining recognition for its insecticidal action due to its abrasive texture and possible insecticidal effects (Oladejo, 2019). Charcoal-based dusts are locally available, non-toxic to humans, and compatible with traditional grain handling practices, making them suitable for use in smallholder storage systems.

This study was therefore conducted to evaluate and compare the effectiveness of *Denettia tripetala* and carbonized coconut endocarps powders in controlling *Sitophilus zeamais* infestation in stored maize with emphasis on adult insect mortality and progeny suppression. The findings are expected to contribute to **Experimental site:** The laboratory bioassay was carried out in the Entomology Laboratory of the Nigerian the development of sustainable and locally adapted stored product pest control measures.

Methodology

Stored Products Research Institute (NSPRI), Headquarters, Ilorin, Kwara State, Nigeria.

Collection and Processing of Coconut Endocarps and *Dennettia tripetala* Seeds

Coconut endocarps were gathered from coconut sellers at mandate market, Ilorin. The endocarps (husk) were washed under tap running water to remove dirt and thereafter dried for 14 days, burned to obtain coconut charcoal also known as carbonized charcoal. The *D. tripetala* was purchased at Eku-market in the

southern Delta region of Nigeria. It was washed with tap running water and dried at room temperature for 30 days, thereafter, the fruit (exocarp) was removed. The charcoal from coconut husk and the Denettia seeds were pulverized to fine powder (150µm) using Bletec 12 U.S. Industrial blender model to obtain carbonized coconut endocarps and *D. tripetala* seed powders (CCEP and DtSP). The powders were then stored separately in an airtight container before use.

Source of Grain: Maize (Yellow-testa) was used for the experiment. It was obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Prior to use, the grains were sterilized by cold shocking for seven (7) days to ensure elimination of residual insect infestation from the field. Thereafter, they were removed from the refrigerator and air dry to safe moisture content (SMC) of 13%.

Insect Culture: *Sitophilus zeamais*, was obtained from the insectary of the Nigerian Stored Product Research Institute, Ilorin. New culture was prepared from an existing stock and maintained at 30±1°C and 70±4% relative humidity, as described by Nwaubani *et al.* (2014). Only adult insects aged 1 – 3 days were used for the study.

Laboratory Bioassay

Dennettia tripetala Seed *P*owder (DtSP) and Carbonized Coconut Endorcap Powder (CCEP) were differently tested against *S. zeamais* at three dosages, 0.5, 1.0 and 1.5g/50g of grain. The dosages were administered to undamaged and clean maize grain inside a cylindrical plastic vial measuring 7.5 x 7.5 x 5.5 cm, respectively. The vial was manually shaken for approximately 1 minute to ensure proper coating of the treatment with the grain and twenty (20) 1 – 3 days old, unsexed adult insects were introduced into each vial. Also, 50g of maize was weighed into a different vial which served as control (i.e, grain without treatment) and twenty 1- to 3-day old, unsexed adult insects were introduced. Each vial was covered with muslin cloth before placing the cap cover having a central 2.5 cm hole for aeration. The treated and the control maize grain were replicated three times and the experimental set up was laid out in completely randomized design on laboratory bench. Mortality data were taken at 7 and 14-days post treatments. Weevils were considered to be dead when they failed to respond to pin probe. Data on percentage adult mortality was calculated as described by Zinhoum et al., (2023).

$$\%\,\boldsymbol{Mortality} = \frac{Number\,of\;Dead\,Insects}{Total\,Number\,of\,Insects} X100$$

After fourteen (14) days of treatment exposure, both live and dead insects were sieved out and discarded. Treated grains were then returned into each vials and observed for F_1 adult emergence at day 35±2 (Zinhoum *et al.*, 2023)

Data Analysis

Mortality data for 7 and 14days exposure periods were calculated using Statistical Analysis System software (SAS Institute, 2013). All the tests were performed with three independent replicates, and the data was expressed as percentage and mean values. New Duncan's Multiple Range Test (Zar, 1984) was used to determine the effects of treatments and exposure interval on adult insect mortality.

Result and Discussion

Mortality Effect with Respect to *Dennettia tripetala* Seed Powder: The bar chart in figure 1 compares the number of live and dead insects across different *D. tripetala* treatment dosages (0.5g, 1.0g, 1.5g) and a control, assessed on days 7 and 14. The result shows that at day 7 for 0.5g, about 10% of insects survived while at day 14, all insects were dead. This shows that there was moderate efficacy at first, but 100% mortality was achieved by day 14. Also, at dosage 1.0g and 1.5g for day 7 and 14, 100% mortality was achieved. This indicates that the higher the dosages, the more effective the *Denettia* powder, causing complete insect mortality as early as day 7. However, for the control, all the insects were alive. The dose-dependent effect confirms *Denettia's* potential as a natural insecticide for stored grain protection.

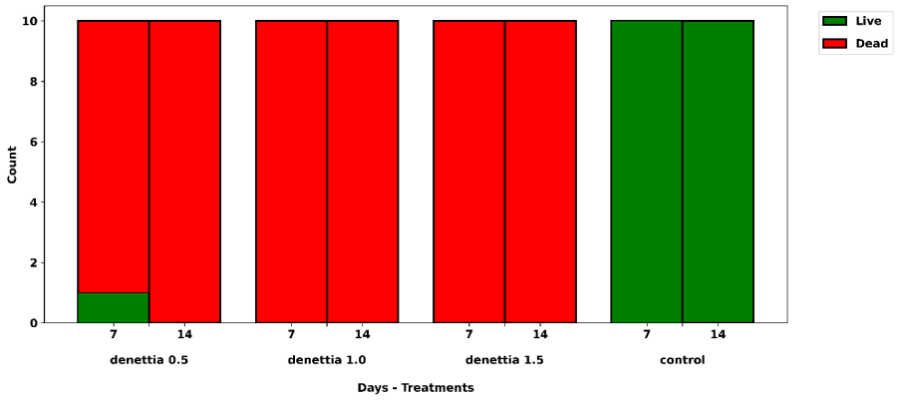


Figure 1. Effect of D. tripetella powder against *S. zeamais* at 7 and 14 days post-treatment

Mortality Effect with Respect to Carbonized Coconut Endocarp Powder: The bar chart in figure 2, presents the mortality of insects exposed to carbonized coconut endocarp powder (charcoal) at 0.5g, 1.0g, and 1.5g dosages at 7 and 14 days, compared with an untreated grain (control). At days 7 and 14, for 0.5g & 1.0g, 100% insect mortality was observed. At dosage of 1.5g, for day 7, minor survival (10%) was observed, while at day 14, 100% insect mortality was achieved. This indicates that, there was a brief

survival period at day 7, but complete insect mortality was achieved at day 14. However, for the control for day 7 and 14, all insects survived, confirming that mortality was caused by the carbonized coconut endocarp powder (charcoal) treatment, not external factors.

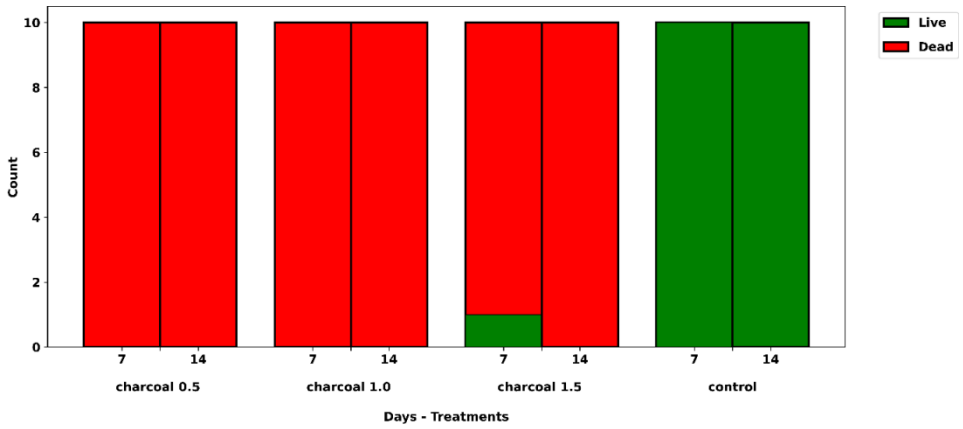
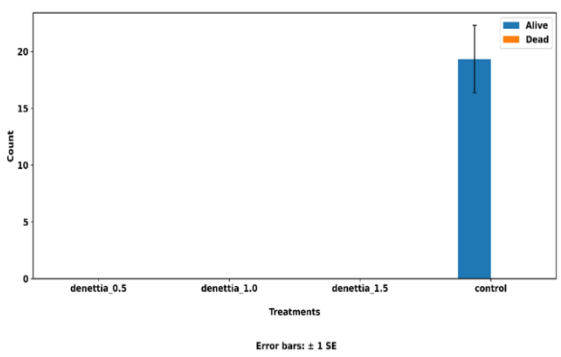


Figure 2. Effect of carbonized coconut endocarp powder against *S. zeamais* at 7 and 14 days post-treatment

In the study, the observed high insect mortality associated with *D. tripetala* and carbonized coconut endocarp powder (charcoal) aligns with the findings from previous research on botanicals and biochar used in stored product protection (Udo and Epidi 2009; Okonkwo & Okoye, 2020; Oladejo et al., 2019). Similarly, Ogunleye *et al.* (2017) found that *D. tripetala* fruit powders caused over 85% mortality in *Sitophilus zeamais* within 7 days of exposure, which corroborates the high efficacy observed in the present study, especially at higher dosages.

The effectiveness of carbonized coconut endocarp powders (charcoal) was also in tandem with the work of Kweyuh (1992) whose report shows that charcoal dust acted as a physical barrier that blocked spiracles and disrupted insect respiration, leading to mortality. Furthermore, from the result, it was observed that both treatment (*D. tripetalla* and carbonized coconut endocarp powders) significantly hinder F1 emergence as shown in Figure 3 and 4. This is similar to the findings of Udo and Epidi (2009), who used extracts from *D. tripetala* to control cowpea weevil and the result shows that it significantly reduced oviposition and adult emergence of *Callosobruchus maculatus*, indicating its potential as a botanical insecticide. Additionally, Oni and Olakojo (2015) showed that coconut husk ash and charcoal-based treatments significantly reduced bruchid emergence and infestation in cowpea storage, suggesting both mechanical and chemical modes of action.



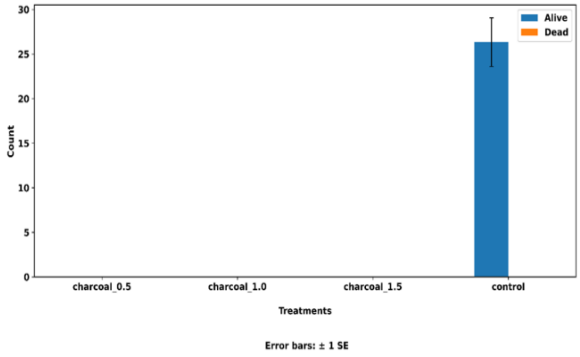


Figure 3. **Figure 4.**

Figure 3 & 4. Inhibition of F1 emergence in *S. zeamais* treated with *D. tripetala* powder and carbonized coconut endocarp powders

Conclusion and Recommendation

The results of this study shows that both plant waste materials caused high mortality rates, especially at higher dosages, aligning with previous research on the efficacy of plant-based and biochar protectants. Their mode of action ranging from toxic phyto-chemicals to desiccation and spiracle blockage offers a dual mechanism that enhances their effectiveness. Importantly, these materials are biodegradable, environmentally friendly, and readily available in rural communities, making them viable alternatives to synthetic insecticides. Future work should focus on the formulation, shelf life, and field-level application of these materials to promote their widespread adoption in post-harvest systems.

References

Emeasor, K. C., Esonu, B. O., Udedibie, A. B. I., & Opara, M. N. (2017). Phytochemical and antimicrobial studies of *Dennettia tripetala* (Pepper fruit). *Journal of Medicinal Plants Studies*, 5(6), 98–101.

FAO. (2021). *Global food losses and food waste – Extent, causes and prevention*. Food and Agriculture Organization of the United Nations. https://www.fao.org

Kweyuh, J. M. (1992). The potential of charcoal dust in the control of storage pests in smallholder farming systems. *Postharvest News and Information*, 3(3), 199–203.

Lale, N. E. S., & Mustapha, A. (2000). Potential of combining varietal resistance and neem seed oil for the management of *Callosobruchus maculatus* (F.) in stored cowpea. *Journal of Stored Products Research*, 36(3), 215–222.

Nwaubani S.I., Opit, G.P., Otitodun G.O., Adesida M.A (2014): Efficacy of two Nigeria derived diatomaceous earths against *Sitophilus oryzae* (Coleoptera: Curculionidae) and *Rhyzopertha dominica* (Coleoptera: Bostrichidae) on wheat. *Journal of Stored Products Research* 59:9-16.

Oni, O. O., & Olakojo, S. A. (2015). Effectiveness of coconut husk ash in controlling cowpea bruchids in storage. *Journal of Stored Products and Postharvest Research*, 6(4), 37–43.

Ogunleye, R. F., Adebayo, R. A., & Agbaje, A. R. (2017). Evaluation of selected plant powders as protectants against *Sitophilus zeamais* infestation on stored maize. *Nigerian Journal of Entomology*, 34, 75–82.

Okonkwo, E. U., & Okoye, W. I. (2020). Evaluation of insecticidal properties of *Dennettia tripetala* seed extracts against storage pests of maize. *Nigerian Journal of Entomology*, 36(1), 47–55.

Oladejo, O. A., Akinneye, J. O., & Adebayo, T. A. (2019). Insecticidal potential of coconut shell and neem leaf powders against *Sitophilus zeamais* (Coleoptera: Curculionidae) on stored maize grains. *International Journal of Agriculture and Biosciences*, 8(2), 85-90.

Udo, I. O., & Epidi, T. T. (2009). Efficacy of some plant materials on the control of *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) in stored cowpea. *Journal of Plant Protection Research*, 49(3), 243–246.

Zinhoum, R. A., Abotaleb, A. O., Abdelfattah, N. A., &Fawki, S. (2023): Efficacy of solar heating system on mortality, reproduction, and antioxidant enzymes in *Trogoderma granarium* Everts and *Stegobiumpaniceum* (L.). *Egyptian Academic Journal of Biological Sciences. A, Entomology*, *16*(1), 165-178.

Comparative Evaluation of Phytochemical and Antinutrient Composition of Flours Produced from Three Different Varieties of African Black Beans (*Phaseolus Vulgaris*)

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Abstract

African black beans (*Phaseolus vulgaris*) accumulate a spectrum of bioactive compounds in their seed coats and cotyledons. Selection of a variety rich in health-promoting phytochemicals yet low in antinutrients will be valuable to consumers in tackling non communicable diseases. The study assessed phytochemical and antinutrient composition of flours produced from three different varieties of African black beans namely "Apama (APM), Oralu di (ORD)) and Akidi Igbo (AKD). The samples were processed into flours using various processing methods. The phytochemical and antinutrient composition were analyzed using standard methods. Descriptive statistics such as means and standard deviation were used to present results. One-way Analysis of variance was used to determine significan-t difference between variables while Duncan's New Multiple Range Test was used to separate and compare means. A p - value of < 0.05 was considered statistically significant. Qualitative analysis on phytochemicals screening of the flours showed that APM, ORD & AKD presented higher flavonoids compared to the other secondary metabolites. Phytochemical analysis showed that sample APM had the highest Alkaloid, glycoside and flavonoid content (0.60 mg, 1.75 mg and 2.45 mg) respectively. APM had the lowest oxalate content (1.50 mg/100 g). APM had the highest phytate content (0.65 mg/100g). In conclusion, the study indicates that these African black beans contain appreciable phytochemicals and low antinutrients. The findings suggest that consumption of African black beans may be useful in the treatment of non -communicable diseases such as diabetes mellitus and heart diseases.

Keywords: African Black Beans, Phytochemicals, Antinutrients, Varieties.

Introduction

Atherosclerosis is a chronic inflammatory disease of the arteries and a major health challenge in the world. It is primarily caused by the buildup of plaque, which is a sticky substance made of fats, cholesterol, calcium, and other substances in and on the artery walls. The overall prevalence of subclinical atherosclerosis in Nigeria is estimated at approximately 43.3% (Ojo et al., 2023). Poor diet such as increased consumption of processed foods high in salt, sugar, and unhealthy fats and lifestyle can accelerate the rise of atherosclerosis.

Plant-based food can serve as a key dietary strategy in prevention of atherosclerosis**.** Certain foods can help reduce inflammation and improve cardiovascular health. legumes are a powerful dietary ally in reducing the risk of atherosclerosis. African black bean ((*Phaseolus vulgaris)* also known as cowpeas or "Akidi Igbo", are a special type of beans that are a staple food in Nigeria and other parts of Africa. They are widely cultivated in sub-Saharan Africa and are well adapted to various African climates and soils, contributing to agricultural sustainability. They are commonly used in traditional African dishes. where they serve as a vital source of nutrition. They can be used to prepare a variety of dishes, including stews, soups, and can be used as a main meal or a side dish. Phytochemicals act as synergistic agents, allowing nutrients to be used more efficiently by the body. They are less toxic, low cost, readily available, versatile, packed with nutrients and phytochemicals.

Phytochemicals are the secondary metabolites and bioactive compounds that combat oxidative stress reducing the risk of chronic diseases (Wu et al., 2021). Qualitative phytochemical tests can be used to detect the presence of these compounds in plant extracts. These bioactive compounds exhibit preventive and therapeutic potential against several life-threatening diseases. Several studies have been reported the cardioprotective, hepatoprotective, antimicrobial, anticancer, anti-inflammatory, antioxidant, anti-obesity, and antidiabetic effects of phytochemicals of black beans (Angeles et al., 2021; Wu et al., 2021 Phytochemicals in legumes help prevent and manage artery diseases through several mechanisms: They neutralize free radicals, reducing oxidative damage to blood vessels.

African black beans contain quercetin, a natural anti-inflammatory that appears to reduce the risk of atherosclerosis and protect against the damage caused by low-density lipoprotein (LDL), (Natalie, 2018). Studies have shown that regular legume consumption can lower LDL cholesterol, reduce inflammation, and improve vascular health, making African black bean is a functional food for cardiovascular disease which can improve lipid profiles associated with the development of atherosclerotic lesions (Mensah, 2020; Angeles et al., 2021).

However, some compounds found in this legume may contain antinutrients which may pose challenges to nutrient absorption. These substances in food interfere with the nutritional value of foods by reducing mineral absorption, protein digestibility, and causing toxicity and health disorders when present in high concentrations. Antinutrients like phytic acid, tannins, and lectins can bind to essential minerals (iron, calcium, zinc), reducing their bioavailability. High antinutrients in foods may lead to bloating, gas, or digestive discomfort. Various strategies can be employed to reduce the levels of anti-nutrients in foods, such as soaking, sprouting, fermenting, and cooking). Identifying the best black bean varieties with lower

antinutrient levels and high phytochemical content is crucial for maximizing health benefits and minimizing nutrient absorption. Exploring on African black beans with low-antinutritional factors can help to improve digestion and can allow breeders to develop nutritionally optimized cultivars suited for dietary needs especially for elderly populations. This can support food security and public health in developing regions like Nigeria, where beans are a major protein source. Limited studies have been conducted in this area. Therefore, this study l evaluated the phytochemical and antinutrient composition of flours produced from three varieties of African black beans.

Methodology

Study design: The study adopted an experimental design

Procurement of sample: Three different varieties of African black beans were obtained from ogige main market in Nsukka Local Government of Enugu State, Nigeria.

Sample Preparation and Flour Production: The bean seeds were sorted manually to remove extraneous materials like dirt, residue, shriveled and diseased seeds, soaked in water for 4 hours which helped to loosen the hulls easily from the seed, washed, dried, ground into fine flour using an electric grinder. The different flours were sieved into fine powder and stored in an air tight container for further laboratory analysis.

Chemical Analysis

Chemical analysis on phytochemical and antinutrients content were carried out using standard methods.

Qualitative Phytochemical Analysis

Qualitative analysis on glycoside, flavonoid, alkaloid and saponin of the three varieties of African black beans (*Phaseolus vulgaris)* was carried out using standard methods.

Glycoside test: Five (5 mL) of plant extract was bolied with 5 mL of dilute sulfuric acid for 5 minutes. The solution was cooled and filtered. The filtrate was shaken with 5 mL of benzene and was allowed to separate into layers. 2 mL of ammonia solution was added and shaken. A pink color in the ammoniacal layer indicated the presence of anthraquinone glycosides.

Flavonoid test: Lead acetate test was used for the test**. A** few drops of 10% lead acetate solution were added to the plant extract in test tube. It was observed for precipitate formation. Appearance of yellow color was observed which indicated the presence of flavonoids.

Alkaloid test: One gram of mercuric chloride and 5 g of potassium iodide was dissolved in 100 mL of distilled water. Plant extract was macerated in ethanol which was later filtered to obtain a clear solution

and about 2–3 mL of the plant extract was poured into a clean test tube.A drop of Mayer's reagent was added to the extract. A cream precipitate was formed which indicated presence of alkaloids.

Saponin test: Foam test (froth test) was used. Five (5 mL) of distilled water was added to 0.5 g of plant extract in a test tube. This was shaken vigorously in a test tube for several minutes. It was allowed to stand for 10 minutes. A stable foam or froth was formed, which indicated the presence of saponins. If the foam persists for 10-15 minutes or more, it indicates that saponins are present.

Quantitative Phytochemical Analysis

Quantitative analysis on alkaloid, glycoside, flavonoid of the three varieties of African black beans (*Phaseolus vulgaris)* was carried out using standard methods.

Alkaloid content determination: The alkaloids content of the sample was determined using the method of Harborne (1973). Five grammes of the sample was weighed into a 250ml beaker and 200ml of l0% acetic acidThis was filtered and the extract concentrated on a water bath to one - quarter of the original volume. Concentrated ammonium hydroxide was added drop-wise to the extract till a precipitate was formed. The precipitate was collected and washed with dilute ammonium hydroxide and then filtered. The residue was dried then reweighed and the alkaloid content was calculated.

Glycoside content determination: Flavonoid content was determined according to the method of Harborne (1973). Five grams of sample was diluted in methanolic extract by adding 2 mL of the extract to 10 mL of the mobile phase. Later, 20 µL of the diluted extract was injected into the HPLC column. Glycosides were detected at a wavelength of 254 nm.

Flavonoid content determination: Flavonoid content was determined according to the method of Harborne (I973). Five grammes of the sample was boiled in 50ml of 2M HCI solution for 30min under reflux. It was allowed to cool and filtered. The dried crucible was reweighed and the difference in the weight was then the quantity of flavonoid content in the sample.

Antinutrients Analysis

Antinutrients analysis on oxalate and phytate of the three varieties of African black beans (*Phaseolus vulgaris)* was carried out using standard methods.

Oxalate content determination: Oxalate was determined by the method described by AOAC Association of Official Analytical Chemists (2010). One gram of the sample was weighed into 100mL conical flask. Then, 75mL of 3M H_2SO_4 was added and the solution stirred intermittently with a magnetic stirrer for about one

hour. It was filtered and the filtrate collected and titrated hot. O.1N potassium permanganate (KMno4) solution temperature of (80-90 c) until a faint pink color appeared and persisted for at least 30 seconds. The oxalate content was then calculated

Phytate content determination: This was determined according to the method of Samotus & Schwimmer (1962). Plant material was extracted with 0.2N HCL and 3-30Hlg ml-l phytate solution was gotten. 0.5ml of extract was pipetted into a test tube fitted with a gross glass stopper. 1ml of solution was added and the tube was covered with the stopper and fixed with a clip. The tube was heated in a boiling water bath for 30minutes. Care was taken to ensure that the first 5 minutes that the tube was well stopped. After cooling in ice water for l5minutes it was allowed to adjust to room temperature.

Statistical Analysis

This was carried out using statistical product for service solution (SPSS) version 23. All data were presented as mean and standard deviation using statistical product for service solution (SPSS version 22). The significant level was determined using one-way analysis of variance (ANOVA) and accepted at ($p>0.05$).

Results

Qualitative analysis on phytochemicals of flours produced from three different varieties of African black beans (*Phaseolus vulgaris*).

Table 1 presents the qualitative analysis on flour produced from three different varieties of African black beans. The APM, ORD & AKD showed a higher presence of flavonoids (+ +) while other secondary metabolites such as glycoside, alkaloid and saponin screened had a lower content (+).

Table1: Qualitative analysis on phytochemicals produced from three varieties of African black beans (*Phaseolus vulgaris*).

Samples	Glycoside	Flavonoid	Alkaloid	Saponin
APM	+	++	+	+
ORD	+	++	+	+
AKD	+	++	+	+

Keys: APM=Apama; ORD=Oralu di; AKD=Akidi igbo.

Phytochemical composition of flour produced from three different varieties of African black beans.

Table 2 presents the phytochemical composition of flour produced from three different varieties of African black beans. The Alkaloid content of the samples ranged from 0.35-0.60mg/100g. The sample (APM) had the highest Alkaloid content (0.60mg/100g) while the sample (ORD) had the lowest Alkaloid content (0.35mg/100g). The percentage glycoside of the samples ranged from 1.05-1.75mg/100g. The sample (APM) had the highest glycoside content (1.75 mg/100g) while sample (AKD) had the lowest glycoside content (1.05mg/100g). Glycoside samples of APM and ORD were statistically similar. The

percentage flavonoid of the samples ranged from 1.20-2.45mg/100g. The sample (APM) had the highest flavonoid content (2.45mg/100g) than the sample (ORD) which is lower (1.20 mg/100g).

Table 2: Phytochemical composition of flour produced from three different varieties of African black beans (*Phaseolus vulgaris*).

Samples	Alkaloids mg/100g	Glycoside mg/100g	Flavonoids mg/100g
APM	0.60±0.00^{b}	1.75±0.07^{b}	2.45±0.07^{c}
ORD	0.35±0.07^{a}	1.50±0.14^{b}	1.20±0.00^{a}
AKD	0.45±0.07^{ab}	1.05±0.07^{a}	1.50±0.14^{b}

Values are presented as mean ± SD (standard deviation) Means on the same column with different superscripts are significant at P<0.05. Different superscript letters a, b, c on the same column of the table indicated statistical significant difference at the P<0.05 .Keys: APM=Apama; ORD=Oralu di; AKD=Akidi igbo.

Antinutrients composition of flours produced from three different varieties of African black beans (*Phaseolus vulgaris*).

Table 3 presents the antinutrient composition of flour produced from three different varieties of African black beans. The oxalate ranged from 1.20-1.50mg/100g of which sample (APM) had the highest oxalate content (1.50 mg/100g) and sample (AKD) recorded the lowest (1.20 mg/100g). The phytate of the samples ranged from 0.55-0.65mg/100g where sample APM recorded the highest (0.65mg) and Sample (ORD) had the lowest phytate content (0.55 mg/100g). Samples APM, ORD and AKD were statistically similar.

Table 3: Antinutrients composition of flours produced from three different varieties of African black beans (*Phaseolus vulgaris*).

Samples mg/100g	Oxalate mg/100g	Phytate mg/100g
APM	1.50±0.14^{a}	0.65±0.07^{a}
ORD	1.30±0.14^{a}	0.55±0.07^{a}
AKD	1.20±0.14^{a}	0.60±0.00*^{ab}

Values are presented as mean±SD (standard deviation) Means on the same column with different superscripts are significant at P<0.05. Different superscript letters a, b, c on the same column of the table indicated statistically significant difference at the P<0.05. Keys: APM=Apama; ORD=Oralu di; AKD=Akidi igbo.

Discussion

Qualitative analysis on phytochemical of flours produced from three different varieties of African black beans *(Phaseolus vulgaris).*

Table 1 presents the qualitative analysis of the samples namely: Apama, Oralu di and Akidi.The results showed that the three African Black Beans varieties possessed the tested secondary metabolites with similar values.: According to the findings of Oboh et al., (2018), African Black Bean contains glycosides,

flavonoids, tannins, and saponins. Qualitative phytochemical screening is a foundational method used to identify bioactive compounds in plants, offering a cost-effective and accessible approach to understanding their medicinal potential (Maheshwaran et al., 2024).

Phytochemical composition of flours produced from three different varieties of African black beans *(Phaseolus vulgaris).*

The findings on phytochemical composition of the Apama, Oralu di and Akidi showed that alkaloid content of the samples ranged between 0.35-0.60mg/100g). This is slightly similar with works by Ezeocha and Ojimelukwe (2012) in their study where alkaloid content of varieties of black beans ranged from 0.21% to 1.15%. A study by Filomena et al. (2012) reported that the alkaloid content of *Phaseolus vulgaris* seeds ranged from 0.00 to 0.26mg/100g, which is lower than the values obtained in this study. This discrepancy could be associated with genetic variation in plant, geographical location and soil nutritional components. Alkaloids are known to have blood glucose lowering activity. Alkaloids are also known to be anti-arrythmic effects, antihypertensive effects, anticancer and antimalarial activity (Nyamai et al., 2016). Alkaloids exhibit quite diverse medicinal properties, such properties as stimulants, anti-inflammatory, analgesic, antitumor, anticonvulsant, diuretic and antiarrhythmic effects (Angles et al., 2021).

The results showed that the glycoside content ranged between (1.05-1.75mg/100g) which is higher when compared to 0.36 - 0.88 mg/100g as reported by Oboh et al. (2018). However, differences in growing conditions, soil composition, and bean variety could account for these discrepancies. Glycosides play crucial roles in plant defense and have been associated with potential health benefits, including antioxidant, anti-inflammatory, and anticancer activities (Kumar et al., 2020).

The results showed that the flavonoid content ranged between 1.20 - 2.45mg/100g which is relatively higher compared to findings by Oboh et al. (2018) who reported that the flavonoid content of various African black bean cultivars ranged from 0.81 - 1.47 mg/100g. The differences could be as a result of soil composition and bean variety. However, flavonoids are known for their antioxidant, anti-inflammatory, and anticancer activities, as well as their potential role in reducing the risk of cardiovascular diseases and neurodegenerative disorders

Antinutrient composition of flour produced from three different varieties of African black beans *(Phaseolus vulgaris)*

The findings on Antinutrient composition of the Apama, Oralu di and Akidi showed that the oxalate content varied between (1.20 -1.50mg/100g). This value is slightly similar when compared to the study by Eneche et al. (2014) with the value 1.63 mg/100g to 2.13 mg/100g. Some antinutrients such as phytates,

oxalates, polyphenols, tannins and alkaloids are present in spices and may exert beneficial health effects at low concentrations (Soni et al., 2024).

The results showed that the phytate content ranged between 0.55-0.65mg/100g. This is consistent when with the findings by Alkhatib et al. (2014) where phytate ranged from 0.63 to 1.00 mg/100g, Phytate when used at low levels have been shown to reduce the blood glucose and insulin responses to starchy foods and/or the plasma cholesterol and triglycerides. Phytate, especially when consumed in moderate amounts through whole grains, legumes, nuts, and seeds can act as a powerful antioxidant and may help prevent cancer, heart disease, and osteoporosis (Soni et al., 2024).

Conclusion

The study explored the phytochemical and antinutrient composition of flours produced from three different varieties of African black bean (*Phaseolus vulgaris*): Apama, Oralu di, and Akidi. The findings of the study on qualitative analysis of African black beans revealed the presence of various bioactive compounds that can contribute to their overall nutritional value and health benefits. The most prominent compounds identified in the samples were flavonoids and are known for their potent antioxidant properties. The samples contain significant amount of some phytochemicals such as alkaloids, flavonoids, glycosides. Antinutrient levels of phytates and oxalates varied significantly across the three varieties. The antinutritional values were low which indicates that they may be beneficial to man. The findings revealed that these flours produced from three different varieties of African black bean exhibit distinct profiles of phytochemicals and antinutrients, reflecting varietal differences that influence their nutritional and functional potential. The study suggests that consumption of these three black beans varieties should be encouraged since they are packed with phytochemicals which have antioxidants properties to combat atherosclerosis.

Recommendations

The following recommendations were made after the findings of this study:

1. Regular consumption of African black beans should be encouraged to prevent atherosclerosis and risk of diet-related chronic diseases since the have therapeutic potentials.

2. Home makers should be encouraged to incorporate African black beans into recipes such as biscuits, cookies and food preparation because of the health benefits.

3. Nutrition education programs should be mounted in urban and rural areas on the utilization of these African black beans in prevention and management of nutrition related diseases.

References

Aneta, A., & Dasha, M. (2019). Phytic acid and phytase: *the importance of phytate level and bioavailability of minerals.*

Angeles, J.G.C., et al. (2021). *Legumes as Functional Food for Cardiovascular Disease*. Applied Sciences, 11(12), 5475. Aniszewski, T. (2015). Alkaloids – *Secrets of Life: Alkaloid Chemistry, Biological Significance, Applications and Ecological Role.* Elsevier Science.

AOAC (2010). Official Methods of Analysis of Association of Official Analytical Chemists. 18th Edition, Washington, DC.

Chen, M., Li, Y., & Liu, X. (2025). *A review of the role of bioactive components in legumes in the prevention and treatment of cardiovascular diseases*. Food & Function.

Eneche, C.J., Eze, N.O., Adeyeye, A., Ikhajiagbe, B., Nkwocha, F.I., & Aduba, E.B. (2014). Phytochemical constituents and antioxidant properties of lima bean (Phaseolus lunatus L.) seed. *African Journal of Food Science and Technology*, 5(2), 51-56.

Ezeocha, V. C., & Ojimelukwe, P. C. (2012**).** Nutrient and anti-nutrient composition of African yam bean (*Sphenostylis stenocarpa*) varieties. *African Journal of Food Science and Technology*, 3(4), 92–98.

Maheshwaran, L., Nadarajah, L., Senadeera, S. P. N. N., Ranaweera, C. B., Chandana, A. K., & Pathirana, R. N. (2024). *Phytochemical Testing Methodologies and Principles for Preliminary Screening/ Qualitative Testing*. Asian Plant Research Journal, 12(5), 11–38. https://doi.org/10.9734/aprj/2024/v12i5267

Susceptibility of Selected Sorghum Varieties to Maize Weevil, *Sitophilus zeamais* (Motschulsky) Infestation

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Abstract

Infestation of stored sorghum by insect pests represent significant threat to food security and agricultural productivity, resulting in considerable food losses. This study evaluated the susceptibility of three sorghum varieties (white, red, and yellow kernel colours) to maize weevil, *Sitophilus zeamais* in the laboratory at an ambient temperature of 28.7°C and 80% relative humidity. Susceptibility indices (Dobie Index, total emerged insects, median developmental time and grain damage) along with physicochemical characteristics such as thousand-kernel weight, protein, tannins and phenol contents were evaluated on each variety. Results showed that all three sorghum varieties were susceptible to *S. zeamais* infestation, as indicated by high mean insect emergence counts in white (160.5±19.5), yellow (129.0±13.0) and the red (110.2±14.1) types. Weevil development was rapid (≤ 32 days) in all three sorghum types. However, seed damage was significantly reduced in the red variety. The yellow sorghum variety had lower protein, tannin and phenol contents. Despite the relatively high tannin and phenol contents in the red sorghum, the rate of *S. zeamais* development was not significantly affected. These findings highlight that insect attack may be influenced by sorghum type, and thus, this information can guide the development of improved integrated pest management strategies for safe sorghum storage against insect pests.

Keywords: Grain damage, insect emergence, sorghum, *Sitophilus zeamais*, susceptibility level.

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is an essential component of global food security. Nigeria is the largest sorghum producer in Africa, with the bulk of the production derived from the Northern region.

There are several varieties cultivated and are identified locally by their kernel colours, while consumption depends on individual choice and location (Mohammed *et al*., 2019). Generally, sorghum is used for consumption or stored until sold. During storage, sorghum grain is highly susceptible to diverse insect pest attacks due to its exposed seeds and lack of protective covering. Among such insects is *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae), the ubiquitous species in tropical and sub-tropical regions causing considerable losses to many smallholder farmers who keep grains for future purposes (Nhamucho *et al*., 2017). The resistance of grains against pest has been linked with varietal, physical and biochemical attributes of kernels (Arthur *et al*., 2020). However, the oviposition and rate of progeny produced by *Sitophilus* weevils on sorghum varieties have been indicated to relate to physical, and biochemical (phenolic compounds) characteristics which present inhibitory properties against pests and pathogens (Mwenda *et al*., 2019). However, partially or completely threshed sorghum with naked caryopsis are commonly stored, making it vulnerable to stored-insect pests. Given the high production rate of sorghum for food and other end-use products in Nigeria, there is need to evaluate some physicochemical characteristics of selected sorghum varieties to highlight their possible effects on susceptibility to *S. zeamais*.

Methodology

This study was carried out in the Entomology Laboratory of Nigerian Stored Products Research Institute (NSPRI), Lagos under ambient laboratory conditions of 28±2°C temperature and 80±2% relative humidity.

Grain source

Three sorghum samples selected based on their kernel colour: white (hereafter SGW), red (hereafter SGR), and yellow (hereafter SGY) varieties were obtained from Dawanau market, Kano, Nigeria. The grains were pre-conditioned at -5°C for one week to kill any living insect from previous infestation, and thereafter kept under experimental room temperature and humidity condition before use in the experiment.

Insect culture

Adult *S. zeamais* were collected from laboratory cultures maintained in NSPRI Lagos. The insects were then reared on white sorghum in a 2L jar covered with muslin cloth to prevent insect escape and keep aeration. Subsequent progenies (first generation) of *S. zeamais* produced were used in the study.

Sorghum susceptibility test

The population growth of *S. zeamais* was conducted on 20 g sorghum placed in a plastic cylindrical cups (5 x 5 cm) for individual sorghum variety. Thereafter, 10 unsexed adults of *S. zeamais* were introduced into each cup. Each cup was then covered with muslin cloth, and held in place with rubber bands to provide ventilation and keep insects. For each *S. zeamais*-variety combination, there were ten replicates in a completely randomized design arranged on laboratory shelf maintained under laboratory condition. After a 10-day oviposition period, the parental adults were removed and the grain were returned. Data collection started after three weeks until six weeks where the number of F_1 weevil emergence was noted every two days until no more weevils emerged. The sorghum was removed from the shelf and then sifted through a 2 mm mesh (Endecotts Limited, UK) to remove adult progeny along with the frass and feeding damage. The number of insect damaged kernels (IDK) per 20 g sample in each cup were recorded. For Dobie Susceptibility Index (DSI), this was calculated with the formula:

$(Log\ P * 100)/_{MDT}$ where P is the emerged progeny and MDT is the median developmental time (Dobie, 1974). The DSI scale which ranged from 0 to 11 (Dobie, 1974) was used to classify sorghum varieties, where: 0 – 4 = resistant, 4.1 – 7.0 = moderately resistant, 7.1 – 10.0 = susceptible and > 10.1 = highly susceptible varieties.

Physicochemical characteristics of sorghum varieties

The physical properties determined on each of three sorghum varieties were: thousand-kernel weight (TKW), this was obtained by multiplying the weight of 100 grains by 10, and kernel morphometrics (length and width) were measured with a digital caliper. Three replicates per each variety were evaluated. For biochemical characteristics, proximate analysis (protein, carbohydrate, fat, ash and moisture contents) of sorghum varieties were conducted using standard procedures, while extraction and analysis of tannins and phenols were determined using standard procedures (Price *et al*., 1978).

Data analysis

All data were subjected to ANOVA and means when significant, were separated using Tukey HSD test at p = 0.05 (IBM Corp. SPSS 20.0).

Results and Discussion

Susceptibility of *S. zeamais* on sorghum varieties

The susceptibility parameters of the three sorghum varieties exposed to *S. zeamais* are presented in Table 1. The susceptibility range from 7.1 to 7.9 indicating that the evaluated sorghum grains are susceptible to

S. zeamais infestation, while progeny emergence capacity of this species was similar in all three varieties tested, but the rate of development varied with variety. Previous studies on sorghum susceptibility against other storage insects have reported similar high number of progeny emergence in different varieties (Gourgouta et al., 2019; Arthur *et al*., 2020). In this study, the extent of seed damage differed among varieties, this could be related to insect emergence rates, developmental time and kernel size. This findings agrees with Nhamucho *et al* (2017) who reported that susceptible varieties tend to have shorter MDT which would result in large weevil counts and high kernel damage and weight loss.

Table 1. Susceptibility parameters on sorghum grains

	Susceptibility			Losses	
Variety	**DSI**	**MDT (days)**	**Total insects (#)**	**Seed damage (%)**	**Weight loss (%)**
SGR	7.2±0.1[a]	33.4±0.4[b]	110.2±14.1[a]	17.2±3.2[a]	4.3±0.8[a]
SGW	7.6±0.2[a]	30.9±0.4[a]	160.5±19.5[a]	50.0±9.8[b]	12.5±2.5[b]
SGY	7.1±0.2[a]	32.9±0.5[b]	129.0±13.0[a]	35.4±3.5[ab]	8.9±0.9[ab]

Means within columns followed by different letters are significant (Tukey HSD test, P < 0.05). DSI = Dobie Susceptibility Index, MDT = Median Developmental Time, SGR = Red sorghum, SGW = White sorghum, SGY = Yellow sorghum

Physicochemical characteristics of sorghum varieties

The physical traits of the three sorghum is presented in Table 2. The SGY variety had the highest TKW value which indicates it larger and denser characteristics compared to SGR and SGW. For sorghum kernel size, the length values were within the typical range for sorghum (4.0 - 5.0 mm) reported by Hendrival *et al.* (2019). Differences in sorghum kernel size can be attributed to variations in varieties, which may offer space for oviposition and in turn influence insect infestation (Mwenda et al., 2019). Sorghum is a rich source of nutrient contents and these compositions varies between varieties, thereby contributing to food suitability for stored-insect pests. The biochemical content was significantly different among the kernels (Table 3). The SGR had the highest protein content of 7.6% while SGY had 5.4%, though slightly higher than those observed in some commonly consumed sorghum in Nigeria (Mohammed *et al*., 2019). However, a high protein value could relates to insect resistance, but it is a complex relationship. The high carbohydrate value obtained for SGY (78.3%) in this study aligns with reported high value for yellow sorghum compared to other varieties (Mohammed *et al*., 2019). A high starch content in grains is related to soft kernels which makes it easier for insects to perforate. The ash content in this study was higher in SGW and SGY, but lower than values reported by Mohammed *et al*. (2019). The MC values of sorghum varieties were low and within safe moisture level (13%). The concentrations of phytochemical composition (tannin and phenol) of the three sorghum were high compared to reported values, but does

not seem to contribute to sorghum resistance to *S. zeamais*. However, reports have showed that these compounds have important roles in conferring resistance to storage insects (Mwenda *et al*., 2019).

Table 2. Physical characteristics of three sorghum varieties

Variety	Color	TKW (g)	Length (mm)	Width (mm)
SGR	Red	29.7±0.6^{a}	4.1±0.1^{a}	5.1±0.1^{b}
SGW	White	36.0±0.1^{b}	4.6±0.1^{ab}	4.8±0.0^{a}
SGY	Yellow	62.2±0.7^{c}	5.0±0.1^{b}	5.4±0.1^{b}

Means within columns followed by different letters are significant (Tukey HSD test, P < 0.05). SGR = red sorghum, SGW = White sorghum, SGY = Yellow sorghum, TKW = Thousand-Kernel Weight

Table 3. Biochemical characteristics of three sorghum varieties

Variety	% Protein	% CHO	% Fat	% Ash	% MC	Tannin (mg/g)	Total Phenol (GAE)
SGR	7.6±0.1^{c}	67.8±0.7^{a}	3.3±0.1^{a}	1.2±0.1^{a}	11.2±0.1^{a}	3.8±0.1^{b}	10.5±0.2^{b}
SGW	6.7±0.0^{b}	65.8±0.2^{a}	4.7±1.0^{b}	1.3±0.0^{a}	11.4±0.2^{a}	3.7±0.1^{b}	10.2±0.1^{b}
SGY	5.4±0.2^{a}	78.3±0.2^{b}	3.6±0.5^{a}	1.3±0.1^{a}	10.2±0.2^{a}	3.4±0.1^{a}	9.4±0.2^{a}

Means within columns followed by different letters are significant (Tukey HSD test, P < 0.05). SGR = red sorghum, SGW = White sorghum, SGY = Yellow sorghum, CHO = Carbohydrate, MC = Moisture content

Conclusion

This study demonstrated that the three sorghum varieties examined are susceptible to *S. zeamais*, with respect to number of adult insect emergence, seed damage and susceptibility index. Therefore, these varieties should not to be stored for long periods without appropriate pest management strategies.

References

Arthur, F. H., Bean, S. R., Smolensky, D., Cox, H. H., Lin, K. H., Peiris, S. & Petersen, J. (2020). Development of *Rhyzopertha dominica* (Coleoptera: Bostrichidae) on sorghum: quality characteristics and varietal susceptibility. *Journal of Stored Products Research* 87, 101569.

Dobie, P. (1974). The laboratory assessment of the inherent susceptibility of maize varieties to postharvest infestation by *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae). *Journal of Stored Products Research* 10, 183-197

Gourgouta, M., Athanassiou, C. G. & Arthur, F. H. (2021). Susceptibility of four different sorghum varieties to infestation by the khapra beetle. *Journal of Economic Entomology 114*(3), 1373-1379.

Hendrival, H., Putra, R. L., & Aryani, D. S. (2019). Susceptibility of sorghum cultivars to *Sitophilus oryzae* L. (Coleoptera: Curculionidae) during storage. *Journal of Agro Science 7*(2), 110-116.

Mohammed, Z. S., Mabudi, A. H., Murtala, Y., Jibrin, S., Sulaiman, S. & Salihu J. (2019). Nutritional analysis of three commonly consumed varieties of sorghum (*Sorghum bicolor* L.) in Bauchi state, Nigeria. *Journal of Applied Science and Environment 23*(7), 1329-1334.

Mwenda, E. T., Ringo, J. H. & Mbega, E. R. (2019). The implication of kernel phenology in convening resistance to storage weevil and varietal development in sorghum. *Journal of Stored Products Research* 83, 176-184.

Nhamucho, E., Mugo, S., Gohole, L., Tefera, T, Kinyua, M. & Mulima, E. (2017). Resistance of selected Mozambican and improved maize genotypes to maize weevil, *Sitophilus zeamais* (Motschulsky). *Journal of Stored Products Research* 73, 115-124.

Price, M. L., Van Scoyoc, S. & Butler, L. G. (1978). A critical evaluation of the vanillin reaction as an assay for tannin in sorghum grain. *Journal of Agriculture and Food Chemistry* 26, 1214–1218.

Garden Egg Farmers' Behaviour to Food Safety Practices in Nsukka Agricultural Zone, Enugu State, Nigeria

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Abstract

Foodborne illnesses remain a major global threat, with fresh produce like the increasingly popular garden egg often implicated in contamination outbreaks. This study addresses a vital knowledge gap by investigating the food safety behaviors of garden egg farmers in Enugu State, Nigeria. Using structured questionnaires, data were collected from 60 farmers selected through a multi-stage sampling procedure. The data were analysed using percentages, mean scores and frequency. Most (76.7%) respondents demonstrated a high knowledge of food safety. More importantly, their attitudes are strongly positive, with the farmers agreeing that safety measures lead to higher-quality garden eggs ($\bar{x}$=4.97, S. D= 0.18) and protect consumers from health risks ($\bar{x}$=4.97, S.D=0.18). Importantly, they rejected the notion that small-scale farmers should ignore regulations ($\bar{x}$=4.78, S.D=0.56), demonstrating their commitment to compliance, regardless of farm size. In practice, farmers prioritized preventing cross-contamination ($\bar{x}$=3.87; S.D=0.39) and ensuring the use of clean, safe water for washing ($\bar{x}$=3.52; S. D=0.65). The study concludes that farmers' possession of high knowledge and positive attitudes towards food safety practices is a powerful driver that can ensure the production of higher-quality garden eggs, thereby protecting consumers from health risks and enhancing their economic well-being. The study recommends that policymakers and agricultural extension workers should provide regular monitoring and support to ensure adherence to food safety practices.

Keywords: Food safety, Garden egg, Attitude, Behaviour, Knowledge

Introduction

Foodborne diseases pose a major global public health challenge, occurring daily in both developed and developing countries, and resulting in significant health and economic costs such as medical expenses and sick leave (Rezaei et al., 2018; Kamboj et al., 2020). Millions of deaths are recorded annually due to foodborne illnesses, largely caused by microbiological contamination of food and water (Rezaei et al., 2018). Fresh fruits and vegetables are leading causes of these outbreaks worldwide, with seeded vegetables like cucumbers, tomatoes, and garden eggs most implicated (Rezaei et al., 2018).

Studies show that outbreaks of foodborne illness are frequently traced to products sold at supply chain or farm gates, yet little research exists on farmers' on-the-farm food safety practices (Jeffer et al., 2021; Rezaei et al., 2018). Despite garden egg's growing popularity and consumption in Nigeria, there is insufficient research addressing farmers' behaviour regarding food safety. This knowledge gap limits effective risk assessment and mitigation.

Given the garden egg's cultural, nutritional, and economic importance, ensuring its safety is vital for consumer health and farmer livelihoods. Therefore, it is essential to investigate farmers' behaviour toward food safety practices and identify measures currently adopted in Nsukka Agricultural Zone, Enugu State. This will help safeguard public health while strengthening the sustainability of garden egg production.

The general purpose of the study is to assess food safety behaviours among garden egg farmers in Nsukka Agricultural Zone, Enugu state, Nigeria. The specific objectives of the study are to:

I. Determine their knowledge of garden egg food safety practices;
II. Assess farmers' attitudes towards garden egg food safety practices; and
III. Ascertain the food safety practices adopted by garden egg farmers in the Nsukka Agricultural Zone.
IV. Methodology

Enugu State, located in southeastern Nigeria, is one of the country's 36 states and lies within the tropical rainforest and derived savannah zones (Okeke et al., 2020). Covering about 7,161 square kilometres, it ranked 29th in size and 22nd in population with over 4.4 million people as of 2016 (National Bureau of Statistics, 2021). The state is predominantly inhabited by the Igbo, whose main occupation is subsistence agriculture.

The State is divided into six agricultural zones: Agbani, Agwu, Enugu, Enugu-Ezike, Nsukka and Udi. The Nsukka agricultural zone was purposively selected for the study. The population of the study comprised all garden egg farmers in Nsukka Agricultural Zone. A multi-stage sampling procedure was employed to select 60 garden farmers for the study. This sample size was used due to limited budget and short study duration for the research. Data were collected using structured questionnaires and direct observation and analysed using percentages, mean, and standard deviation.

Methodology

Farmers' knowledge of food safety practices

The result of the respondents' knowledge level of garden egg food safety practices shows that the majority (76.7%) of the respondents had high knowledge of food safety, about 20% had moderate knowledge and 3.3% had low knowledge of food safety. The fact that a significant portion of the respondents have good knowledge of garden egg food safety practices suggests that farmers could be conscious of food safety in their production of garden eggs.

This high knowledge of food safety practices could encourage farmer-to-farmer discussions on food safety, leading to the faster dissemination of information and reaching a considerable portion of the rural farming population, contributing to increased awareness and knowledge about food safety practices. This high knowledge could be because of the high farming experience and education obtained. This agrees with the findings of Otekunrin et al. (2021), that efforts should be geared towards promoting households' education-related intervention programs to improve their nutrition-related knowledge that can enhance their food security status.

The study also suggests that while most farmers understand crucial food safety practices, a significant proportion still lacks full knowledge, which may pose risks to public health. The result also suggests that garden egg farmers with high knowledge could be more conscious of promoting and practising food safety in garden egg farming than those with low knowledge.

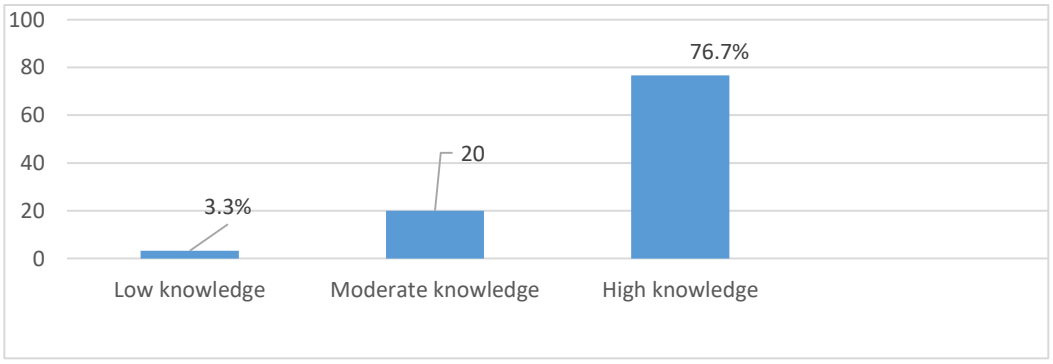


Figure 1: The respondent's knowledge level of garden egg food safety practices.

Attitude of garden egg farmers towards food safety practices

Table 1 shows the attitude of garden egg farmers towards food safety practices. The respondents agreed to the following statements: Proper food safety practices led to higher quality garden eggs ($\bar{x}$=4.97, S.D=0.18), food safety guidelines will protect consumers from health risks associated with garden eggs

($\bar{x}$=4.97, S.D=0.18), and safe pesticide use contributes to the overall safety and marketability of garden eggs ($\bar{x}$=3.93, S.D=1.16

They disagreed that small-scale garden egg farmers do not need to worry about food safety regulations ($\bar{x}$=4.78, S.D=0.56). The result shows that all garden-egg farmers, irrespective of their scale of production, encourage food safety regulations.

The result suggests that farmers understand that food safety protocols enhance the quality of their produce. Thus, adopting safer farming methods could encourage better yields and market appeal. Farmers' agreement on the linkage between food safety practices and consumers' health is germane in reducing foodborne illnesses and ensuring safer food supply chains. Moreover, trust is vital in the marketing of agricultural products. Thus, the more food-conscious the farmers are, the more trust they attract from the consumers, leading to an increase in product demand.

The farmer's disagreement with some negative attitudinal statements reflects a growing awareness and positive outlook on food safety within the garden egg farming community. This agrees with the findings of Wenbin et al. (2025), that the maintenance of food safety standards is crucial for protecting public health and economic integrity of the food industry. The farmers' disagreement to the statement that they do not need to worry about food safety regulations shows that all garden-egg farmers irrespective of their scale of production encourage food safety regulations.

Food safety practices currently used by garden egg farmers

The result of Table 2 reveals the food safety practices currently used by the respondents. The result shows that the respondents do separate garden egg from other food items to avoid cross-contamination ($\bar{x}$=3.87; S.D=0.39). The result of the study shows that the farmers adopt the following food safety practices: Ensuring that any water used in the washing process is clean and safe ($\bar{x}$=3.52; S. D=0.65) and keeping records of cleaning schedules.

The result shows that most farmers prioritize preventing cross-contamination, which is critical in maintaining food safety by avoiding the transfer of harmful microorganisms from other food products to garden eggs. Ensuring that the water used in the washing process is clean and safe is a crucial practice since contaminated water can introduce pathogens leading to severe health risks.

Table 1: Attitude of garden egg farmers towards food safety practices

s/n	Attitude	Mean (N=60)	Std. Deviation
1	Proper food safety practices lead to higher-quality garden eggs.	4.97	0.18
2	Confident that following food safety guidelines will protect consumers from health risks associated with garden eggs.	4.97	0.18
3	I believe that food safety practices help in building trust with customers.	4.92	0.28
4	Small-scale garden egg farmers do not need to worry about food safety regulations.	4.78	0.56
5	Adopting food safety practices improves your farm's reputation in the marketplace.	4.47	1.00
6	I think that investing in food safety measures is worth the cost.	4.47	0.50
7	Using unapproved pesticides on garden eggs has no significant effect on consumer health.	4.35	0.80
8	Food safety practices are unnecessary for garden egg farming.	4.32	0.83
9	Unconcerned about the potential health risks of not practicing food safety during garden egg cultivation.	4.12	1.32
10	Contamination in garden eggs is not a serious issue for your farm.	3.97	0.84
11	Safe pesticide use contributes to the overall safety and marketability of garden eggs.	3.93	1.16

Cut off mean ≥3.05 Source: Field survey 2025

Table 2: Food safety practices currently used by garden egg farmers

s/n	Food safety practices	Mean	Std. Deviation
1	Separating garden eggs from other food items to avoid cross-contamination.	3.87*	0.39
2	Ensuring that any water used in the washing process is clean and safe.	3.52*	0.65
3	Keeping records of cleaning schedules and maintenance for equipment and facilities.	3.50*	0.75
4	Inspecting garden eggs for signs of spoilage before selling or consuming them.	3.45*	0.93
5	Implementing pest control measures in the area where garden eggs are grown and stored.	3.35*	0.61
6	Use of protective clothing, such as gloves and aprons when handling garden eggs.	3.25*	0.88
7	Practice proper handwashing before handling garden eggs	3.05*	0.62
8	Regular review and update of your food safety practices and protocols.	2.37	0.61
9	Monitoring and recording the temperatures of storage areas for garden eggs.	1.70	0.77

Cut off mean ≥2.5 source: field survey 2025 Note: * = Current food safety practices

Conclusion

The overall purpose of the study was to assess the food safety attitudes of garden egg farmers in Nsukka Agricultural Zone, Enugu State. The study concludes that the majority of the farmers had a good knowledge of food safety practices, suggesting that the farmers could have been learning information about food safety from each other, without any contact with an extension agent. They apply many different food safety practices to boost the safety of garden eggs for the safety of the consumers and to make a profit. The study concludes that the farmers have positive food safety attitudes, which could enhance the quality of their produce.

Recommendations: Based on the study's findings, it is recommended that the government establish a strong framework for revitalising agricultural extension services, which would boost extension visits and improve farmers' access to information and new farming technologies.

References

Jeffer, S. B., Kassem, I. I., Kharroubi, S. A., & Abebe, G. K. (2021). Analysis of food safety management systems in the beef meat processing and distribution chain in Uganda. *Foods*, *10*(10). https://doi.org/10.3390/foods10102244

Kamboj, S., Gupta, N., Bandral, J. D., Gandotra, G., & Anjum, N. (2020). Food safety and hygiene: A review. *International Journal of Chemical Studies*, *8*(2), 358–368. https://doi.org/10.22271/chemi.2020.v8.i2f.8794

National Bureau of Statistics *(2021). Population 2006-2016.*

Okeke, F., Sam-Amobi, C., & Okeke, F. (2020). Role of local town planning authorities in building collapse in Nigeria: Evidence from Enugu metropolis. *Heliyon. 6.* http://doi.org/e04361. 10.1016/j.heliyon.2020.e04361

Otekunrin, O. A., Sawicka, B., & Pszczółkowski, P. (2021). Assessing food insecurity and its drivers among smallholder farming households in rural Oyo State, Nigeria: The HFIAS approach. *Agriculture*, *11*(12), 1189. https://doi.org/10.3390/agriculture11121189

Rezaei, R., Mianaji, S., & Ganjloo, A. (2018). Factors affecting farmers' intention to engage in on-farm food safety practices in Iran: Extending the theory of planned behavior. *Journal of Rural Studies*, *60*, 152–166. https://doi.org/10.1016/j.jrurstud.2018.04.005

Wenbin, Y., Zhiwei, O., Yufei, Z., Yi, L., Changhe, W., Yayi, T., Bin, H. (2025). Research progress on the artificial intelligence applications in food safety and quality management. *Trends in Food Science & Technology*, *156*, 104855. https://doi.org/10.1016/j.tifs.2024.104855

Review of Food Quality and Safety Concerns in the Agricultural Value Chain of Oil seed and Beverage Crops

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Abstract

Oilseed crops such as peanuts, soybeans, and sunflowers, along with beverage crops like coffee, tea, and cocoa, are vital to diets, livelihoods, and cultural traditions worldwide. Yet their safety is often compromised by mycotoxins, pesticide residues, heavy metals, polycyclic aromatic hydrocarbons (PAHs), adulteration, and processing contaminants. These risks can appear at any stage of the value chain, from farming to storage, transport, and retail, and are heightened by climate stress, poor infrastructure, and uneven regulation. This review draws together recent evidence on key hazards and examines how global frameworks such as Hazard Analysis and Critical Control Points (HACCP), Codex Alimentarius, the United States Food Safety Modernization Act (FSMA), and European Union (EU) standards are addressing them. Priority measures suggest strengthening Good Agricultural Practices (GAPs), implementing integrated pre- and post-harvest measures to control aflatoxins and ochratoxin A, enhancing pesticide monitoring and traceability in coffee and tea, and expanding access to affordable testing technologies in resource-limited regions. Safeguarding these crops is essential to protect health, maintain consumer trust, and sustain global trade.

Keywords: Adulteration, food safety, mycotoxins, oilseeds, pesticide residues

Introduction

Oil seed crops such as peanut, soybean, sunflower, and rapeseed, alongside beverage crops like coffee, tea, and cocoa, are central to global food systems, nutrition, and rural economies. They provide edible oils, protein-rich meals, and culturally significant beverages, while also serving as high-value exports that generate critical foreign exchange (FAO, 2021; ICO, 2020). Their dual role as dietary staples and economic drivers makes their safety and quality a matter of public health, trade and development concern.

Despite this importance, these value chains are highly vulnerable to food safety risks. Oilseeds, which supply over one-third of global edible oil, are often affected by mycotoxins and pesticide residues (Kumar *et al*., 2021), while beverage crops move through fragmented global chains that expose them to adulteration and weak regulatory oversight (Potter *et al*., 2021). Mycotoxins such as aflatoxins and

ochratoxins remain especially concerning, with links to liver cancer, immune suppression, and stunted growth, disproportionately affecting populations in Sub-Saharan Africa and South Asia (Eskola *et al*., 2020). Pesticide residues contribute not only to dietary risks but also constitute also to environmental and occupational health concerns (Merhi *et al*., 2022). Economically motivated adulteration (Spink & Moyer, 2011) and processing contaminants such as polycyclic aromatic hydrocarbons (PAHs) and solvent residues further complicate management.

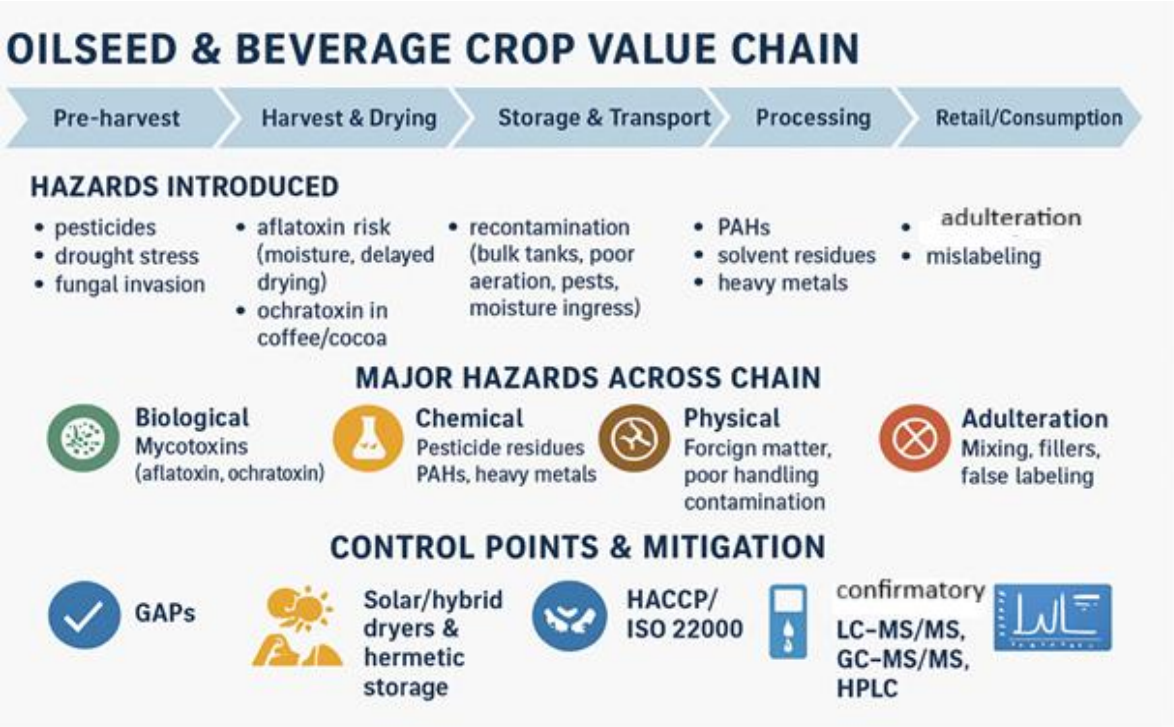
The economic toll is also significant: aflatoxin-related trade rejections cost African economies an estimated USD 670 million annually (Wu & Khlangwiset, 2010), while pesticide-related rejections of coffee and tea consignments damage both income and reputation (Pandey *et al*., 2023). For smallholder farmers, these losses directly threaten livelihoods and food security.

Addressing such challenges requires a value-chain perspective that recognizes how hazards emerge and persist from cultivation through retail. Within this framework, Good Agricultural standards represent not only technical tools but also essential governance mechanisms for managing risk (Kumar *et al*., 2021; Merhi *et al*., 2022).

Major Hazards in Oilseed and Beverage Value Chains

Oil seed and beverage crops are vulnerable to a range of hazards that threaten both food safety and trade. Among biological risks, aflatoxin B1 (AFB1) from *Aspergillus* spp. is the most critical, contaminating peanuts, cottonseed, sunflower, and derived products under warm, humid, and poorly managed storage conditions, with severe health impacts including hepatocarcinogenicity and immunosuppression (Kumar *et al*., 2021). In coffee, cocoa, and tea, ochratoxin A is of greatest concern, with risks shaped by drying and fermentation practices and amplified by climate variability, which is shifting contamination patterns and creating new hotspots (Pandey *et al*., 2023; Shekhar *et al*., 2025). Pesticide residues also pose persistent challenges, particularly in coffee and tea, where intensive chemical use often leaves residues that survive processing. While detection has advanced with QuEChERS coupled with liquid chromatography–tandem mass spectrometry (LC–MS/MS) and gas chromatography–tandem mass spectrometry (GC–MS/MS), field-level problems such as overuse, runoff, and inadequate protective measures persist (Merhi *et al*., 2022). Economically motivated adulteration further undermines quality and safety, from blending edible oils with cheaper substitutes to diluting coffee and tea with fillers, though spectroscopy, chemometrics, and lipid profiling are strengthening detection (Pandey *et al*., 2023). Additional risks arise during processing and handling, including heavy metals, polycyclic aromatic hydrocarbons (PAHs), solvent residues, and contamination from transport systems, highlighting the need for Hazard Analysis and Critical

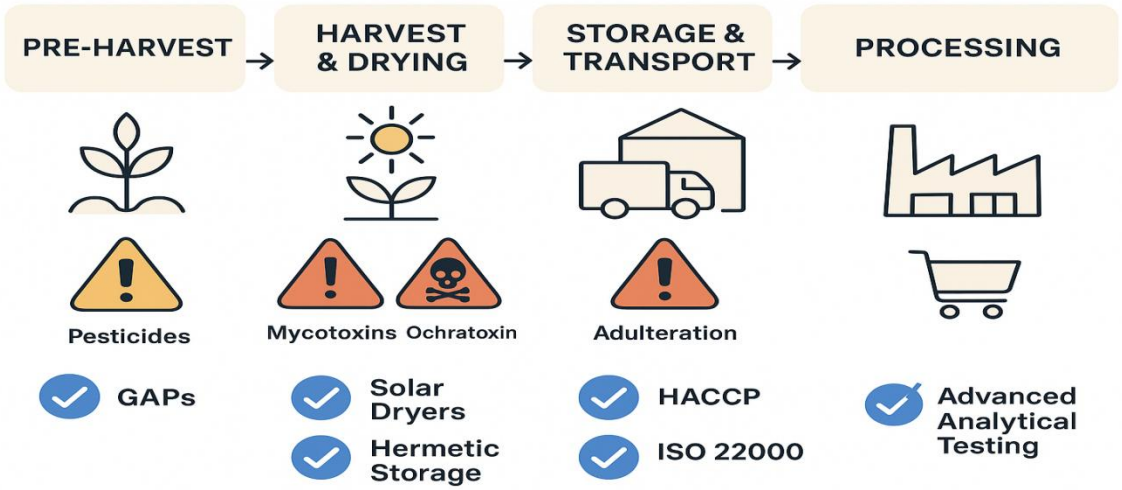
Control Points (HACCP)-based management and stronger regulatory standards (World Bank/IFC, 2015; European Commission/FEDIOL, 2010).



Value-Chain Entry Points for Hazards

- **Pre-harvest:** Crop variety, insect damage, drought stress, and pesticide application practices shape initial contamination risk. Integrated pest management and GAPs can mitigate these hazards (Kumar *et al*., 2021).
- **Harvest and drying:** Delayed harvesting, uneven drying, and inadequate moisture control during storage drive mycotoxin formation in oilseeds and cocoa. In coffee and tea, fermentation and drying protocols influence both quality and contamination risk (Pandey *et al*., 2023).
- **Storage and transport:** Moisture ingress, poor aeration, and contamination from bulk storage facilities or transport tanks represent critical risk points. European Union sectoral guidance highlights these vulnerabilities in crushing and refining chains (European Commission/FEDIOL, 2010).
- **Processing:** Thermal treatments such as roasting and refining can reduce some contaminants but may also create new ones (e.g., PAHs) or fail to eliminate heat-stable toxins like aflatoxins

(Shekhar *et al*., 2025).



Detection, Monitoring, and Analytical Capacity

Advances in analytical chemistry have greatly improved detection sensitivity for mycotoxins and pesticide residues. Techniques such as enzyme-linked immunosorbent assay (ELISA), high-performance liquid chromatography (HPLC), and liquid chromatography–tandem mass spectrometry (LC–MS/MS) are widely used for mycotoxin analysis, while Quick, Easy, Cheap, Effective, Rugged, and Safe (QuEChERS) based liquid chromatography/gas chromatography–mass spectrometry (LC/GC–MS) methods dominate pesticide monitoring (Merhi *et al*., 2022).

Nonetheless, limited infrastructure in low-resource settings constrains effective monitoring. Affordable, field-deployable diagnostics and robust sampling strategies, including pooled sampling, offer promising pathways for strengthening surveillance capacity (Pandey *et al*., 2023).

Global Frameworks for Food Safety Governance

International frameworks provide structured approaches to managing hazards in oilseed and beverage value chains. The Codex Alimentarius, Hazard Analysis and Critical Control Points (HACCP), the U.S. Food Safety Modernization Act (FSMA), and International Organization for Standardization (ISO) 22000 set widely adopted standards, with HACCP serving as the backbone of processing-level control. Commodity-specific guidance, such as the European Federation of the Vegetable Oil and Protein Meal Industry (FEDIOL) protocols, offers tailored measures (European Commission/FEDIOL, 2010; Canadian Grain Commission, 2022). Harmonizing maximum residue limits (MRLs) and aflatoxin thresholds remains essential for fair and sustainable trade (World Bank/IFC, 2015).

Conclusion

Maintaining food safety and quality in oilseed and beverage value chains requires a holistic, systems-based approach encompassing cultivation, post-harvest handling, processing, and retail. Mycotoxins, particularly aflatoxins, alongside pesticide residues, represent the most significant risks to both public health and international trade. Effective mitigation hinges on strengthening farmer training, expanding infrastructure, enhancing analytical capacity and harmonizing regulatory standards. Looking forward, progress will depend on affordable diagnostic tools, integrated management strategies, and climate-responsive interventions to protect consumers and sustain access to global markets.

Recommendations

To enhance food safety and market competitiveness, harmonizing limits for mycotoxins and pesticide residues across major markets is essential, alongside expanding technical support and investing in infrastructure such as solar dryers and hermetic storage systems. Industrial facilities should adopt HACCP and ISO 22000 standards, while applying risk-based sampling with confirmatory LC–MS/MS testing to ensure reliable monitoring. Research should focus on developing low-cost, portable detection tools and understanding how climate change affects contamination risks. Together, these measures can strengthen food safety, protect public health, and support sustainable trade.

References

Canadian Grain Commission. (2022). *Generic HACCP plan for grains, oilseeds & pulses*. Canadian Grain Commission.

Merhi, A., Kordahi, R., & Hassan, H. F. (2022). A review on the pesticides in coffee: Usage, health effects, detection, and mitigation. *Frontiers in Public Health, 10,* 1004570. https://doi.org/10.3389/fpubh.2022.1004570

Pandey, A. K., Samota, M. K., & Sanches Silva, A. (2023). Mycotoxins along the tea supply chain: A dark side of an ancient and highly valued aromatic beverage. *Critical Reviews in Food Science and Nutrition, 63*(27), 8672–8697. https://doi.org/10.1080/10408398.2022.2061908

Potter, C., Burney, J., & Wheeler, T. (2021). Agricultural value chains and food safety: Global patterns and policy implications. *Food Policy, 102*, 102042. https://doi.org/10.1016/j.foodpol.2021.102042

Spink, J., & Moyer, D. C. (2011). Defining the public health threat of food fraud. *Journal of Food Science, 76*(9), R157–R163. https://doi.org/10.1111/j.1750-3841.2011.02417.x

World Bank/IFC. (2015). *Environmental, health, and safety guidelines: Vegetable oil processing*. World Bank Group.

Wu, F., & Khlangwiset, P. (2010). Health economic impacts and cost-effectiveness of aflatoxin reduction strategies in Africa: Case studies in biocontrol and post-harvest interventions. *Food Additives & Contaminants: Part A, 27*(4), 496–509. https://doi.org/10.1080/19440040903437865

Effect of Malting and Extrusion on the Polyphenol abd Antioxidant Properties of Extrudates from Flour Blends of Malted Brown Rice and Pigeon Pea

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Abstract

The properties of extrudates are influenced by the processing conditions and extrusion variables applied to them. The combined impact of malting and extrusion on the antioxidant properties of malted-extruded has not been extensively studied. Malted pigeon pea and brown rice flours were processed into blends and extruded under various conditions of feed moisture level (15 – 20), pigeon pea composition (8 - 30%), and barrel temperature (100 - 130 ^{o}C), and analysed using Response Surface Methodology with a Box-Behnken design. The polyphenol, DPPH and ABTS activity were evaluated and used to assess the antioxidant effect of the extrudates. The Polyphenol content (468.44 - 1471 µg GAE/g) of the extrudates and antioxidant activities (DPPH: 375.05- 801.44 mgTE/g; ABTS: 1010.44- 2283.90 mgTE/g) increased significantly ($p<0.05$) with increase in barrel temperature and feed composition. Malting and some extrusion variables, particularly barrel temperature, had a significant impact on the antioxidant properties of the malted-extrudates which can be attributed to synergistic effects of malting and extrusion, particularly the Maillard reaction and phenolic release. The findings suggest that optimized extrusion of malted legume and cereal blends can yield nutritionally superior, antioxidant-rich functional foods

Keywords: Box-Behnken design; brown rice; extrusion; malting; pigeon pea

Introduction

Pigeon pea (*Cajanus cajan*), is an excellent source of polyphenolic compound, has lower lipid content free of cholesterol, possesses potent anti-hyperglycemic activity and has been used in the treatment of diabetes. Malted pigeon pea exhibits more secondary metabolites (phenolic compounds and flavonoids) than the un-malted counterpart and has been established to relieve oxidative stress, lipid peroxidation, inhibit alpha-amylase and alpha-glucosidase, stabilize blood glucose and increase glutathione levels (Uchegbu and Ishiwu, 2016). The total phenolic and DPPH scavenging activity increased by 30.12 and 63.52 %, respectively, after malting pigeon pea (Uchegbu and Ishiwu, 2016). Brown rice contains a large amount of dietary fibre, vitamin E, B vitamins (B1, B3 and B6), minerals and gamma-aminobutyric acid

(GABA) than white and parboiled milled rice grains after dehulling. Its nutrients are enhanced after malting which have great influence on the antioxidant properties of malted brown rice. Bioactive compounds obtained during malting of grains reduce drastically following conventional heat treatment before it is consumed which led to exploring the use of extrusion cooking: a high temperature short time (HTST) processing technology in this study. The objective of this study was to assess the combined effect of malting and extrusion on the antioxidant properties of the extrudates from flour blends of malted brown rice and pigeon pea.

Methodology

The brown rice (FARO 44 variety) [100 kg] *Oryza sativa glaberrima* was obtained during 2020 harvest season from the National Cereal Research Institute in Badeggi Bida, Niger State, Nigeria. The Red Pigeon pea (*Cajanus cajan L.*) [50 kg] was obtained at Ogige market in Nsukka LGA in Enugu State, Nigeria, The raw materials were cleaned by winnowing and sorted to remove impurities and were then packaged in ziploc bags. They were subsequently stored at room temperature (30 °C) until they were needed. The brown rice and pigeon pea were malted and processed into flour blends using Box-Behnken design and thereafter subjected to different extrusion conditions as described by Azuka *et al.* (2025).

Designing formulations using Response Surface Methodology

Minitab software was utilized to establish a Response Surface Methodology (RSM) in a three-factor Box-Behnken design. The operating ranges and three standardized levels were determined following multiple preliminary trials and operating ranges; feed moisture level: 15-20 (X_1), barrel temperature 100-130 °C, (X_2) and feed composition: 8-30 % (amount of pulse combined with malted and unmalted rice flour- X_3), were the independent variables considered.

Total Polyphenol Determination

Total polyphenol content assay using plate reader according to Dewanto *et al.* (2002) with modifications was used.

Antioxidant activity assay

DPPH (2, 2- Diphenyl-1- picrylhydrazyl) assay

DPPH assay was used for analysis as described by Baliyan *et al*. (2022).

ABTS (2, 2'- azino-di-[3-ethylbenzthiazolin sulfonate]) assay

ABTS assay was used for analysis as described by Kolarov *et al*. (2021).

Statistical Analysis

The measurements were done with 3 replicates, and reported as the mean value ± standard deviation. An ANOVA was conducted using Minitab software, with significance set at $p < 0.05$. The results from the Box-

Behnken design were analyzed to assess the impact of feed moisture level, feed blend composition, and barrel temperature as well as the impact of malting on the polyphenol and antioxidant properties of the extrudates.

Table 1: Polyphenol and antioxidant activity of extruded blend of malted rice-pigeon pea

Runs	Design Points (X1, X2, X3)	Polyphenol (µg GAE/g)	DPPH (mg TE/g)	ABTS (mg TE/g))
1	(15, 100, 19)	511.22 ±0.00	375.24 ±0.01	1112.02 ±0.01
2	20, 100, 19)	468.44 ±0.00	376.53 ±0.00	1265.11 ±0.02
3	(15, 130, 19)	1059.67 ±0.01	669.11 ±0.01	2283.90 ±0.03
4	(20, 130, 19)	1005.00 ±0.01	660.89 ±0.01	1662.86 ±0.02
5	(15, 115, 8)	585.33 ±0.00	494.35 ±0.00	1533.44 ±0.02
6	(20, 115, 8)	747.00 ±0.01	388.72 ±0.01	1010.44 ±0.01
7	(15, 115, 30)	1407.22 ±0.01	801.44 ±0.03	1928.17 ±0.01
8	(20, 115, 30)	1471.00 ±0.01	712.43 ±0.01	1947.67 ±0.02
9	(17.5, 100, 8)	572.44 ±0.00	375.05 ±0.01	1111.50 ±0.01
10	(17.5, 130, 8)	806.67 ±0.01	515.98 ±0.00	1503.20 ±0.02
11	(17.5, 100, 30)	817.33 ±0.00	494.35 ±0.01	1538.66 ±0.02
12	(17.5, 130, 30)	1274.89 ±0.01	743.10 ±0.01	2184.51 ±0.02
13	(17.5, 115, 19)	1024.11 ±0.01	649.79 ±0.00	1739.20 ±0.02
14	(17.5, 115, 19)	900.00 ±0.00	648.32 ±0.01	1576.62 ±0.03
15	(17.5, 115, 19)	873.00 ±0.01	617.13 ±0.01	1362.00 ±0.04
16	BRF	474.89 ±0.01	593.89 ±0.01	1035.05 ±0.02
17	MBRF	451.11 ±0.01	541.85 ±0.01	1081.46 ±0.01
18	PPF	1744.78 ±0.01	915.23 ±0.01	2710.54 ±0.01

Key (X1, X2, X3) (x1= Feed moisture, X2 = Extruder barrel Temperature X3= Feed Composition). BRF= Brown rice flour, MBRF=Malted brown rice four, PPF=Pigeon pea flour

As shown in Table 1, the polyphenol content increased significantly ($p < 0.05$) from 468.44 to 1471 µg GAE/g with increase in both barrel temperature and feed composition. According to the observations from result, the pigeon pea flour contained the largest amount of polyphenols, measuring 1744 µg GAE/g, compared to the other flours employed in this study. The rise in phenolic acid levels in extruded products with increase in barrel temperature, is primarily caused by the liberation from the cell wall matrix during the extrusion process as higher temperatures lead to the breakdown of the insoluble phenolic components and other cellular constituents, thereby enhancing the overall phenolic content. Malting pigeon pea increases the levels of bioactive substances, including total phenolic components, reducing power, metal chelating activity, and flavonoids (Rizvi *et al*., 2022). The variations in these changes can be attributed to the seed type and the conditions under which germination occurs. The study utilized red pigeon pea seeds, and according to Rizvi *et al*. (2022), the red pigeon pea exhibits a higher concentration of bioactive components compared to the white variety.

Antioxidant activity

The extrudates exhibited DPPH activity ranging from 375.05 to 801.44 mg TE/g. There was a significant ($p < 0.05$) increase (Table 2), in the DPPH activity with increase in feed composition and barrel temperature. This is expected as the polyphenol content increased likewise. The antioxidant activity and antiradical activity of extruded products rely on both the quantity and content of bioactive components. Pigeon pea contains a significant amount of tannin and when the grain proteins are subjected to the extrusion process, which involves kneading and high temperatures, the structure of the proteins becomes loose and open. This enhances the interaction between tannin and protein, resulting in the development of tannin-protein complexes. These complexes retain the antioxidant activity of the pigeon pea and degradation in the human gastrointestinal system, resulting in the liberation of bound tannins and their ability to function as scavengers of free radicals (Riedl and Hagerman, 2001). Raising the barrel temperature resulted in a rise in the Maillard reaction. The Maillard reaction, specifically the formation of melanoidins, is well-known for its antioxidant properties. The malting process of grains including brown rice, plays a significant role in enhancing antioxidant activity by hydrolyzing starch into sugars and promoting amino acid synthesis. Consequently, at high barrel temperatures, the Maillard reaction occurs between these components, resulting in an increased antioxidant capacity.

ABTS Activity

The Trolox equivalent antioxidant capacity, as measured by ABTS, of the extrudates ranged from 1010.44 to 2283.90 mgTE/g. The lowest degree of activity was seen in the product that was extruded at a feed moisture level of 20, a barrel temperature of 115 ^{o}C, and a pigeon pea composition of 8%. The extrudates with the highest ABTS activity were found in samples extruded with a feed moisture level of 15, a barrel temperature of 130 ^{o}C, and a pigeon pea composition of 19%. A significant ($p< 0.05$) increase (Table 2), was observed with the rise in barrel temperature and feed composition. The higher level of activity observed with lower feed moisture, increased feed composition, and higher barrel temperature indicates a stronger interaction between amino acids and simple sugars, leading to the occurrence of the Maillard reaction. The process of malting the grains resulted in a notable rise in amino acids and simple sugars, thereby promoting enhanced activity of the extrudates at high barrel temperature, mostly because of the Maillard reaction. Malted brown rice contains a high amount of ferulic acid, which is a powerful substance that can eliminate harmful free radicals. The inclusion of ferulic acid and tannin in malted pea is likely a significant factor in the antioxidant activity of the extrudates.

Table 2: Analysis of variance of the polyphenol and antioxidant properties of the developed quadratic model for malted rice–pigeon pea blend

Source	polyphenol p-value	DPPH p-value	ABTS p-value
Model	0.000	0.000	0.000
X1 (feed moisture)	0.510	0.043	0.004
X2 (barrel temperature)	0.000	0.000	0.000
X3 (feed composition)	0.000	0.000	0.000
$X1^2$	0.850	0.159	0.719
$X2^2$	0.000	0.000	0.992
$X3^2$	0.003	0.442	0.676
X1X2	0.931	0.890	0.001
X1X3	0.476	0.808	0.021
X2X3	0.109	0.121	0.264
Lack of fit	0.000	0.000	0.354
Coefficient of variation (%)	5.34	6.49	10.30
Coefficient of determination (R^2)	88.36%	87.30%	81.70%
Adjusted R^2	85.36%	84.03%	76.99%

Conclusion

Extrudates produced from flour blends of malted pigeon pea and brown rice showed significant ($p< 0.05$) increases in polyphenol content, ABTS and DPPH activity with increase in feed composition and barrel temperature, which can be attributed to synergistic effects of malting and extrusion, particularly the Maillard reaction and phenolic release. The findings suggest that optimized extrusion of malted legume and cereal blends can yield nutritionally superior, antioxidant-rich functional foods.

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Reference

Azuka, C., Onwuchekwa, A., Nwosu, A., Holmes, M., Boesch, C., Okafor, G.. (2025). The Effects of Malting and Extrusion on the Functional and Physical Properties of Extrudates from Malted Brown Rice and Pigeon Pea Flour Blends. *Foods* 14(3), 422. doi: 10.3390/foods14030422.

Baliyan, S., Mukherjee, R., Priyadarshini, A., Vibhuti, A., Gupta, A., Pandey, R. P., and Chang, C.-M. (2022). Determination of Antioxidants by DPPH Radical Scavenging Activity and

Quantitative Phytochemical Analysis of Ficus religiosa. Molecules, 27(4), 1326. https://doi.org/10.3390/molecules27041326

Dewanto, V., Wu, X., Adom, K.K. and Liu, R.H. (2002). Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity. Journal of agricultural and food chemistry, 50(10), pp.3010-3014.

Kolarov, R., Tukuljac, M.P., Kolbas, A., Kolbas, N., Barać, G., Ognjanov, V., Ljubojević, M. and Prvulović, D. (2021). Antioxidant capacity of wild-growing bilberry, elderberry, and strawberry fruits. Acta Horticulturae et Regiotecturae, 24(2), pp.119-126.

Riedl, K.M. and Hagerman, A.E., 2001. Tannin– protein complexes as radical scavengers and radical sinks. Journal of agricultural and food chemistry, 49(10), pp.4917-4923.

Rizvi, Q.U.E.H., Guiné, R.P., Ahmed, N., Sheikh, M.A., Sharma, P., Sheikh, I., Yadav, A.N. and Kumar, K. (2024). Effects of soaking and germination treatments on the nutritional, anti-nutritional, and bioactive characteristics of adzuki beans (Vigna angularis L.) and Lima beans (Phaseolus lunatus L.). Foods, 13(9), p.1422.

Uchegbu, N.N., and Ishiwu, C.N. (2016). Germinated Pigeon Pea (Cajanus cajan): a novel diet for lowering oxidative stress and hyperglycemia. Food Science andamp; Nutrition, 4(5), 772-777. https://doi.org/10.1002/fsn3.343

Effect of Storage on the Antioxidant and Vitamins of Tomato and Tomato-Pepper Mix Paste

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Abstract

Tomato and tomato-pepper mix pastes are prized for their nutritional profile, culinary versatility, and economic value, but their perishability and tendency to deteriorate during storage compromise their quality and safety. This study aimed to investigate the effect of storage on some chemical parameters of tomato and tomato-pepper mix paste over a period of 6 months. The antioxidant and vitamin analysis indicated that storage caused progressive chemical changes in tomato (TOM) and tomato-pepper mix pastes (TMP), including slight changes in vitamin C, 21.70 – 19.54 mg/100 g and 21.70 – 23.73 mg/100 g at 3 months in TOM and TMP respectively. Minimal changes in lycopene levels occurred in TOM (11.25 to 11.17 mg/100 g) after storage. Therefore, the study suggests that tomato paste products with or without the mixture of pepper and onion can be effectively stored for adequate preservation to maintain the safety and quality of tomato-based pastes, thereby contributing to reduced postharvest losses and food security.

Keywords: Shelf-life, Nutritional composition, Nutrient retention, Value addition, Food quality

Introduction

Tomato (*Solanum lycopersicum*) is globally one of the most cultivated and consumed vegetable fruits, playing a vital role in food security and nutrition. Fresh tomatoes (*Solanum lycopersicum*) are a common climacteric fruit that adds a lot of variety to cooking and are essential since they are high in vitamins, minerals, and antioxidants, such as lycopene. Peppers (*Capsicum spp.*) are also integral in Nigerian cuisine, often combined with tomatoes to enhance flavour and nutritional content in local dishes. Tomatoes contain lycopene, beta-carotene, vitamin C, and polyphenols, while peppers supply capsaicinoids, vitamin C, and flavonoids (Duranova et al., 2021). These compounds possess antioxidative and anti-inflammatory properties, which contribute to disease prevention and health maintenance. Onions (Allium cepa) are nutrient-dense, low-calorie vegetables that deliver multiple health benefits through vitamins, minerals and abundant bioactive compounds. Regular consumption is associated with antioxidant and anti-inflammatory effects, improved cardiovascular markers (blood pressure, lipids), modulation of blood

glucose, and prebiotic support for gut microbiota effects largely attributed to flavonoids notably quercetin, organosulfur compounds including thiosulfinates and sulfoxides, fructooligosaccharides and vitamin C. Processing tomatoes, peppers and onions into value-added products such as pastes contributes significantly to reducing losses and extending shelf life. This study aims to investigate the effect of storage on the chemical parameters of tomato and tomato-pepper mix pastes. The findings will provide valuable insights into product stability, guiding improvements in processing and storage practices for enhanced food security and nutrition in the region.

Methodology

Procurement of samples

Mature ripe tomatoes of the "Roma" variety, scotch bonnet and onion bulbs were procured from Bodija market, Ibadan, Oyo State, Nigeria. The vegetables were transported to the processing centre of Nigerian Stored Products Research Institute, Ibadan, in sterile polythene bags.

Preparation of tomato and tomato-pepper mix paste

The raw tomatoes were sorted and wholesome ones were separated into two groups, washed and then weighed following the method of Safdar et al., (2010) with some modifications. A portion of the cleaned tomatoes (3.181 kg) was smoothly blended without straining, with the aid of a kitchen grinder to imitate major Nigerian cuisine styles and the puree was boiled in a clean pot (without preservatives) until paste formation. Tomato paste (TOM) was immediately hot-filled (at 95-100 °C) equally in three pre-sterilized glass bottles, corked with sterilized airtight cap and subsequently cooled. Antioxidant and vitamin analyses were carried out on a 3-month interval. Following the same method, tomato-pepper mix (TMP) paste (Figure 1) was prepared. After sorting and washing, the second portion of the tomatoes (3.181 kg) equivalent to 85.93% of a traditional recipe, scotch bonnet (2.24%) and onions (11.83%), were milled together and smoothly blended without straining.

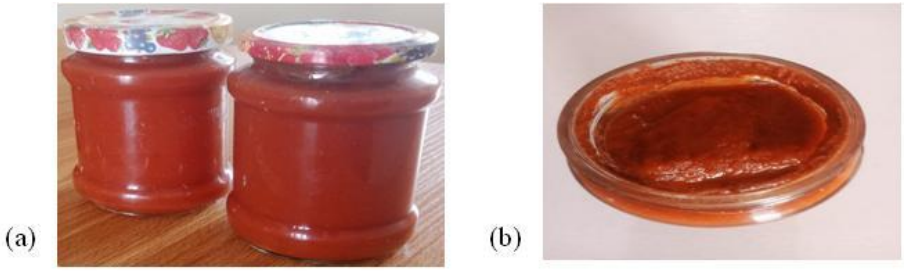


Figure 1. Photograph of (a) Tomato paste after 3-month storage period and (b) Tomato-pepper mix paste after 6 month

Flavonoid Determination

The flavonoid content of the samples was determined according to the procedure described by Park et al. (2008).

Determination of Phenol

Two millilitres of the paste was mixed with 0.5 mL of Folin-Ciocalteau Reagent and 1.5 mL Sodium Carbonate (20%). The mixture was stirred for 15 s and allow to stand at 40 °C for 30 min to develop colour. Phenol was measured at A_{765} and expressed in Gallic Acid Equivalent

Determination of ß-carotene content

ß-carotene content of the sample was determined according to AOAC (2005) procedure.

$$\text{ß} - \text{carotene}\left(\mu g/100g\right) = \frac{\text{Absorbance of sample} \times \text{Dilution factor}}{\text{Weight of sample}}$$

Determination of vitamin B_6

Vitamin B_6 (Pyridoxine) content of the sample was determined according to the procedure by (AOAC, 2005). Vitamin B6 in mg/100g was calculated using the formula:

$$\frac{\text{Absorbance of sample} \times \text{Gradient Factor} \times \text{Dilution factor}}{\text{Weight of sample} \times 100}$$

Determination of vitamin B_9

The vitamin B_9 (Folic acid) content of the sample was determined according to the procedure by Eitenmiller and Landen (1999).

Determination of ascorbic acid

The ascorbic acid content of the sample was determined using the titratable method by Eitenmiller and Landen (1999).

Statistical analysis

Data were expressed as the mean of triplicate determinations ± Standard error of mean, analyzed by ANOVA, and the means separated by significant difference at 5% level, using SPSS Version 20 according to Duncan Post Hoc Test.

Results and Discussion

Effect of storage on the antioxidant and vitamin content of pastes

From the results (Table 1), it was observed that lycopene in TOM, decreased from 11.25 mg/100 g to 11.17 mg/100 g at 6 months. Flavonoids also reduced from 5.91 to 5.49 mg/100 g. Ascorbic acid reduced to 21.72 mg/100 g at 6 months in TOM. However, in TMP, lycopene dropped to 9.64 mg/100 g at 6th month, while the flavonoid content decreased to 4.08 mg/100 g at the end of storage. The ascorbic acid in TMP

increased to 23.73 mg/100 g at 3 months and later observed to have decreased (20.76 mg/100 g) after 6 months. Vitamin C supports immune function, collagen synthesis, and iron absorption (Alberts et al., 2025).

Table 1. Effect of storage on the antioxidant and vitamin content of the samples

Sample	Antioxidants	Storage Length		
		0 month	3 months	6 months
TOM	ß-carotene (µg/100g)	7.74±0.162^{b}	6.60±0.038^{a}	6.22±0.022^{a}
	Lycopene (mg/100g)	11.25±0.049^{b}	7.40±0.045^{a}	11.17±0.045^{b}
	Ascorbic acid (mg/100g)	21.70±0.220^{b}	19.54±0.192^{a}	21.72±0.078^{b}
	Flavonoid (mg/100g)	5.91±0.071^{c}	3.54±0.139^{a}	5.49±0.045^{b}
	Phenol (mgGAE/100g)	73.47±19.206^{a}	74.21±19.378^{a}	71.72±19.089^{a}
	Vitamin B_6 (mg/100)	0.79±0.084^{a}	0.61±0.015^{a}	0.58±0.015^{a}
	Vitamin B_9(mg/100)	12.25±0.064^{c}	9.61±0.179^{a}	10.15±0.024^{b}
TMP	ß-carotene (µg/100g)	5.89±0.018^{b}	6.37±0.015^{c}	5.34±0.015^{a}
	Lycopene (mg/100g)	11.25±0.049^{b}	16.62±0.026^{c}	9.64±0.015^{a}
	Ascorbic acid (mg/100g)	21.70±0.220^{b}	23.73±0.218^{c}	20.76±0.095^{a}
	Flavonoid (mg/100g)	4.51±0.048^{c}	3.83±0.074^{a}	4.08±0.018^{b}
	Phenol (mgGAE/100g)	57.48±13.090^{a}	55.89±12.540^{a}	58.01±13.223^{a}
	Vitamin B_6 (mg/100)	0.43±0.022^{b}	0.24±0.012^{a}	0.45±0.009^{b}
	Vitamin B_9(mg/100)	10.64±0.147^{b}	8.46±0.07^{a}	8.64±0.009^{a}

Values are represented as the mean of triplicate determinations ± standard error of mean. Means in the same row that are followed by the same letters are not significantly different at 5% level according to Duncan Post Hoc Test. TOM: Tomato paste. TMP: Tomato-pepper mix paste.

B-carotene decreased in both TOM (6.22 µg/100g) and TMP (5.34 µg/100g) at 6 months. This aligns with reports that heat and storage can initially improve carotenoid extractability but eventually cause oxidative degradation. Total phenols appeared to be stable, with TOM ranging from 73.47 to 71.72 mg/100 g and TMP from 57.48 to 58.01 mg/100 g. The stability of phenolic compounds suggests that antioxidant capacity was largely maintained during storage, in line with the findings of García-Alonso et al. (2009). Therefore, the general implication is that both TOM and TMP retain antioxidant potential after 6 months of storage, preserving their nutritional and functional value.

Vitamin B_9 (Folate) declined in TOM from 12.25 to 10.15 mg/100 g, while it reduced in TMP from 10.64 to 8.64 mg/100 g. Folates are generally sensitive to processing and storage, with losses of 20–30% common in vegetables. Vitamin B6 was slightly reduced in TOM from 0.79 to 0.58 mg/100 g, while its value fluctuated in TMP. Vitamin B_6 is generally more stable than folate, but can, however, degrade under prolonged storage due to oxidation or reaction with other compounds. Folate is essential for DNA synthesis, methylation processes, and the prevention of neural tube defects, while beta-carotene is vital

for vision and immune function. Lycopene has been associated with reduced risk of cardiovascular diseases and certain cancers due to its potent antioxidant capacity (Tufail et al., 2024).

Conclusion

This study showed that the chemical and nutritional properties of tomato (TOM) and tomato–pepper (TMP) pastes were influenced during storage. For instance in TOM, β-carotene (6.22 µg/100g) and folate (10.15 mg/100 g) exhibited significant reductions over time, confirming their sensitivity to oxidative and storage conditions, whereas vitamin B_6 (0.45 mg/100 g) was comparatively stable. Antioxidant compounds, including lycopene, ascorbic acid, and flavonoids, experienced temporary declines but were generally well retained after six months of storage, supporting the preservation of functional health benefits. Overall, both TOM and TMP demonstrated satisfactory shelf stability. Therefore, processing tomatoes into pastes can potentially enable a preservation strategy that maintains the nutritional and bioactive quality, thereby supporting the development of shelf-stable and health-promoting products.

References

Alberts, A., Elena-Theodora Moldoveanu, Niculescu, A.-G. & Alexandru Mihai Grumezescu. (2025). Vitamin C: A Comprehensive Review of Its Role in Health, Disease Prevention, and Therapeutic Potential. *Molecules*, *30*(3), 748–748. https://doi.org/10.3390/molecules30030748

AOAC. (2005). Association of Official Analytical Chemists. Official Methods of of A.O.A.C International, Gaithersburg, MD. USA.

Duranova, H., Valkova, V. & Gabriny, L. (2021). Chili peppers (Capsicum spp.): the spice not only for cuisine purposes: an update on current knowledge. *Phytochemistry Reviews*. https://doi.org/10.1007/s11101-021-09789-7

Eitenmiller and Landen (1999). Vitamin Analysis For The Health And Food Sciences. Boca Raton, Fl: Crc Press.

García-Alonso, F. J., Bravo, S., Casas, J., Pérez-Conesa, D., Jacob, K. & Periago, M. J. (2009). Changes in antioxidant compounds during the shelf life of commercial tomato juices in different packaging materials. *Journal of agricultural and food chemistry*, *57*(15), 6815-6822.

Safdar, M. N., Mumtaz, A., Amjad, M., Siddiqui, N. & Hameed, T. (2010). Development and quality characteristics studies of tomato paste stored at different temperatures. *Pakistan journal of nutrition*, *9*(3), 265-268.

Tufail, T., Huma Bader Ul Ain, Noreen, S., Ikram, A., Arshad, M. & Abdullahi, M. (2024). Nutritional Benefits of Lycopene and Beta-Carotene: A Comprehensive Overview. *Food Science & Nutrition*, *12*(11). https://doi.org/10.1002/fsn3.4502

Sustainable Soil-Based Storage for Carrots: A Low-Technology Approach to Postharvest Preservation

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Abstract

Fresh produce experiences 30-40% postharvest losses globally, with root vegetables particularly vulnerable in regions like rural sub-Saharan Africa lacking refrigeration infrastructure. This study evaluated sandy soil and loamy soil as storage media for preserving carrot quality under ambient conditions over 20 days. Freshly harvested carrots (n=90) from Mararaba, Ilorin, Nigeria, were divided into three treatments: control (no storage medium), sandy soil, and loamy soil storage. Sandy soil demonstrated superior performance with lowest weight loss (17.49% vs. loamy soil 55.4% and control 66.77%) and decay incidence (12.5% vs. loamy soil 62.5%). It also maintained optimal carotenoid retention (lycopene: 0.061 mg/100 g; β-carotene: 0.02-0.12 mg/100 g). Loamy soil excelled in firmness preservation (28.89 N at day 12) but showed highest decay incidence (62.5%). Control samples exhibited excessive shrinkage by day 12. Sandy soil storage represents an optimal balance between moisture control, aeration, and microbial suppression, offering a sustainable, low-cost alternative to expensive refrigeration systems for smallholder farmers, traditional communities, and off-grid operations worldwide.

Keywords: soil-based storage, sustainable agriculture, smallholder farmers, carrot storage, postharvest quality, low-technology preservation.

Introduction

Postharvest losses represent 30-40% of fresh produce globally, with root vegetables experiencing severe losses in regions like Africa lacking refrigeration infrastructure (Kumar & Sagar, 2017). These losses affect diverse communities including smallholder farmers in developing regions, off-grid agricultural communities, and traditional farming groups such as the Amish who prioritize low-technology solutions. In tropical regions, carrot losses frequently exceed 30% during postharvest handling due to limited cold storage access. Carrot (*Daucus carota* L.), rich in β-carotene and essential antioxidants, faces significant storage challenges despite its nutritional importance (Saini & Keum, 2018). Contemporary storage methods require substantial infrastructure investments exceeding the capacity of many farming operations, creating critical need for low-cost, locally adaptable solutions. Traditional soil-based storage

practices have been empirically developed across agricultural communities worldwide. These methods have been used historically in diverse contexts, from root cellars in temperate climates to earth pits in tropical regions, but lack comprehensive scientific validation (Eze & Uzoechi, 2016). This study evaluates sandy and loamy soils as natural storage media under ambient tropical conditions to determine their effectiveness in maintaining carrot quality and minimizing postharvest losses. It was hypothesized that sandy soil would provide better aeration and lower microbial activity than loamy soil, leading to improved shelf stability.

Methodology

Experimental Design

Freshly harvested carrots (*n* = 90; 10.5–80.5 g each) were obtained from Mararaba, Ilorin Local Government Area, Kwara State, Nigeria, during the dry season (April). The samples were sorted into three groups of 30, with the control group receiving no storage treatment. Sandy soil, and Loamy soil. Storage boxes (25×30×20 cm, made of paperboard) were used with top cut open, Boxes contained a 2 cm drainage layer of sand at the bottom, followed by 9 kg of sieved soil. Soil was sieved using 1.25 mm mesh to remove debris and ensure uniform particle size. Sandy and loamy soil were collected from the Nigerian Stored Products Research Institute. Carrots were not washed, air-dried for 2 hours, and no fungicide was applied before storage. Carrots were layered without touching and analyzed every 4 days over 20 days. Storage was conducted under ambient conditions with average temperature 28-32 °C and relative humidity 70-85% during the dry season in Ilorin.

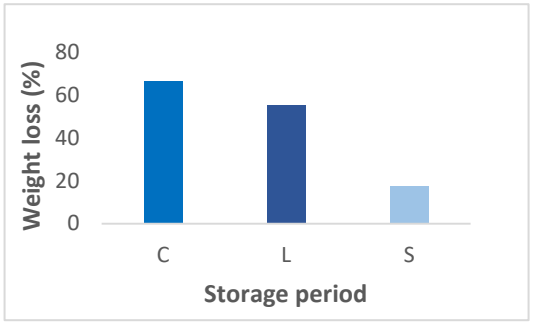
Analytical Methods

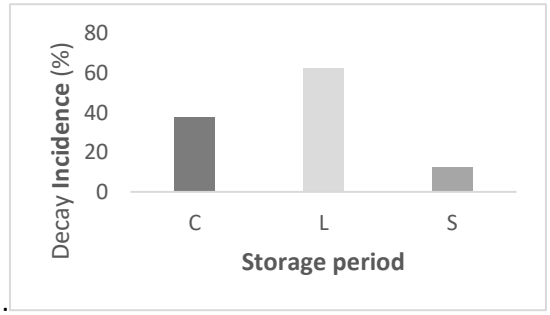
AOAC (2019) methods were used to determine moisture and ash content. pH, titratable acidity (TTA), and total soluble solids (TSS) were measured using standard procedures. Vitamin C was analyzed using dichlorophenol indophenol titration. Lycopene and β-carotene were estimated spectrophotometrically using Nagata-Yamashita equations. Weight loss was determined as percentage reduction from initial weight. Decay incidence was assessed as the proportion of fruits exhibiting visible spoilage (Mahajan et al., 2014). Color attributes (L*, a*, b*) were measured using a colorimeter in the CIELAB system. Firmness of samples was measured using a Magness-Taylor penetrometer according to AOAC (2019). Statistical analysis was done using SPSS and GraphPad Prism with two-way ANOVA and Tukey's post-hoc test ($P<0.05$).

Results and Discussion

Physicochemical Qualities and Storage Performance

The control group was terminated at day 12 due to >70% decay and firmness below 7 N, making further analysis unreliable. The treated groups were maintained until day 20. Sandy soil achieved optimal balance with lowest weight loss (17.49%) versus loamy soil (55.4%) and control (66.77%). Carrots with <20% weight loss are typically considered marketable; sandy soil achieved this benchmark for 20 days while control and loamy soil exceeded this by day 12. These findings demonstrate that moisture retention alone cannot predict storage success; optimal gas exchange and microbial control are equally critical





Figures 1 and 2: Effect of storage method on weight loss and decay incidence of stored carrots over 20 days. Values represent mean ± SE of triplicate measurements. C= Control; L= Loamy soil; S= Sandy soil.

Ash content increased significantly across treatments due to moisture loss concentrating minerals. Moisture content declined consistently across treatments, with loamy soil retaining significantly more moisture due to superior water-holding capacity. However, this moisture retention paradoxically correlated with highest decay incidence (62.5%) compared to sandy soil (12.5%) and control (37.5%). The high water activity in loamy soil created anaerobic conditions favoring decay-promoting microorganisms, while sandy soil's coarse texture facilitated gas exchange and maintained aerobic conditions that suppressed spoilage (Ozturk et al., 2019).

pH remained stable (6.67-7.09), appropriate for low-acid vegetables and indicating stable biochemical conditions in sandy and loamy soil treatments. TTA increased from 0.0536 to 0.1876 by day 16, reflecting organic acid production through microbial fermentation. Sandy soil maintained more consistent pH levels, suggesting reduced fermentation compared to loamy soil conditions. TSS patterns revealed sophisticated storage dynamics. Sandy soil consistently maintained highest values, particularly during days 8-12 when sugar concentrations peaked. Moderate sugar concentration (9.53°Brix in sandy soil at day 16) is desirable for consumer preference, indicating that sandy soil storage maintains both nutritional and sensory quality.) The anomalous increase in TSS in control samples (15.63°Brix at day 12) reflects concentration due to severe water loss and enzymatic breakdown rather than true quality maintenance.

Table 1: Physicochemical qualities of stored carrot

Sample	Storage days	Ash (%)	Moisture (%)	pH	TSS (°Brix)	TTA (%)
Control		1.14±0.00^{a}	89.79±0.45^{a}	6.90±0.01^{a}	9.20±0.10^{a}	0.06±0.00^{a}
Sandy	0	1.14±0.00^{a}	89.79±0.45^{a}	6.90±0.01^{a}	9.20±0.10^{a}	0.06±0.00^{a}
Loamy		1.14±0.00^{a}	89.79±0.45^{a}	6.90±0.01^{a}	9.20±0.10^{a}	0.06±0.00^{a}
Control		1.31±0.13^{a}	87.58±0.07^{a}	6.90±0.01^{b}	8.30±0.10^{c}	0.05±0.00^{a}
Sandy	4	1.21±0.03^{a}	90.75±0.54^{c}	6.80±0.01^{a}	6.20±0.10^{a}	0.05±0.00^{a}
Loamy		1.60±0.12^{b}	89.61±0.13^{b}	6.89±0.02^{b}	6.60±0.10^{b}	0.07±0.00^{b}
Control		1.06±0.11^{b}	81.77±0.29^{a}	6.81±0.01^{a}	12.03±0.12^{c}	0.10±0.00^{c}
Sandy	8	0.41±0.13^{a}	90.34±0.63^{b}	6.78±0.03^{a}	4.20±0.00^{b}	0.09±0.00^{b}
Loamy		0.40±0.03^{a}	91.38±0.66^{b}	6.89±0.03^{c}	3.43±0.06^{a}	0.07±0.00^{a}
Control		2.61±0.02 ^{c}	66.01±0.43 ^{a}	7.09±0.01^{c}	15.63±0.03^{c}	0.33±0.03^{c}
Sandy	12	1.28±0.01^{b}	91.29±0.67^{b}	6.85±0.01^{a}	4.47±0.06^{a}	0.06±0.00^{a}
Loamy		0.30±0.00^{a}	90.66±0.18^{b}	6.92±0.02^{b}	5.60±0.00^{b}	0.07±0.01^{b}
Control		-	-	-	-	-
Sandy	16	0.87±0.01^{a}	86.83±0.01^{b}	6.78±0.01^{b}	9.53±0.12^{b}	0.18±0.01
Loamy		0.98±0.01^{b}	85.98±0.01^{a}	6.68±0.02^{a}	8.77±0.12^{a}	0.11±0.01
Control		-	-	-	-	-
Sandy	20	1.37±0.01^{a}	85.61±0.32^{a}	6.96±0.01^{a}	8.03±0.06^{b}	0.08±0.00
Loamy		1.45±0.03^{b}	86.01±0.40^{b}	6.98±0.01^{a}	6.97±0.06^{a}	0.17±0.00

Result represents mean ± standard error (SE) of triplicate values. At day 0, all treatments were identical, hence SE = 0.00. Means with unshared superscripts (a, b, c) in the same column are significantly different at $P<0.05$ by Tukey's post-hoc test

Nutritional qualities of stored carrots

Vitamin C declined across all treatments, with loamy soil showing better early retention due to moisture-conserving properties reducing oxidative stress. Sandy soil demonstrated moderate but consistent preservation, while control samples showed initial increase followed by drastic decline. Sandy soil retained 70% of initial vitamin C at day 20, compared to 87% in loamy soil and 59% in control (by day 12). The stability in sandy soil correlated with controlled water activity that inhibited ascorbic acid oxidase (Matějková & Petříková, 2013). Carotenoid compounds exhibited remarkable responses to storage conditions. Lycopene content increased during early storage, reaching maximum 0.061 mg/100g in sandy soil by day 12. This may reflect either de novo biosynthesis in response to mild storage stress or concentration due to moisture loss. Further metabolomic analysis would clarify the mechanism. β-carotene patterns (0.02-0.12 mg/100g range) mirrored lycopene trends. Sandy soil's porous structure facilitates gas exchange, maintaining aerobic conditions that reduce oxidative stress and preserve carotenoids (Saini & Keum, 2018).

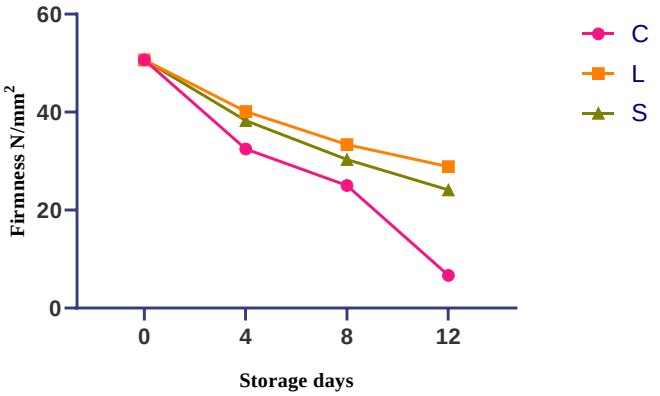
Table 2: Nutritional qualities of stored carrots

Sample	Storage days	β-carotene (mg/100 g)	Vitamin C (mg/100 g)	Lycopene (mg/100 g)
Control	0	0.09±0.00^{a}	9.52±0.36^{a}	0.03±0.00^{a}
Sandy		0.09±0.00^{a}	9.52±0.36^{a}	0.03±0.00^{a}
Loamy		0.09±0.00^{a}	9.52±0.36^{a}	0.03±0.00^{a}
Control	4	0.11±0.00^{c}	12.14±0.33^{a}	0.03±0.00^{a}
Sandy		0.08±0.00^{b}	14.24±0.24^{c}	0.03±0.00^{a}
Loamy		0.07±0.00^{a}	13.61±0.19^{b}	0.03±0.00^{a}
Control	8	0.11±0.00^{b}	10.70±0.60^{c}	0.01±0.00^{a}
Sandy		0.12±0.00^{c}	8.71±0.11^{a}	0.02±0.00^{b}
Loamy		0.03±0.00^{a}	9.36±0.14^{b}	0.03±0.00^{c}
Control	12	0.05±0.00^{b}	5.61±0.11^{a}	0.04±0.00^{a}
Sandy		0.04±0.00^{a}	9.78±0.19^{b}	0.04±0.00^{a}
Loamy		0.07±0.00^{c}	12.59±0.04^{c}	0.04±0.00^{a}
Control	16	-	-	-
Sandy		0.04±0.00^{b}	7.75±0.12^{a}	0.06±0.00^{b}
Loamy		0.03±0.00^{a}	8.27±0.06^{b}	0.04±0.00^{a}
Control	20	-	-	-
Sandy		0.06±0.00^{b}	6.64±0.15^{a}	0.02±0.00^{a}
Loamy		0.02±0.00^{a}	8.27±0.06^{b}	0.03±0.00^{b}

Result represents mean ± standard error (SE) of triplicate values. Means with unshared superscript in the same column are significantly different.

Texture and visual quality assessment of stored carrots

Firmness measurements revealed dramatic differences across treatments. Although loamy soil maintained superior firmness (28.89 N) compared to sandy soil (24.16 N) at day 12, this advantage was negated by rapid decay in 62.5% of samples, making it unsuitable for practical storage. Control samples deteriorated to 6.67 N, attributed to reduced dehydration stress and preserved cellular architecture in loamy soil (Seljåsen et al., 2013; Kumar & Sagar, 2017)



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Figure 3: Effect of storage method on firmness (N) of stored carrots over 20 days. Values represent mean ± SE of triplicate measurements. C= Control; L= Loamy soil; S= Sandy soil.

Color stability analysis showed sandy soil produced most stable visual characteristics. Total Color Intensity increased from 5.82 to 17.39, indicating enhanced vibrancy through controlled pigment concentration. Control samples experienced severe hue angle decline (82.15° to 64.06°), reflecting enzymatic browning and pigment degradation, indicating poor visual quality and unmarketable appearance (Hendrick et al., 2019).

Table 3: Colour attributes of stored carrots

		Control	Sandy	Loamy
Colour Index	**Colour readings**	**Treatment groups**		
Total Color Intensity (TCI)	Initial	5.82±2.34	5.82±2.34	5.82±2.34
	final	17.399^{a}±0.12	17.393^{a}±0.95	18.301^{a}±0.51
Perceptible Color change (ΔE)	Initial	0.00	0.00	0.00
	final	14.495^{b}±1.16	14.625^{b}±1.54	8.485^{a}±0.79
Hue angle (h°)	Initial	82.149±3.25	82.149±3.25	82.149±3.25
	final	64.089^{a}±0.25	64.057^{a}±1.10	67.917^{b}±0.56
Chroma (C*)	Initial	25.007±1.68	25.007±1.68	25.007±1.68
	final	35.528^{b}±0.83	35.540^{b}±0.50	23.142^{a}±1.39

Conclusion

Sandy soil represents an optimal storage medium for ambient carrot preservation, offering accessible solutions for diverse contexts including smallholder farmers in tropical regions, off-grid agricultural operations, and traditional farming communities worldwide that prioritize low-technology approaches. Sandy soil's effectiveness emerges from its unique ability to balance moisture retention with adequate aeration, creating microenvironments that minimize both dehydration stress and microbial proliferation. While loamy soil demonstrated advantages in moisture and firmness retention, its tendency toward

anaerobic conditions and microbial proliferation limits practical effectiveness. The accessibility and low cost of this method make it immediately adoptable across various agricultural systems globally.

Recommendation

Farmers and vegetable retailers should adopt sandy soil storage systems using clean, well-drained soil with 0.05-2.0 mm particle sizes sourced from river beds or gardens while avoiding polluted areas. Storage containers such as cardboard boxes which are readily available, incorporating a 2-3 cm layer of sand before adding the produce. Regular monitoring and mild wetting every 4 days through visual inspection and gentle squeezing enables early detection and removal of deteriorating specimens showing soft spots, slime, or mold. Agricultural extension programs should develop demonstration plots in farmer cooperatives, train farmer-to-farmer extension agents, and create simple visual guides in local languages. Future research should prioritize testing across different carrot cultivars and climatic zones, optimizing soil particle size and moisture content for various conditions, and evaluating scalability for commercial operations while examining cost-effectiveness across different contexts.

References

AOAC (2019). Official Methods of Analysis of AOAC International, 21st Edition. AOAC International, Rockville, MD, USA

Bender, I., Moor, U., & Luik, A. (2015). The effect of growing systems on the quality of carrots. *Research for Rural Development Conference Proceedings*, 1, 118-123.

Eze, J. I., & Uzoechi, O. (2016). Effect of clay-soil storage on the postharvest quality of carrots under tropical conditions. *Nigerian Food Journal*, 34(1), 45-53.

Hendrick, N.J., Schifferstein, H.N.J., Wehrle, T., & Carbon, C.C. (2019). Consumer expectation for vegetables with typical and atypical colours: The case of carrots. *Food Quality and Preference*, 72, 98-108.

Islam, M. N., Khan, M. M. R., & Rahman, M. M. (2010). Retention of nutritional quality of solar dried carrot during storage. *Bangladesh Journal of Scientific and Industrial Research*, 45(4), 359-362.

Kumar, P., & Sagar, V. R. (2017). Effect of storage environments on quality and shelf life of carrot roots. *Postharvest Biology and Technology*, 131, 95-102.

Mahajan, P. V., Caleb, O. J., Singh, Z., Watkins, C. B., & Geyer, M. (2014). Postharvest treatments of fresh produce. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 372(2017), 20130309.

Matějková, J., & Petříková, K. (2013). Changes in vitamin C content and soluble solids of carrot roots during long-term storage. *Acta Horticulturae et Regiotecturae*, 16(1), 1-5.

Ozturk, I., Yilmaz, M. T., & Khawar, K. (2019). Comparison of different storage conditions for carrots and their influence on shelf life and microbial load. *LWT - Food Science and Technology*, 105, 190-198.

Rashidi, M., Ranjbar, I., Gholami-Parashkouhi, M., & Abbassi, S. (2010). Prediction of Total Soluble Solids and Firmness of Carrot Based on Carrot Water Content. *International Journal of Agriculture and Biology*, 12(2), 237-240.

Saini, R. K., & Keum, Y. S. (2018). Significance of genetic, environmental, and pre-and postharvest factors affecting carotenoid contents in crops: a review. *Journal of Agricultural and Food Chemistry*, 66(21), 5310-5324.

Seljåsen, R., Kristensen, H. L., Lauridsen, C., Wyss, G. S., Kretzschmar, U., Birlouez-Aragone, I., & Kahl, J. (2013). Quality of carrots as affected by pre- and postharvest factors and processing. *Journal of the Science of Food and Agriculture*, 93(11), 2611-2626.

Challenges and Prospects of Milk Handling Practices in Nigeria: A Review

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Abstract

Milk handling practices in Nigeria face significant challenges that affect the quality, safety, and availability of dairy products. This review examines the challenges and prospects of milk handling in Nigeria, a country where dairy farming is predominantly carried out by smallholder farmers using traditional methods that contribute to high contamination rates and post-harvest losses. The informal milk sector, accounting for about 95% of total production, often operates without adequate quality control measures, posing public health risks through consumption of contaminated raw milk. Key challenges identified include inadequate infrastructure, poor hygiene practices, limited access to credit facilities, marketing constraints, and weak regulatory enforcement. Prospects for improvement include adoption of modern technologies, capacity building for farmers and handlers, policy interventions, and growing demand for dairy products. This review paper recommends enhanced farmer training, improved infrastructure, strengthening regulatory frameworks, and stringent quality control system to ensure milk safety and quality. Addressing these challenges is essential for improving dairy production, enhancing food security, and reducing Nigeria's reliance on imported dairy products.

Keywords: Contamination, food safety, milk handling

Introduction

Milk is a complex biological fluid containing proteins, fats, lactose, enzymes, minerals, organic acids and vitamins. It serves as the primary source of nutrition for young mammals and plays an important role in enhancing food security and household income (Yusuf, 2024). However, milk is a highly perishable, with a short shelf life of about 3–5 hours due to its rich nutrient composition, which supports the rapid microbial growth and poses significant public health risks. In Nigeria, dairy farming is primarily practiced by smallholder farmers who predominantly utilize traditional methods for milk collection which frequently result in high contamination rates, spoilage, and significant post-harvest losses (Williams et al., 2023). The Nigerian milk sector operates under two main systems: the informal and formal sectors. The informal system accounts for approximately 95% of milk production, mainly through pastoralist communities and traditional processing into local products like nono and fura da nono. In contrast, the formal system is dominated by multinational companies and a few local processors relying on imported milk, and

distribution through formal retail channels. The informal chain focuses on local markets with raw or minimally processed products sold by Fulani women, while the formal chain utilizes advanced processing and packaging for products like powdered milk and yoghurt, distributed through wholesalers and retail outlets. Inadequate quality control for milk produced and handled in the informal channels, makes milk easily contaminated. Milk handlers constitute a major critical point in the transmission and control of milk-borne infections to consumers. The sale of unpasteurized milk to consumers, either directly or indirectly through small-scale vendors, is a common scene in the rural and urban areas of Nigeria. Local production of milk in Nigeria is less than 1% with milk consumption falling below the global average of about 40 litres per head annually. Thus, limited amount of milk and milk products are available for consumption by the populace. More than 90 % of annual milk production is derived from cows reared in low-input, low-yielding pastoral systems and marketed through informal value chains (Ghali-Mohammed, et al., 2022). Given this challenged, this review aimed to examine the current milk handling practices in Nigeria, identifying the key challenges affecting milk quality and safety, and explore prospects for improvement through technological, institutional and policy interventions.

Importance of milk handling and its impact on public health

Quality milk is the milk of normal chemical composition, free from harmful bacteria and toxic substances. Good hygienic practice is important in the production of milk. Poor milk handling poses a significant public health risk by spreading pathogens like *Salmonella* and *E. coli* through contaminated raw milk, leading to foodborne illnesses, especially in vulnerable populations such as children, the elderly, and the immunocompromised (Silveira et al., 2023).

Challenges of milk handling practices in Nigeria

The dairy industry in Nigeria comprises a chain of activities, including collection, bulking, processing, transportation, distribution, and marketing. Ensuring milk safety in Nigeria remains a significant challenge due to poor handling and hygiene practices, particularly in informal settings (Ghali-Mohammed et al., 2025). Notable challenges affecting milk handling in Nigeria are outlined below:

Inadequate infrastructure

One of the major challenges facing the milk industry in Nigeria is inadequate infrastructure. The lack of proper infrastructure, such as good roads, storage facilities, and processing plants, has hindered the growth and development of the sector. Also, inadequate storage facilities have led to post-harvest losses, reducing the profitability of dairy farming. Many dairy farmers still rely on traditional and outdated farming practices, resulting in low yields and poor-quality milk.

Marketing and distribution

Marketing and distribution are also major challenges facing milk farmers in Nigeria. The lack of organized marketing systems and distribution networks has made it difficult for farmers to find markets for their products. Because of this, many farmers are forced to sell their products to middlemen at low prices, reducing their profits. Furthermore, the lack of proper packaging and labeling of milk products has limited their marketability and contributed to their low demand (Tunji et al., 2020).

Access to credit

Another significant challenge faced by milk farmers in Nigeria is the lack of access to credit. Many farmers lack the necessary funds to purchase the inputs they need to boost their productivity, such as improved breeds of cattle, veterinary services, and dairy equipment. Many farmers rely on personal savings or informal sources of credit, which can be unreliable and expensive (Kumar et al., 2023).

Lack of training and regulatory Challenges

Many farmers lack the necessary knowledge and skills to implement modern farming practices, such as improved feeding and breeding techniques, that could help boost their productivity. Regulatory challenges in Nigerian milk handling include the existence of weak and evolving regulations, insufficient enforcement, a lack of clear guidelines for veterinary drug use and antibiotic resistance (Owusu-Kwarteng et al., 2020).

Prospects and of Milk Handling Practices in Nigeria

To achieve sustainable dairy production in Nigeria, it is essential to implement measures that enhance milk quality, promote the development of value-added milk products, and improve animal productivity must be urgently addressed. Reinforcement and implementation of the existing government policies on the availability of suitable and adequate food supply to the citizenry, laws that will support animal grazing without causing any harm to the residents, and application of smart and modern dairy farming technologies are promising solutions to boosting sustainable dairy development in Nigeria. There should be government interventions in providing the basic social amenities, sensitization and proper training of the dairy farmers including handlers and processors on best practices, and maintenance of hygienic practices during milking to curb any foodborne diseases (Adesulu-Dahunsi et al., 2023). Furthermore, the growing demand for dairy products in Nigeria presents significant opportunities for expansion and investment within the milk value chain.

Conclusion

The Nigerian dairy industry holds immense potential for growth and long-term sustainability. By addressing the key challenges of low productivity, inadequate infrastructure, and limited access to essential resources, stakeholders can unlock the full potential of the sector. Strategic interventions, capacity building, and effective collaboration among government agencies, researchers, and private investors are vital to achieving this goal. With these concerted efforts, Nigeria can strengthen its dairy production system, enhance food security, and significantly reduce reliance on imported dairy products.

Recommendations

1. There should be capacity building and regular training of dairy farmers and milk handlers on hygiene, milking techniques, and animal health.
2. Improvement of infrastructure by investing in cooling facilities, proper storage, and transportation systems.
3. Development and enforcement of standards for milk handling and processing including regular testing for quality and safety parameters should be implemented.

References

Adesulu-Dahunsi, A. T., Eze, E. E., Adeleke, A. J., James, F. A., Ayodele, P. F. & Osueke, C. O. (2023). Sustainable dairy development: a panacea to food insecurity in Nigeria (A review). *Trends in Science and Technology Journal,* 8(3), 222-230.

Ghali-Mohammed, I., Azeez, A. A., Adetona, M. A. Bakare, A.A.., Isola, T. O., Olawoye, D. C., Alhaji, N. B. & Odetokun, I. A. (2025). Knowledge, attitude and practice levels of Fulani milk processors toward milk contamination and hygiene in Northern Oyo State, Nigeria. *Discover Food,* 5(205). https://doi.org/10.1007/s44187-025-00506-3

Ghali-Mohammed, I., Odetokun, I. A., Raufu, I. A. & Adetunji, V. O. (2022). Handling practices and contamination of raw milk sold for consumption in markets of Kwara State, Nigeria. *Sokoto Journal of Veterinary Sciences*, 20(1), 50-58. http://dx.doi.org/10.4314/sokjvs.v20i1.7

Kuma, S. S., Umoh, D. B., Asogwa, T. H., Uzochukwu, A., Ezebuilo, R. U., Asogwa, K. A. & Azu, B. (2023). Access to credit and financial services on marketing of farm produce in Benue State, Nigeria. *Journal of African Studies and Development*, 15(2), 36-45. DOI: 10.5897/JASD2023.0681

Owusu-Kwarteng, J., Akabanda, F., Agyei, D., & Jespersen, L. (2020). Microbial safety of milk production and fermented dairy products in Africa. *Microorganisms*, 8(5), 752. Doi: 10.3390/microorganisms8050752

Silveira, A., Carvalho, J. P., Loh, L. & Benusic, M. (2023). Public health risks of raw milk consumption: Lessons from a case of paediatric hemolytic uremic syndrome. *Canada Communicable Diseases Report*, 49(9), 375-379. doi: 10.14745/ccdr.v49i09a03

Tunji, I., Buba, W., Saleh, I., Mohammed, A. T., Yusuf, M. A. & Paul, A. J. (2020). Cattle milk processing and marketing characteristics among agro-pastoralists in northwest Nigeria. *Nigerian Journal of Animal Production,* 46(1), 246-255. DOI:10.51791/njap.v46i1.1294

Williams, S. O., Agboola, A., & Famakinwa, M. (2023). Perception of Pastoralists on Dairy Production Technologies in Oyo State, Nigeria. *Sustainability, Agriculture, Food and Environmental Research*, 11. https://doi.org/10.7770/safer-V11N1-art2392

Yusuf, A. A. (2024). The prospect of beef and dairy products in Nigeria. *International Journal of Innovative Food, Nutrition and Sustainable Agriculture*, 12(2), 44-51.

Effect of Pre-treatments and Packaging Materials on the Quality of Dried Tomatoes during Storage.

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Abstract

Tomatoes (*Solanium lycopersicum* L.) are highly perishable due to their high moisture content and susceptibility to microbial spoilage. Effective preservation strategies such as pretreatment, drying and appropriate packaging are therefore essential to mitigate losses and maintain product quality. In this study, freshly harvested tomatoes were subjected to three (3) pre-treatments - steam for 5 minutes (T1), 10% salt solution (T2), and 10% lemon solution (T3) with an untreated control (T4). Samples were dried at 55^0C for 14 h using Nigerian Stored Product Research Institute (NSPRI) multi-crop dryer and stored for three (3) months in aluminum foil, polyethylene nylon, and brown envelopes. Data were collected on moisture content, microbial load, and insect infestation. Initial moisture content before packing in different packaging materials was highest in T4 (15.247±0,851 %) and lowest in T2 (14.677±0.872 %). Across the storage period, aluminum foil maintained the lowest moisture increase, whereas brown envelopes allowed significant moisture adsorption (up to 25.45 ± 0.95% by the third month). Microbial load was within the acceptable limit and no insect infestation was observed under any treatment. The findings indicate that salt pre-treatment combined with moisture-resistant packaging such as aluminum foil is best for storing dried tomatoes. Adoption of these strategies could substantially reduce postharvest losses, improve food availability, and enhance farmer income.

Keywords: Moisture content, packaging materials, pre-treatment, storage quality, tomatoes

Introduction

Tomato (*Lycopersicon lycopersicum* L) is one of the most widely consumed vegetables worldwide (Collins *et al*., 2022). According to FAOSTAT, global tomato production reached approximately 192 million tonnes in 2023, making tomato one of the most produced and consumed vegetable crops worldwide (Food and Agriculture Organization of the United Nations [FAO], 2024). Despite its importance, tomato is highly perishable due to its high moisture content, which ranges from 90-94%, making it extremely susceptible to microbial spoilage and rapid deterioration under ambient conditions (Agbabiaka *et al*., 2024).

Postharvest losses of tomato in Nigeria are alarmingly high, with estimates indicating that between 35–50% of harvested tomatoes are lost annually due to inadequate storage, poor handling, and microbial contamination (FAO & Kaduna State Government, 2025; Ojeleye *et al*., 2023; Abolade & Meludu, 2020). The perishable nature of fresh tomatoes, coupled with seasonal gluts, underscores the need for effective preservation techniques.

Drying is a widely adopted preservation method that reduces water content thereby minimizing microbial activity and extending shelf life (Pandya, 2024). Drying of agricultural produce markedly reduces weight and volume through moisture removal, which in turn lowers packaging, transport, and storage costs while extending shelf life (Mina *et al*., 2025; Ujong *et al*., 2024; Alp & Bulantekin, 2021). However, the success of drying depends on appropriate pretreatments and packaging materials that protect the dried product during storage. Pretreatment methods such as chemical dips (e.g. NaCl, $CaCl_{2)}$, blanching, or sulfur dioxide treatments, before drying, have been shown to preserve nutritional qualities and reduce microbial load in tomato products (Leke & Bembur, 2023).

Despite growing research on drying technologies, there is limited empirical evidence in Nigeria on how the combination of pretreatments and packaging materials influences the storability, microbial quality, and insect safety of dried tomatoes. This study therefore investigates the effect of selected pretreatments (salting, steaming, lemon solution) and packaging materials (aluminum foil, polyethylene nylon, and brown envelopes) on the quality attributes of dried tomatoes during storage.

Methodology

Experimental design and sample preparation

Freshly harvested and mature tomatoes were purchased from Qbest Farm (Ikorodu, Lagos State, Nigeria) and transported to the NSPRI processing unit. Fruits were sorted by removal of diseased, blemished tomatoes. They were washed under potable water, and sliced longitudinally into uniform thickness (5-10 mm). Four pretreatment groups were prepared:

i. Salt (10% w/v NaCl): slices immersed in 10% salt solution for 10 minutes and drained.
ii. Steam: slices exposed to steam for 5 minutes and allowed to cool.
iii. Lemon (10% v/v): slices immersed in 10% lemon (citric acid) solution for 10 minutes and then drained.
iv. Control: no pretreatment (washed only).

Each pretreatment batch (5 kg per replicate) was dried in an NSPRI multi-crop dryer at 55ºC for 14 h and allowed to cool to ambient temperature prior to packaging. The three packaging materials used were:

aluminum foil pouch (laminate foil), polyethylene bag (sealed), and brown paper envelope. Samples were taken at 0 (before packaging), 1, 2, and 3 months for analyses.

Moisture content

Moisture content (MC) was determined according to AOAC (2019). The moisture content was determined according to AOAC, official method 925.10. the moisture content was calculated as:

$$\% \text{ moisture} = (W1 + W2) - \frac{W3}{W1} \times 100$$

Where, W1 is the weight (g) of sample before drying; W2 is weight (g) of can; W3 is weight of sample after drying.

Microbial Analysis

Microbial assessment was carried out using the pour plate method of Aruwa and Akinyosoye (2015). Here, 1 g of each dried tomato sample was weighed aseptically into test tubes containing 9 ml of sterilized distilled water. A five-fold serial dilution of each treatment sample was prepared. One (1) ml of dilution factor 10^{-2} and 10^{-4} were inoculated into sterile petri dishes containing nutrient agar (NA) for Total Viable Count of bacteria, MacConkey agar for coliform bacterial count and Sabouraud dextrose agar (SDA) and fungal growth respectively. Incubation was carried out at 37˚C for 24 hours for bacterial growth, and 25˚C for 48-72 h for fungal growth.

Insect Infestation assessment

Samples were visually inspected monthly for signs of insect infestation (live insects, larva, frass, webbing, holes) during the 3-month storage period.

Statistical Analysis

Data generated from this study were analyzed using analysis of Variance (ANOVA). Values were expressed as mean ± standard error of the mean (SEM) from three determinations. Differences in mean were compared using Duncan's multiple test range. $P< 0.05$ was considered significant (Osuocha *et al.*, 2018)

Results and Discussion

Moisture content of pre-treated dried tomatoes

The initial MC of different pretreated dried tomatoes for salted, steamed, control and lemon before packaging ranged between the values of 14.677 ± 0.872 and 15.112 ± 1.553% as shown in Figure 1. Pretreatment before drying could improve the characteristics of the process and reduce the negative effects of drying on the quality of a product (Ade-Omowaye *et al,* 2002). The MC of the pretreated dried tomatoes before packaging falls within UNECE Standard for Dried Tomatoes (DDP-19, 2024) which stated

that reduced MC value is between 12 % – 18 %. The result shows that there's a significant difference (at $p<0.05$) in control dried tomatoes and lemon pretreated dried tomatoes. It was observed that moisture content increased during the storage period regardless of the pretreatment method. This is shown in figure 2. Result shows that foil packaging consistently maintained low moisture content (16.848 ± 0.245^{a}) in the first month to 18.760 ± 0.357^{a} % in the third month. Regardless of the pretreatment method during the three months storage, salted pretreatment in foil packaging maintained a low moisture content in the first two months while lemon pretreatment has the lowest moisture content in the third month. Brown envelope packaging materials shows increase in moisture content between 17.759 ± 1.556^{ab} % in the first month to 25.451 ± 0.948^{c} % in the third month, the implication is that moisture absorption occurred more in the brown envelope hence the increase in moisture content within the three months. This is consistent with the work of Latapi and Barrett (2006) who reported that the moisture content of the sun-dried tomatoes increased during storage. The high value of moisture content of the dried pretreated tomatoes is similar to the work of Vodouhe, *et al*, 2014 who stated that observations showed that dried tomato slices resulting from the various treatments shows an appreciable increase in moisture content from 24.76 to 47.11%.

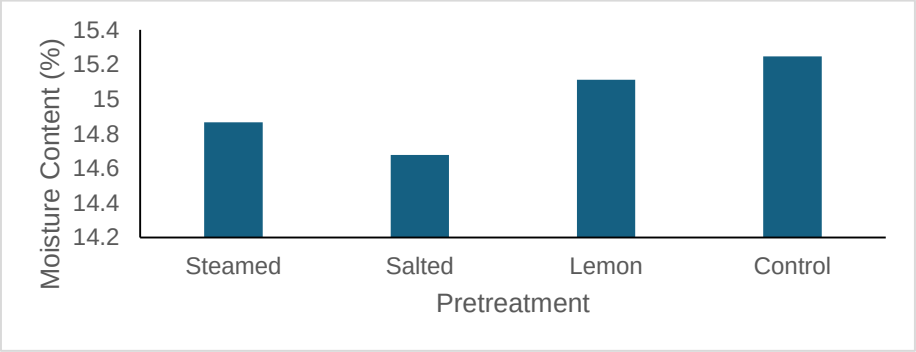
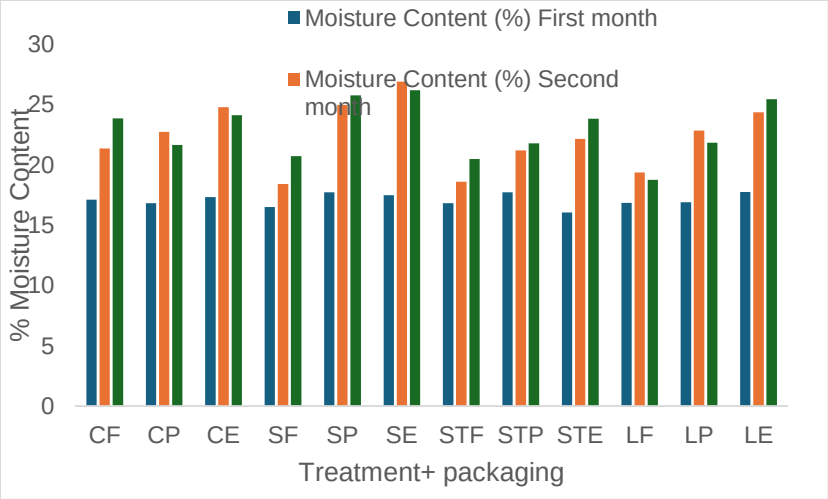


Figure 1: Percentage (%) Moisture content before Packaging



Where CF- Control in Foil, CP-Control in Polyethylene, CE- Control in Envelope, SF-Salted in foil, SP- Salted in polyethylene, SE- salted in envelope. STF- Steamed in foil, STP- steamed in polyethylene, STE-Steamed in envelope. LF- Lemon in foil, LP-lemon in polyethylene, LE- Lemon in envelope.

Figure 2: Percentage (%) Moisture content for three months using different packaging materials

Insect infestation

In this study, no insect infestation was observed in any of the dried-tomato treatment and packaging combinations over the 3-month storage period. This result is important because stored-product insects are a common cause of quantitative and qualitative losses in dried fruits and vegetables and can render products unsalable or unsafe (Hagstrum & Subramanyam, 2012). The absence of insect infestation over three months in this study demonstrates that good drying practice, pretreatment, hygienic handling, and moisture-resistant packaging can together prevent stored-product insect problems in dried tomatoes.

Microbial Analysis:

Microbiological quality is a common criterion used to determine the acceptability and shelf life of dehydrated plant-based products. This study shows that dried tomatoes are microbiologically safe as there were no bacterial and fungal growth on the dried pretreated tomatoes in the first two months, the same results were recorded by Latapi and Barrett (2006) in sun dried tomatoes which showed no bacterial and mold growth. The total bacterial and fungal count of samples were within the accepted range by Olaniyi et *al,* 2010 where values of $< 10^{-5}$ for bacteria and 10^{-3}-10^{-4} for fungi are recommended as shown in Table 3. The absence of coliform growth indicates good sanitary conditions and hygienic practices after drying and packaging. Coliform counts are used as hygienic indicators and its absence suggests proper handling and processing procedures.

Table 1: Microbial load and Insect infestation of dried tomatoes under different pretreatments and packaging materials during three months of storage

Pretreatment	Packaging material	Bacterial growth (TVC, CFU/g)	Fungal growth (CFU/g)	Coliform growth (CFU/g)	Insect Infestation
Control	Foil	0.5×10^{-2}	0.2×10^{-4}	ND	ND
Control	Polyethyelene	0.8×10^{-4}	0.4×10^{-3}	ND	ND
Control	Brown envelope	$1.1 X10^{-2}$	0.4×10^{-4}	ND	ND
Salted	Foil	$0.3x 10^{-4}$	0.2×10^{-4}	ND	ND
Salted	Polyethyelene	$0.4 X10^{-4}$	0.6×10^{-2}	ND	ND
Salted	Brown envelope	$0.6x 10^{-2}$	0.5×10^{2}	ND	ND
Streamed	Foil	$0.7 X10^{-4}$	0.4×10^{-2}	ND	ND
Streamed	Polyethyelene	$1.0 X10^{-2}$	0.5×10^{-2}	ND	ND
Streamed	Brown envelope	$1.2 X10-^{4}$	$0.5x 10^{-4}$	ND	ND
Lemon	Foil	$0.6 X10^{-4}$	0.3×10^{-2}	ND	ND
Lemon	Polyethelene	$1.0 X10^{-2}$	$0.5x 10^{-4}$	ND	ND
Lemon	Brown envelope	$1.1X10^{-2}$	0.5×10^{-4}	ND	ND

ND: Not Detected within the detection limits of pour plate method (10^3-10^5 dilutions)

Insect infestation was assessed by physical inspection of stored samples throughout the three-month storage period

Conclusion

This study demonstrated that pretreatments and packaging materials play an important role in maintaining the quality of dried tomatoes during storage. Given Nigeria's high rate of postharvest tomato losses, often estimated between 35-50% annually, the findings provide evidence-based strategies for reducing wastage, improving shelf life, and strengthening food security. Adoption of simple but effective preservation methods such as salting pretreatment combined with aluminum foil packaging could extend the marketability of tomatoes, reduce seasonal glut-related losses, and increase farmer incomes.

References

Abolade, T. J. & Meludu, N. T. (2020). Farmers' engagement in tomato postharvest handling activities and rate of losses in Kaduna State, Nigeria. Nigerian Journal of Rural Sociology, 20(2):52-58. https://doi.org/10.22004/ag.econ.347355

Ade-Omowaye, B. I. O.; Rastogi, N. K.; Angersbach, A.; Knorr, D. (2002). Osmotic Dehydration Behavior of Red Paprika (Capsicum Annuum L.). J. Food Sci. 2002, 67(5), 1790–1796. DOI: 10.1111/j.1365-2621.tb08724. x.

Agbabiaka, T. O., Saliu, B. K., Sule, I. O., Oyeyiola, G. P. & Odedina, G. F. (2024). Microbial deterioration of tomato fruit (Lycopersicon esculentum) sold in three popular markets in Ilorin, Kwara State, Nigeria. Fountain Journal of Natural and Apllied Sciences, 4(1): 54. https://doi.org/10.53704/fujnas.v4i1.54

AOAC (2019). AOAC official methods of analytical chemists. 21st edition (New york).

Aruwa, C.E. & Akinyosoye, F.A. (2015). Microbiological Assessment of Ready-To- Eat Foods (Rtes) for the Presence Bacillus Species. *Journal of Advances in Biology & Biotechnology*, **3**,145-152. https://doi.org/10.9734/JABB/2015/17407

Collins, E. J., Bowyer, C., Tsouza, A. & Chopra, M. (2022). Tomatoes: an extensive review of the associated health impacts of tomatoes and factors that can affect their cultivation. Biology (Basel), 11(2): 239. https://doi.org/10.3390/biology11020239.

Food and Agriculture Organization of the United Nations, & Kaduna State Government. (2025). FAO and Kaduna State Government partner to transform tomato value chain. FAO Nigeria. https://www.fao.org/nigeria/news/detail-events/ar/c/1733325/

Latapi, G.& Barrett, D. M. (2006). Influence of Pre-drying Treatments on Quality and Safety of Sun-dried Tomatoes. Part II. Effects of Storage on Nutritional and Sensory Quality of Sun-dried Tomatoes Pretreated with Sulfur, Sodium Metbisulfite, or Salt. J. Food Sci., 71(1), 1–6. DOI: 10.1111/j.1365-2621.2006.tb12402.x

Leke, L. & Bembur, K. (2023). Effect of pre-treatment methods on the quality attributes of tomato powder. Nigerian Annals of Pure and Applied Sciences, 6(1). https://napas.org.ng.

Mina, Z. P., Kaseke, T., Fadiji, T., Silue, Y. & Fawole, O.A. (2025). Combined oven/freeze drying as a cost and energy –efficient drying method for preserving quality attributes and volatile compounds of carrot slices. Frontiers in Horticulture, 3. https://doi.org/10.3389/fhort.2024.1447957.

Olaniyi J.O, Akanbi W.B, Adejumo T.A & Akande O.G (2010) Growth, fruit yield and nutritional quality of tomato varieties. African Journal of Food Science 4(6): 398-402.

Osuocha u.k., chukwu, C.E., & Ezekwe, S.A., (2018). soil quality assessment and phytoaccumulation potentials of selected edible vegetables around Ntigha solid waste dump, Abia State Nigeria. journal of scientific Agriculture, 2, 14-15.

Pandya, U. (2024). Food preservation: techniques and importance for food security. African Journal of Food Science and Technology, 15(11). https://dx.doi.org/10.14303//ajfst.2024.111.

Ujong, A. E., Emelike, N. J. K., Ofiks, A., Ohanehi, H. A. & Olumide, B. A. (2024). Effect of drying methods and variety on the chemical composition, functional, and microbial properties of date flour. JSFA Reports, 4(12): 398-405. https://doi.org/10.1002/jsf2.221.

UNECE. UNECE Standard DDP-19: (2024) Dried or Dehydrated Tomatoes. Revised and adopted in 2024. United Nations Economic Commission for Europe.

Vodouhe, M. C. D.; Houssou, A. P. F.; Kpangbin, C.; Labintan, E.; Mensah, G. A. (2014). Séchage de la tomate (Lycopersicon esculentum): Une autre alternative pour sa valorisation au Bénin. Bulletin de La Recherche Agronomique Du Bénin., 229, 58–65.

Good Agricultural Practices and Food Safety in Smallholder Farming: Opportunities, Challenges and Way Forward

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Abstract

Good Agricultural Practices (GAP), as defined by the Food and Agriculture Organization (FAO), provide a science-based framework of principles and procedures that ensure food safety, sustainability, and market confidence across agricultural value chains. GAP covers soil and water management, responsible pesticide use, hygienic harvesting and postharvest handling and worker hygiene, while also emphasizing traceability and compliance with Maximum Residue Limits (MRLs). For smallholder farmers, particularly in developing countries, GAP adoption is critical in reducing microbiological, chemical and physical hazards linked to inadequate food safety practices. Research indicates that GAP enhances consumer trust, supports international trade and contributes to yield increase, food security and environmental sustainability. However, challenges such as limited resources, poor training, weak extension services and climate change impacts hinder effective implementation. Addressing these barriers through targeted policies, training and investments will empower smallholders to adopt GAP effectively, ensuring safe, sustainable and marketable food systems globally.

Keywords: Adoption barriers, food safety, Good Agricultural Practices (GAP), smallholder farmers, sustainable agriculture

Introduction to GAP and Food Safety

According to the Food and Agriculture Organization (FAO), Good Agricultural Practices (GAP) offer a science-driven structure that is flexible, designed to ensure safe and sustainable food

production and it covers all stages from soil preparation to postharvest handling. GAP is essential for ensuring food safety, protecting the environment and building consumer trust; an increasingly critical factor in maintaining access to international markets. Despite their vital role in global food supply, smallholder farmers in developing countries often face challenges such as limited resources, poor training and outdated regulations, which heighten risks of microbiological, chemical and physical contamination. By promoting responsible pesticide use, safe water management, hygienic handling and compliance with Maximum Residue Limits (MRLs), GAP reduces contamination risks and enhances market opportunities (Mei, 2025). Broader adoption can strengthen food security, trade competitiveness and sustainability worldwide.

Core Components of GAP

The breakdown of the core components of GAP will be helpful in understanding how it works. These may vary depending on context (crop, geography, regulation) but it commonly includes:

Soil and water management: Soil management involves preventing soil contamination with toxic substances, controlling soil erosion and maintaining soil fertility (organic matter, crop rotation, cover crops, conservation tillage). While water management or irrigation guarantees that irrigation water is safe and clean (i.e., low in chemical contaminants or pathogens), that irrigation scheduling is managed and that excessive or improper use of water is avoided as this may result in standing water and microbial growth (VanHeurck et al., 2020).

In accordance with international food safety standards, pest and disease management includes the use of officially registered and authorized pesticides while avoiding products that are prohibited or uncontrolled. In order to minimize residues and safeguard farm workers, it is equally crucial that they apply these products responsibly by adhering to the proper dosages, mixing, loading and timing, as well as by monitoring preharvest intervals (PHIs) and re-entry intervals (REIs). While fostering long-term ecological balance, proactive disease surveillance and integrated pest management (IPM) assist in reducing the hazards connected to the use of chemical pesticides (Kapari et al., 2023).

Harvesting and Postharvest handling practices entails the maintenance of food safety and quality, crops are harvested at the right stage of maturity and under hygienic conditions. Proper training

in these practices is vital for smallholder farmers to comply with food safety standards and reduce the incidence of foodborne pathogens. Furthermore, safe drying, proper sorting, hygienic packaging and well-managed storage practices including controlling moisture levels and preventing cross-contamination are essential to preserving both the safety and shelf life of produce. Maintaining workers' hygiene to ensured food safety in fresh produce supply chain requires the involvement of well-trained workers who practice good hygiene, such as regular handwashing, use of protective clothing and keeping tools and surfaces clean. Moreover, record-keeping, traceability measures, and worker welfare and hygiene are essential components of GAP. These elements enhance food safety and also facilitate compliance with regulatory standards which are crucial for gaining access to higher-value markets (Osei-Kwarteng & Ogwu, 2024).

Benefits of GAP Adoption in Smallholder Systems

The adoption of Good Agricultural Practices (GAP) by smallholder farmers offers multiple benefits for both producers and consumers, particularly in enhancing food safety through practices that reduce microbial and chemical contamination risks. Research shows that GAP implementation not only boosts consumer confidence by lowering pesticide residues in produce, but also opens access to lucrative markets such as organic and fair-trade systems which demand strict food safety compliance. Beyond safety, GAP promotes higher yields by improving soil health and optimizing resource use, which is a vital outcome in resource-limited settings where farmers face the dual challenge of producing safe and sufficient food (Okeyo et al., 2023). These improvements directly enhance food security at household and community levels and ensures greater availability of nutritious food.

Importantly, the environmental benefits associated with GAP adoption, including improved biodiversity and reduced greenhouse gas emissions, are essential in the context of climate change adaptation. By promoting sustainable practices, such as agroforestry and conservation tillage, GAP can improve the resilience of farming systems to climatic shocks (VanHeurck et al., 2020). This dual focus on environmental sustainability and productivity positions GAP as a critical framework for supporting smallholder farmers in their efforts to contribute to global food security while addressing the pressing challenges of climate change.



Figure1. Illustrated Benefits of GAP Adoption (Mushobozi & Santacoloma, 2010)

Challenges Facing Smallholder Farmers

Despite the benefits, smallholder farmers face significant challenges that hinder the effective implementation of GAP. One of the primary issues is limited access to resources, including financial capital, technical knowledge, and training. The financial constraints often prevent farmers from investing in necessary infrastructure or inputs required for effective GAP implementation. For instance, many smallholders lack access to credit due to inadequate collateral and low credit scores, exacerbating their vulnerability during adverse agricultural seasons (Ono-Raphel et al., 2025).

Furthermore, inadequate extension services and insufficient training programs limit farmers' knowledge of food safety protocols and best practices. Studies show that a lack of information and education regarding GAP hinders compliance, leading to suboptimal food safety outcomes. Additionally, the complex nature of agricultural supply chains often poses barriers to smallholder market participation and complicate their ability to meet food safety standards which are increasingly demanded by consumers and regulatory bodies (Ono-Raphel et al., 2025).

Lastly, environmental threats, including climate change, further exacerbate the challenges facing smallholder farmers. Climate variability can lead to unpredictable harvests and increased pest

and disease pressure, making it more difficult for farmers to consistently implement GAP effectively. As climate impacts continue to grow, smallholder farmers will need additional support and resources to adapt their practices and ensuring that they can sustainably produce safe food within changing environmental conditions.

Conclusion

The integration of Good Agricultural Practices (GAP) into the operations of smallholder farmers presents a compelling case for enhancing food safety and sustainability. While the core components of GAP provide a structured approach for promoting food safety and environmental stewardship, the benefits derived from its adoption can substantially improve food security and economic viability for smallholder systems. However, addressing the multifaceted challenges that limit these Farmers' abilities to implement GAP is essential for realizing the full potential of these practices. Future policies and investments are recommended to prioritize access to resources, training, and support systems to empower smallholders in their pursuit of sustainable agricultural practices amid a changing global landscape.

References

Kapari, M., Hlophe-Ginindza, S., Nhamo, L., & Mpandeli, S. (2023). Contribution of smallholder farmers to food security and opportunities for resilient farming systems. Frontiers in Sustainable Food Systems, 7. https://doi.org/10.3389/fsufs.2023.1149854

Mei, S. (2025). Quantifying tolerances or maximum residue limits of pesticide in food commodities via deep neural networks. *Pest Management Science*, 81(10), 7019-7031. https://doi.org/10.1002/ps.70053

Mushobozi, W. L., & Santacoloma, P. (2010). Good Agricultural Practices (GAP) on horticultural production for extension staff in Tanzania. *FAO GAP Working Papers Series (FAO)*, (13).

Okeyo, S., Mulaku, G., & Mwange, C. (2023). Leveraging geospatial technology for smallholder farmer credit scoring. *Journal of Geographic Information System*, 15(05), 524-539. https://doi.org/10.4236/jgis.2023.155026

Ono-Raphel, J., Preez, L., Cherry, A., & Jacobson, M. (2025). Improving smallholder maize production in kwazulu-natal, south africa. *Food and Energy Security*, 14(1). https://doi.org/10.1002/fes3.70053

Osei-Kwarteng, M., & Ogwu, M. C. (2024). Post-harvest Food Quality and Safety. *Food Safety and Quality in the Global South*, *151*.

Van-Heurck, M., Alegre, J., Solis, R., Del Castillo, D., Pérez, L., Lavelle, P., & Quintero, M. (2020). Measuring sustainability of smallholder livestock farming in Yurimaguas, Peruvian Amazon. *Food and Energy Security*, *9*(4), e242.

Inhibitory Activity of Cassia fistula-Synthesized Selenium Nanoparticles against Moulds of Maize

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Abstract

Maize (*Zea mays* L.) is a vital staple food crop which is highly vulnerable to fungal contamination during storage, resulting in postharvest losses and mycotoxin accumulation. Traditional chemical fungicides have limitations, including resistance development and environmental hazards, underscoring the need for eco-friendly alternatives. This study investigated the antifungal potential of biosynthesized selenium nanoparticles (SeNPs) using *Cassia fistula* leaf extract against moulds of maize. SeNPs were characterized by UV–Vis spectroscopy, Fourier Transform Infrared (FTIR) spectroscopy, and Energy Dispersive X-ray (EDX) analysis. UV–Vis spectra showed an absorption peak at 450 nm, while FTIR confirmed the presence of biomolecules (–OH, C=O, amides, nitro, and halides) involved in nanoparticle stabilization. EDX confirmed selenium as the dominant element (80.76%). Antifungal assays demonstrated significant inhibitory activity: SeNPs suppressed mycelial growth of *Aspergillus flavus* (75.1–95.12%), *Penicillium* spp. (71.5–86.25%), *Fusarium* spp. (69.4–84.7%), and *Rhizopus* spp. (66.2–82.3%) at concentrations of 0.75 and 1.0 mg/ml. In contrast, *Cassia fistula* leaf extract showed only 16–40% inhibition. These findings suggest that green-synthesized SeNPs could serve as sustainable antifungal agents for maize preservation, reducing dependence on chemical fungicides and improving food safety.

Keywords: Maize, Selenium nanoparticles, *Cassia fistula*, Antifungal activity, Storage moulds

Introduction

Maize (*Zea mays* L.) is one of the world's most important cereal crops providing food, feed, and industrial raw materials. However, its postharvest quality and safety are threatened by mould infestations, particularly by *Aspergillus flavus*, *Penicillium* spp., *Fusarium* spp., and *Rhizopus* spp. These fungi not only reduce grain quality but also produce mycotoxins such as aflatoxins and fumonisins, which pose severe health hazards (Amare & Keller, 2014; Chukwudi et al., 2022). Conventional strategies for managing maize spoilage include synthetic fungicides and fumigants. While effective, these methods can cause environmental pollution, toxic residues, and resistance among pathogens (Iqbal et al., 2022).

Consequently, eco-friendly alternatives are urgently needed. Nanotechnology offers promising solutions for crop protection. Selenium nanoparticles (SeNPs) are particularly attractive because of their antimicrobial properties, high surface area, and unique redox potential (Iqbal et al., 2022). The "green synthesis" of nanoparticles using plants provides a cost-effective, environmentally safe method of nanoparticle production. *Cassia fistula* L., a medicinal plant rich in phenolics and flavonoids, has been widely used in nanoparticle synthesis. This study investigates the inhibitory activity of *Cassia fistula*-synthesized SeNPs against major moulds isolated from stored maize, with the goal of developing safer postharvest fungal control strategies.

Methodology

Collection of Maize Samples

Infested maize kernels were collected from local markets in Ilorin, Nigeria, and stored in sterile conditions prior to analysis.

Isolation of Fungi

Surface-sterilized maize samples were ground, serially diluted, and plated on Potato Dextrose Agar (PDA). Plates were incubated at 28 °C for 7 days, and distinct colonies were sub-cultured. (Fungal isolates were identified microscopically as *Aspergillus flavus*, *Penicillium* spp., *Fusarium* spp., and *Rhizopus* spp).

Preparation of *Cassia fistula* Leaf Extract

Fresh *Cassia fistula* leaves were washed, shade-dried, and ground into powder. About 1.5 g of powder was soaked in 100 ml of sterile distilled water, filtered, and centrifuged at 4000 rpm for 20 minutes to obtain the aqueous extract.

Biosynthesis of Selenium Nanoparticles

A 10 mM sodium selenite solution was mixed with 10 ml of *Cassia fistula* leaf extract and incubated at 36 °C for 7 days.

Characterization of SeNPs

UV–Vis spectroscopy: Measured absorption spectrum. FTIR spectroscopy: Identified functional groups responsible for nanoparticle stabilization.

Antifungal Assay

Antifungal activity was assessed using the mycelial growth inhibition method (Alagesan et sal., 2019). PDA plates were amended with 0.75 mg/ml and 1.0 mg/ml concentrations of SeNPs, Cassia leaf extract, or sodium selenite. Plates inoculated with fungal plugs were incubated at 25°C. Growth in plates was

measured and the percentage growth inhibition was calculated using the formula below: Percentage inhibition =

$(C - T) \times 100 / C$

Where C = colony diameter (mm) of the control; T = colony diameter (mm) of the test plate.

Results and Discussion

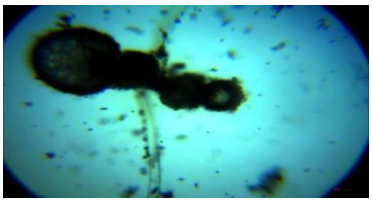
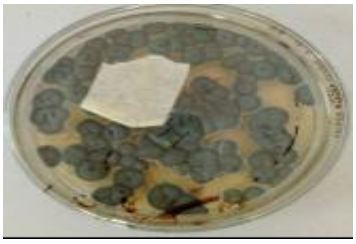
Morphological and cultural characteristics of the fungal isolates

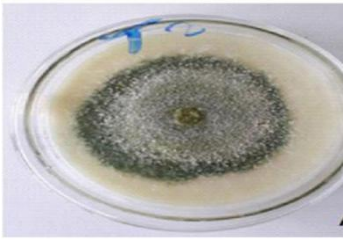
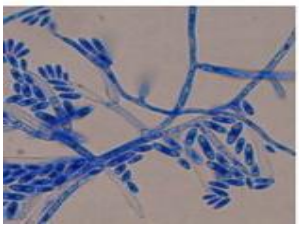
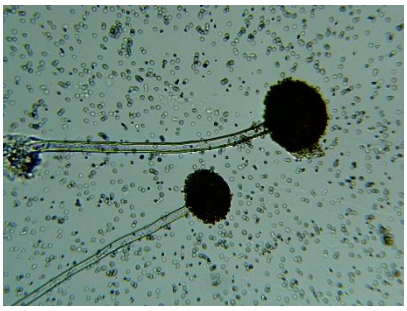
Fungal isolates obtained from maize kernels included *Aspergillus flavus*, *Penicillium* spp., *Fusarium* spp., and *Rhizopus* spp. These were identified based on cultural and microscopic features (Abdel Sater et al., 2017)

Table1: Morphological characteristics of fungal isolates from the maize

Isolates	Cultural Characteristics	Microscopic Morphological Characteristics
Aspergillus flavus	Velvety colonies	Conidiospores borne laterally on hyphae, non-septate, numerous with sterigmata.
Penicillium spp.	Large white colonies covering surface	Branched, non-septate hyphae, enlarged at apex to form conidiophores, producing chains of conidia.
Fusarium spp.	Cottony, whitish-to-pink colonies	Septate hyphae with crescent-shaped conidia.
Rhizopus spp.	Fast-growing, fluffy white colonies turning gray-black	Non-septate hyphae with sporangia borne on sporangiophores.

Table 2: Cultural characteristics of the fungal isolates from maize

No.	Growth on PDA Plate	Photomicrograph	Probable fungi
1			*Aspergillus flavus*
2			*Penicillium* spp.

3			*Fusarium* spp.
4			*Rhizopus* spp.

Aqueous extraction and Biosynthesis of Selenium Nanoparticles

During biosynthesis, a noticeable color change to brown occurred after 7 days of incubation, confirming SeNP formation. (Pyrzynska and Sentkowska, 2022).)

UV–Vis spectroscopy: Biosynthesized SeNPs exhibited a distinct absorption peak at 450 nm, confirming nanoparticle formation (Figure1), Abirami t al. (2022).

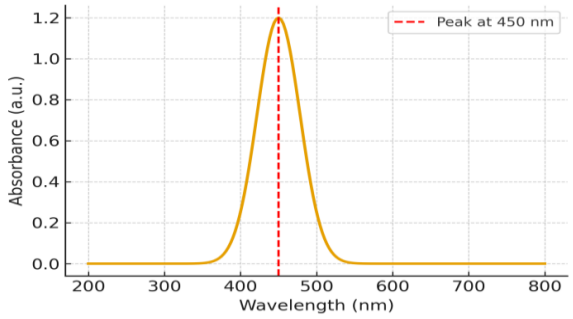


Figure 1: UV Spectroscopy of Biosynthesized SeNPs (CFSNPs)

FTIR spectroscopy: FTIR spectra revealed peaks at 3173.00 cm−1, 2361.44 cm−1, 1594.00 cm−1, 1373.00 cm−1, 1027.29 cm−1, and 674.23 cm−1. These correspond to O–H, C=O, amide, nitro, alkyl/aryl halide groups, confirming the role of biomolecules in reduction and stabilization of SeNPs (Figure 2).

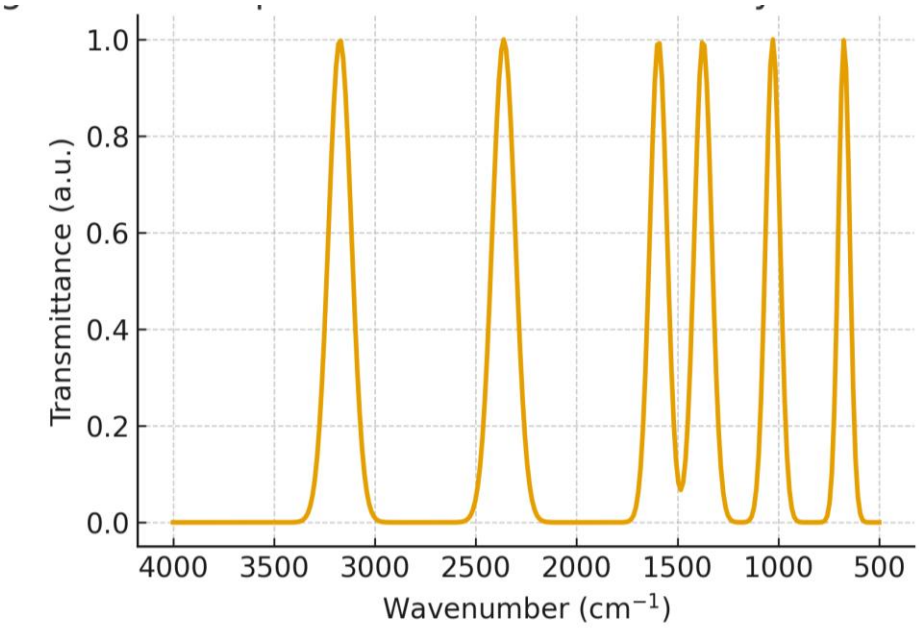


Figure 2: FTIR spectrum of biosythesized selenium nanopartcles

EDX analysis: Elemental selenium was predominant (80.76%), with minor oxygen and carbon signals, confirming nanoparticle purity (Figure 4).

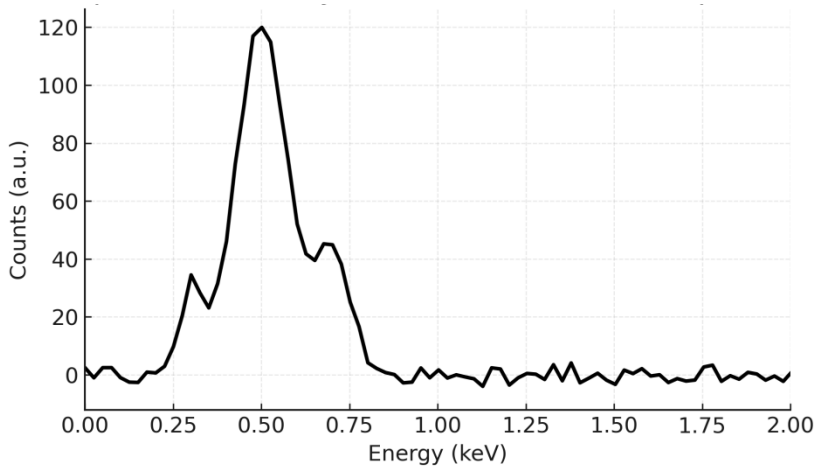
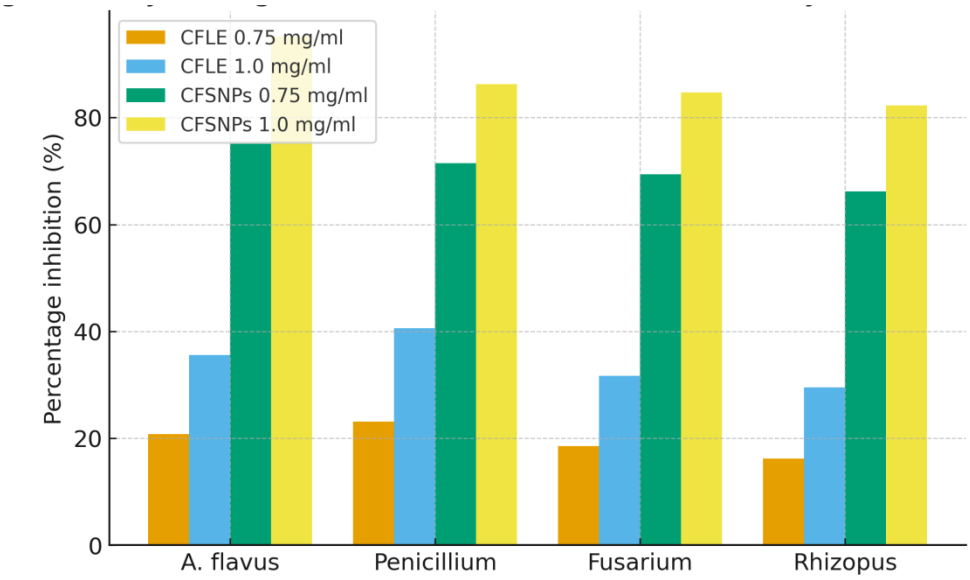


Figure 4: EDX Spectrum of biosynthesized nanopartcles

The biosynthesized CFSNPs exhibited excellent fungal mycelial growth inhibition against maize molds: *Aspergillus flavus*: 75.1% (0.75 mg/ml) and 95.12% (1.0 mg/ml) inhibition. *Penicillium* spp.: 71.5% (0.75 mg/ml) and 86.25% (1.0 mg/ml) inhibition. In contrast, aqueous *Cassia fistula* leaf extract showed much lower inhibitory effects: *A. flavus*: 20.8% (0.75 mg/ml) and 35.6% (1.0 mg/ml). *Penicillium* spp.: 23.1% (0.75 mg/ml) and 40.6% (1.0 mg/ml). These results confirm the superior antifungal efficacy of

biosynthesized SeNPscompared to crude plant extract and sodium selenite, consistent with previous findings on nanoparticle antifungal activity (Iqbal et al., 2022).



CFLE: Cassia Fistula Leaf Extract, CFSNPs: Cassia Fistula biosynthesized nanoparticles

Figure 5: Percentage of Mycelia inhibition of the fungal Isolates from infested maize and biosynthesized nanoparticles (CFSNPs)

Conclusion

Cassia fistula-mediated selenium nanoparticles were susccessfully synthesized and characterized. The nanoparticles exhibited strong antifungal effects against *A. flavus*, *Penicillium* spp., *Fusarium* spp., and *Rhizopus* spp. isolated from maize. Compared with leaf extract, SeNPs showed significantly higher inhibition, indicating their potential as safe biocontrol agents for maize storage protection. Future work should focus on formulation, application strategies, and safety evaluations for field use.

References

Abdel- Sater, M.A., Abdel- Hafez, S.I.I., Nemmat, A.H., & A.L- Amer, E.A. (2017). Fungi associated with maize and sorghum grains and their potential for amylase and aflatoxin production. *Egypt Journal of Botany*. 57(1), 119-137.

Abe, C.A.L., Faria, C.B., Castro, F.F., Souza, S.R., Santos, F.C., Silva, C.N., Tessmann, D.J., & Barbosa, I. P. (2020). Fungi isolated from maize (Zea mays L.) grains and production of associated enzyme activities. *International Journal of Molecular Sciences*. 16(7), 15328-15346

Alagesan, V., & Sujatha, V. (2019). Green Synthesis of Selenium Nanoparticle Using Leaves Extract of Withaniasomnifera and Its Biological Applications and Photocatalytic Activities. *BioNanoScience*, 9(1), 105–116. https://doi.org/10.1007/s12668-018-0566-8

Amare, M. G., & Keller, N. P. (2014). Molecular mechanisms of Aspergillus flavus secondary metabolism and development. *Fungal Genetics Biology,* 66:11–18.

Chukwudi, U.P., Kutu, F.R., & Mavengahama, S. (2022). Mycotoxins in Maize and Implications on Food Security: A Review. Agricultural reviews. 42(1), 42-49

Iqbal, M. S., Abbas, K., & Qadir, M. I. (2022). Synthesis, characterization, and evaluation of biological properties of selenium nanoparticles from *Solanum lycopersicum*. *Arabian Journal of Chemistry*, 15(7), 103901.

Pyrzynska, K., & Sentkowska, A. (2021). Biosynthesis of selenium nanoparticles using plant extracts. *Journal of Nanostructure in Chemistry*, 12(4), 467–480. https://doi.org/10.1007/s40097-021-00435-4

Optimization of Fermented Cabbage (Sauerkraut) Using *Lactobacillus paracasei* Cultivated in Tofu Whey"

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Abstract

Fermented vegetables such as sauerkraut are valued for their nutritional and probiotic benefits; however, optimizing fermentation parameters and exploring sustainable culture media remain important for improving product quality. This study characterized sauerkraut fermented using a Lactobacillus paracasei starter culture grown in tofu whey—a nutrient-rich by-product of soybean processing. Using response surface methodology, the effects of culture volume (3.2–36.8 ml), fermentation time (17.3–30.7 days), and salt concentration (0.3–3.7 g/100 g) on biochemical, textural, and colorimetric properties were determined. Culture volume demonstrated the most significant influence on all response variables. Optimized conditions (30 ml culture volume, 28 days fermentation, 1 g/100 g salt) yielded sauerkraut with enhanced lactic acid bacteria count (8.20 log CFU/ml) and phenolic content (3.15 mg/g), while exhibiting reduced chewiness (9.14) compared to traditional preparations. A color difference (ΔE = 4.28) from traditional sauerkraut was observed, though sensory evaluation showed no significant difference ($p > 0.01$) between findings demonstrate that tofu whey can serve as an effective and sustainable medium for L. paracasei propagation, supporting high-quality sauerkraut production with improved functional and sensory properties. This approach not only enhances fermentation efficiency but also promotes the value-added utilization of agro-industrial by-products.

Keywords: *Lactobacillus paracasei*, tofu whey, phenolic compounds, texture profile, color difference, response surface methodology

Introduction

Sauerkraut, a fermented cabbage product, has gained renewed interest due to its potential probiotic content and health-promoting properties, including its association with improved gut health and antioxidant activity (Dimidi et al., 2019). The fermentation process, driven by a succession of lactic acid bacteria (LAB), can be optimized through the use of defined starter cultures to ensure consistency, safety, and enhanced functional attributes of the final product (Marco et al., 2017). Specifically, probiotic strains

such as *Lactobacillus paracasei* have been shown to improve the quality and potential health benefits of fermented foods (LeBlanc et al., 2020).

Concurrently, there is growing emphasis on sustainable food production practices, including the valorization of food processing side-streams. Tofu whey, a by-product of tofu manufacturing, represents both an environmental challenge due to its high organic load and an opportunity as a nutrient-rich fermentation medium. It contains valuable compounds such as isoflavones and prebiotic oligosaccharides that can support microbial growth (Chua & Liu, 2019). Utilizing tofu whey as a cultivation medium for starter cultures aligns with circular economy principles while potentially reducing production costs.

However, the specific impact of using a *L. paracasei* starter culture propagated in tofu whey on the comprehensive quality profile of sauerkraut particularly its biochemical, textural, and colorimetric properties remain insufficiently explored. Therefore, this study aimed to characterize sauerkraut produced using *L. paracasei* cultivated in tofu whey, with a focus on its biochemical properties (LAB viability and phenolic content), textural characteristics (particularly chewiness), and colorimetric properties. Using response surface methodology, the effects of culture volume, fermentation time, and salt concentration were systematically investigated to identify optimal processing conditions for maximizing product quality while valorizing an underutilized by-product.

Methodology

Materials

White cabbage (*Brassica oleracea* L. var. *capitata*) was obtained from local markets in Bhopal, India and stored in polythene bags in a cold chamber set at 4 °C. *Lactobacillus paracasei* 63 was acquired from the National Collection of Dairy Cultures (NDRI, Karnal, India). Tofu whey was collected from the pilot plant at the Centre for Excellence in Soybean Processing and Utilization (ICAR-CIAE, Bhopal).

Experimental Design

A central composite rotatable design (CCRD) with three independent variables at five levels each was employed, generating 20 experimental runs. The variables included: culture volume (3.2-36.8 ml), fermentation time (17.3-30.7 days), and salt concentration (0.3-3.7 g/100g).

Starter Culture Preparation and Fermentation

The starter culture was prepared by inoculating *L. paracasei* into tofu whey-based media supplemented with 0.2% yeast extract and 1.5% glucose, followed by incubation at 37°C for 24 hours. Shredded cabbage was mixed with salt and starter culture according to experimental design and fermented at 20°C in 150 ml glass containers.

Analytical Methods

Biochemical analysis was conducted by determining the lactic acid bacteria (LAB) count using the standard plates count method (Kårlund et al., 2015). While the total phenolic content was assessed using

The Folin–Ciocalteu method (Marco et al., 2017). For texture evaluation, chewiness was measured through texture profile analysis employing a TA-XT texture analyzer. Colour differences between the starter culture and traditional sauerkraut were calculated using Hunter Lab values to determine the ΔE. Statistical analyses, including response surface methodology.

Results and Discussion

Comparative Analysis of Sauerkraut Properties

The biochemical characteristics of the optimized starter culture sauerkraut (SCS) were determined and compared against traditional sauerkraut (TS) and raw cabbage (RC) (Table 1). The application of the *L. paracasei* starter culture significantly influenced the final product's properties.

Biochemical Properties

The progressive decrease in pH from RC (6.34) to TS (4.33) to SCS (3.91), along with the corresponding increase in titratable acidity, indicates more intensive acid production in the inoculated fermentation. Notably, the phenolic content in SCS (3.15 mg/g) was substantially higher than in both TS (1.72 mg/g) and RC (1.66 mg/g) as shown in (Table 1). This enhancement can be attributed to the ability of lactic acid bacterial strains to produce enzymes that liberate bound phenolic compounds, thereby increasing their bio accessibility (Hur et al., 2014). The variations in ascorbic acid content and antioxidant activity between TS and SCS suggest differences in metabolic pathways during fermentation.

Model Fitting and Statistical Analysis

The experimental data were successfully fitted to second-order polynomial models, with ANOVA revealing highly significant models ($p < 0.01$) for all measured responses. The models demonstrated satisfactory coefficients of determination ($R^2 = 0.84$-0.92) and non-significant lack of fit, confirming their adequacy for prediction within the experimental domain (Table 2). The high R^2 values indicate that the models can explain most of the variability in the responses, which is consistent with the effective use of RSM in optimizing fermented food processes (Witek-Krowiak et al., 2014).

Optimization and Validation

The numerical optimization yielded optimum conditions of 30 ml culture volume, 28 days fermentation time, and 1 g/100 g salt concentration. Under these conditions, the experimental values showed strong agreement with model predictions (Table 3), validating the model's accuracy. The starter culture

sauerkraut produced under these optimal conditions showed a LAB count of 8.20 log CFU/ml, chewiness of 9.14 N, and color difference (ΔE) of 4.28 compared to traditional sauerkraut.

Textural and Colorimetric Properties

The starter culture sauerkraut exhibited significantly different physical characteristics compared to traditional sauerkraut. Under the optimized conditions, textural analysis confirmed a substantially softer product, with chewiness reduced to 9.14 N (Table 3). Colorimetric evaluation revealed a clearly perceptible difference, with a ΔE value of 4.28 (Table 3), primarily attributed to the increased lightness of SCS (L* = 68.71) compared to traditional sauerkraut (L* = 53.32). This color alteration likely results from pigment degradation under the more acidic fermentation conditions achieved with the starter culture (Nikonorow et al., 2019).

Microstructural Analysis

Scanning electron microscopy revealed distinct structural differences among samples. Traditional sauerkraut showed moderate tissue breakdown, while starter culture sauerkraut exhibited more extensive structural modification, consistent with the texture profile results. The extensive breakdown observed in the starter culture sample indicates pronounced pectinolytic activity during fermentation (Kårlund et al., 2015).

Table 1. Biochemical characteristics of raw cabbage, traditional sauerkraut, and starter culture sauerkraut.

S/N	Parameter	Raw Cabbage (RC)	Traditional Sauerkraut (TS)	Starter Culture Sauerkraut (SCS)
1.	Ph	6.34	4.33	3.91
2.	Titratable Acidity (% Lactic Acid)	0.025	0.063	0.075
3.	Ascorbic Acid (mg/g)	0.45	0.27	0.16
4.	Phenolic Content (mg/g)	1.66	1.72	3.15
5.	Antioxidant Activity (% DPPH inhibition)	19.99	48.41	38.78

Table 2. Analysis of variance for the fitted quadratic models

S/N	Response	R^2	Adjusted R^2	Predicted R^2	F-value	p-value
1.	LAB count	0.86	0.78	0.65	12.86	0.0004
2.	Chewiness	0.92	0.85	0.72	15.43	0.0001

3.	ΔE	0.84	0.75	0.61	9.87	0.0012

Table 3. Optimization results and validation experiments.

S/N	Response	Predicted	Experimental
1.	LAB count (log CFU/ml)	7.90	8.20 ± 0.12
2.	Chewiness (N)	8.92	9.14 ± 0.08
3.	ΔE	4.29	4.28 ± 0.05

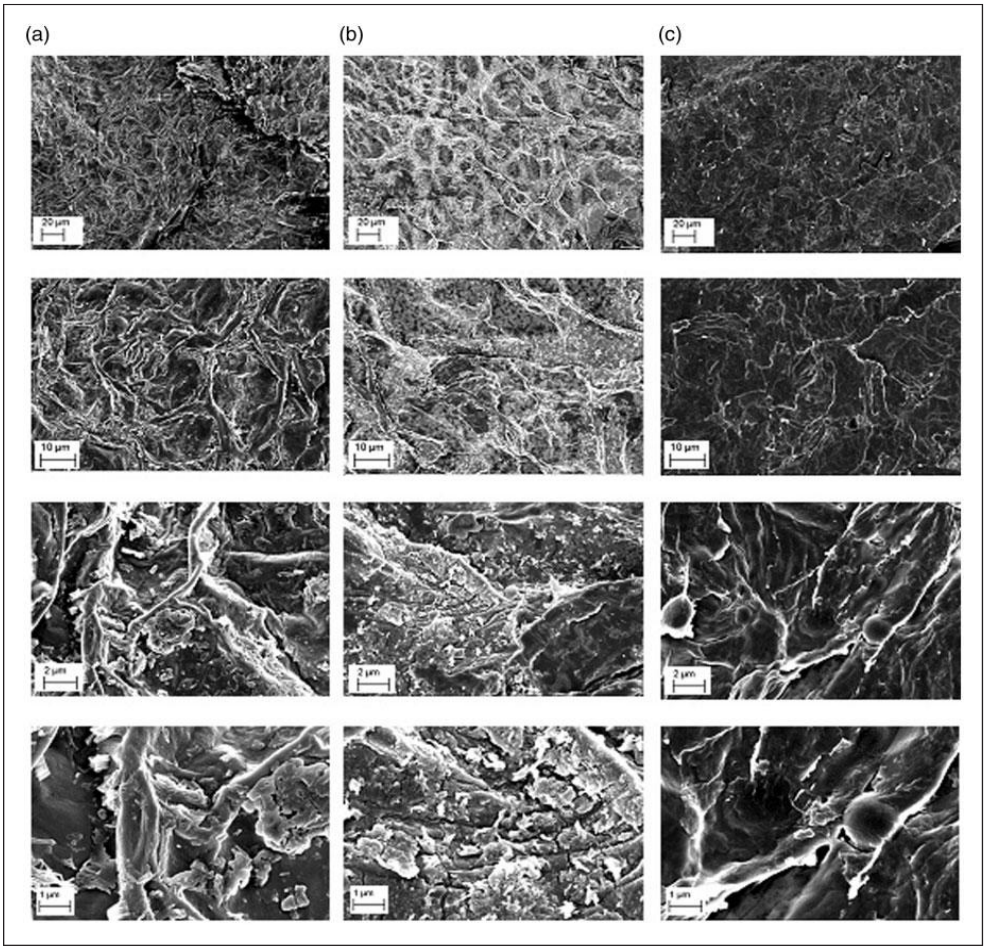


Figure 1. Scanning electron microscopy of (a) raw cabbage shreds, (b) TS and (c) SCS.

Conclusion

This study successfully demonstrates that tofu whey serves as an effective growth medium for *Lactobacillus paracasei* in sauerkraut production. The optimized starter culture sauerkraut showed significant improvements in key quality parameters, including substantially higher phenolic content and enhanced lactic acid bacterial activity. The final product exhibited a softer texture and distinct color profile compared to traditional sauerkraut. Through response surface methodology, optimal processing conditions were established at 30 ml culture volume, 28 days fermentation, and 1 g/100g salt concentration. These findings confirm that tofu whey can be valorized to produce functional sauerkraut with improved biochemical, textural, and colorimetric properties, offering a sustainable solution for by-product utilization while enhancing food quality

References

Chua, J. Y., & Liu, S. Q. (2019). Soy whey: More than just wastewater from tofu and soy protein isolate industry. *Trends in Food Science & Technology*, *91*, 24–32.

Dimidi, E., Cox, S. R., Rossi, M., & Whelan, K. (2019). Fermented Foods: Definitions and Characteristics, Impact on the Gut Microbiota and Effects on Gastrointestinal Health and Disease. *Nutrients*, *11*(8), 1806.

Hur, S. J., Lee, S. Y., Kim, Y. C., Choi, I., & Kim, G. B. (2014**).** Effect of fermentation on the antioxidant activity in plant-based foods. *Food Chemistry*, *160*, 346–356.

Kårlund, A., Salminen, J. P., Koskinen, P., Ahern, J. R., Karonen, M., Tiilikkala, K., & Karjalainen, R. O. (2015). Polyphenols in strawberry (*Fragaria× ananassa*) leaves induced by plant activators. *Journal of Agricultural and Food Chemistry*, *62*(20), 4592–4600.

Marco, M. L., Heeney, D., Binda, S., Cifelli, C. J., Cotter, P. D., Foligné, B., ... & Hutkins, R. (2017). Health benefits of fermented foods: microbiota and beyond. *Current Opinion in Biotechnology*, *44*, 94–102.

Nikonorow, A., Tylingo, R., & Białobrzewski, I. (2019). The effect of fermentation conditions on the production of sauerkraut. *Journal of Food Science and Technology*, *56*(2), 899–908.

Witek-Krowiak, A., Chojnacka, K., Podstawczyk, D., Dawiec, A., & Pokomeda, K. (2014). Application of response surface methodology and artificial neural network methods in modelling and optimization of biosorption process. *Bioresource Technology*, *160*, 150–160.

Microbiological Assessment and Mineral Composition of Stored Tomato and Tomato-Pepper Mix Paste

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Abstract

Tomato and tomato-pepper mix pastes are popular food products valued for their rich nutrient content, versatility in cooking, and economic significance. Nevertheless, their chemical quality in raw state can be compromised due to high perishability and vulnerability to deterioration during storage which in turn impacts their microbiological quality. The K and Mg values increased from 0.1551–0.2015% and 0.0012–0.0022% respectively in tomato paste after 6-month storage period. Calcium level however reduced in both samples with a decline from 0.0358–0.0285% in tomato-pepper mix paste. Progressive increase in bacteria load from 0.5–6.5 × 10^4 CFU/mL and 4.0–6.0× 10^4 CFU/mL were observed in the TOM and TMP respectively. This rise however was not above the acceptable microbial limit of processed foods. Comparative research studies on tomato paste storage including pepper and onion blends are limited in the literature. This study therefore proposes that tomato-based pastes, whether containing pepper and onion or not, can be effectively stored under suitable conditions while maintaining product safety, quality and ultimately reducing postharvest losses thereby promoting food security.

Keywords: Tomato paste, Shelf-life, Nutritional composition, Value addition, Food safety

Introduction

Tomato (*Solanum lycopersicum*) is among the most extensively cultivated and consumed vegetables worldwide, playing a critical role in enhancing food security and human nutrition. Fresh tomatoes, a climacteric fruit, are widely appreciated for their culinary versatility and nutrient richness, serving as excellent sources of vitamins, minerals, and antioxidants such as lycopene (Duret et al., 2024). Peppers (*Capsicum spp.)* are equally essential in Nigerian cuisine and are often blended with tomatoes to improve taste, aroma, and nutritional value in various traditional dishes. Both tomatoes and peppers are abundant in bioactive compounds. Onions (Allium cepa) are another vital ingredient in local diets and are nutrient-dense, low-calorie vegetables that deliver a range of health benefits. They are rich in flavonoids-particularly quercetin, organosulfur compounds and vitamin C. Collectively, these bioactive constituents provide antioxidant protection, support cardiovascular health, regulate blood glucose levels, and promote

gut microbiota balance. This study was designed to evaluate the impact of storage on the microbiological characteristics and mineral composition of tomato and tomato-pepper mix pastes.

Methodology

Preparation of tomato and tomato-pepper mix paste

Fresh, wholesome tomato fruits were selected for processing and were divided into two groups. The fruits were washed thoroughly and weighed following the procedure described by Safdar et al. (2010), with slight modifications. Cleaned tomatoes (3.181 kg) were blended using a kitchen grinder without further straining to simulate typical Nigerian cooking practices. The blended puree was heated in a clean pot while stirring at intervals until a paste consistency was achieved. The resulting tomato paste was immediately hot-filled (at 95-100 °C) into glass bottles (pre-sterilized along with their airtight caps) and sealed tightly before cooling. Tomato-pepper mix paste (Figure 1) was similarly prepared. The second portion of tomatoes (3.181 kg), scotch bonnet pepper (83 g), and onions (438 g) were blended smoothly without straining to obtain a homogeneous mixture.

Determination of mineral content

Sodium, potassium, magnesium, and calcium were determined according to the AOAC (2005) method, in which the ash of each sample obtained in a crucible by igniting the samples in a muffle furnace was digested. The filtrate was further used to determine mineral concentrations using a digital flame photometer and an atomic absorption spectrophotometer.



Figure 1. Photograph of tomato paste upper and lower (left) and tomato-pepper mix paste upper and lower (right) after 6-month of storage.

Microbiological analysis of tomato and tomato-pepper mix paste

Pour plate technique was used for the analysis of the samples. The isolation of fungi, bacteria and enteric bacteria counts were done using potato dextrose agar, nutrient agar and MacConkey agar respectively. The bacteria plates were subsequently reversed and incubated at 37 °C for 24 – 48 h. Potato Dextrose Agar plates were incubated at room temperature for 3 – 5 days. The number of microbial colonies were enumerated and reported.

Statistical analysis

Data were expressed as the mean of triplicate determinations ± Standard error of mean, analyzed by ANOVA, and the means separated by significant difference at 5% level, using SPSS Version 20.

Results and discussion

Effect of storage on the mineral content of the samples

Potassium ranged from 0.1551–0.2015 % within 0 to 6 months, with an overall increase after an initial dip at 3 months for TOM (Table 1). In TMP, potassium values increased from 0.1490 – 0.1645%. This agrees with observations that ash content generally rises during storage, suggesting concentration of minerals. The sodium content in TOM was between 0.0890 – 0.0883%, while TMP showed a consistent decline from 0.0833 – 0.0728%. Although direct reports on sodium in tomato pastes are limited, such minute decreases may be linked to leaching or binding interactions during storage. The relative stability or slight increase in mineral content with storage are consistent with concentration effects as water is lost. Calcium decreased in both TOM (0.0368% - 0.0304%) and TMP (0.0358% - 0.0285%). This trend is compatible with evidence that calcium can be chelated by phytates, reducing its measurable levels during storage. The high potassium content is significant because potassium plays a key role in regulating blood pressure, reducing cardiovascular risk, and maintaining neuromuscular function (Kim et al., 2024). The retention and even concentration of potassium in TOM and TMP, therefore, enhance their dietary value as functional food ingredients.

Microbiological quality of stored tomato (TOM) and tomato-pepper mix (TMP) paste

The low microbial counts recorded suggests that the storage conditions maintained were effective in preserving product safety (Table 2). Total Bacterial Count (TBC) increased progressively from 0.5×10^4 CFU/g at 0 month to 6.5×10^4 CFU/g at 6 months for TOM, and from 4.0×10^4 CFU/g to 6.0×10^4 CFU/g for TMP. The absence of coliform growth across all samples indicates that sanitary conditions were maintained during processing and storage.

Table 1. Mineral compositions of TOM and TMP

Sample	Minerals	Storage Length		
		0 month	**3 months**	**6 months**
TOM	Na (%)	0.0890±0.00005^{b}	0.0800±0.00010^{a}	0.0883±0.00080^{b}
	K (%)	0.1551±0.00020^{b}	0.1417±0.00020^{a}	0.2015±0.00050^{c}
	Mg (%)	0.0012±0.00005^{b}	0.0009±0.00005^{a}	0.0022±0.00005^{c}
	Ca (%)	0.0368±0.00005^{c}	0.0349±0.00025^{b}	0.0304±0.00020^{a}
TMP	Na (%)	0.0833±0.00020^{b}	0.0802±0.00010^{b}	0.0728±0.00120^{a}
	K (%)	0.1490±0.00025^{b}	0.1438±0.00030^{a}	0.1645±0.00050^{c}
	Mg (%)	0.0009±0.00005^{a}	0.0008±0.00005^{a}	0.0006±0.00010^{a}
	Ca (%)	0.0358±0.00025^{b}	0.0349±0.00015^{b}	0.0285±0.00050^{a}

Values are represented as the Mean of triplicate determinations ± Standard error of mean. Means in the same row that are followed by the same letters are not significantly different at 5% level. TOM: Tomato paste. TMP: Tomato-pepper mix paste.

The observed increase in bacterial counts over time is consistent with the natural progression of microbial metabolism in nutrient-rich substrates. However, the values recorded remained within the acceptable microbiological limit (<10^5 CFU/g) for processed food products as recommended by international food safety standards.

Table 2. Microbiological analysis of stored TOM and TMP

Sample	Storage Duration (month)	TBC (CFU/mL)	TCC (CFU/mL)	TFC (CFU/mL)
TOM	0	0.5×10^4	NVG	NVG
	3	5.0×10^4	NVG	NVG
	6	6.5×10^4	NVG	NVG
TMP	0	4.0×10^4	NVG	NVG
	3	3.5×10^4	NVG	1×10^4
	6	6.0×10^4	NVG	NVG

TBC: Total Bacteria Count; TCC: Total Coliform Count; TFC: Total Bacteria Count; NVG: No Visible Growth

Conclusion

The absence of fungal growth in TOM and TMP, except a single occurrence (1×10^4 CFU/g) in TMP at 3 months, could be due to the acidity and reduced water activity of the paste, which are known to inhibit fungal. Tomato-pepper mix paste showed slightly lower bacterial counts than tomato paste at 3 months, possibly due to the presence of bioactive compounds in pepper, such as capsaicin and phenolic antioxidants (Yakubu et al., 2024). The results of this study demonstrated that storage duration influenced both the mineral composition and microbiological quality of tomato (TOM) and tomato–pepper mix pastes (TMP). These mineral changes suggest that controlled storage not only preserves but can enhance certain nutritional elements of tomato-based pastes, thereby maintaining their dietary value as functional. Microbiological evaluation revealed that both TOM and TMP maintained satisfactory quality throughout storage, with total bacterial counts increasing moderately yet remaining within acceptable safety limits ($<10^5$ CFU/g). Overall, the study concludes that tomato and tomato–pepper mix pastes can be safely stored for up to six months under suitable conditions without compromising their nutritional or microbiological integrity.

References

AOAC (2005) Association of Official Analytical Chemists. Official Methods of Analysis Washington, D.C

Duret, S., Aubert, C., Annibal, S., Derens-Bertheau, E., Cottet, V., Jost, M., Guillaume Chalot, Flick, D., Moureh, J., Laguerre, O., Valérie Mérendet., & Desnoues, E. (2024). Impact of harvest maturity and storage conditions on tomato quality: A comprehensive experimental and modeling study. *Postharvest Biology and Technology*, *219*, 113286–113286. https://doi.org/10.1016/j.postharvbio.2024.113286

Kim, B. S., Yu, M.Y., & Shin, J. (2024). Effect of low sodium and high potassium diet on lowering blood pressure and cardiovascular events. *Clinical Hypertension*, *30*(1). https://doi.org/10.1186/s40885-023-00259-0

Safdar, M. N., Mumtaz, A., Amjad, M., Siddiqui, N., & Hameed, T. (2010). Development and quality characteristics studies of tomato paste stored at different temperatures. *Pakistan journal of nutrition*, *9*(3), 265-268.

Sharma, R., Yadav, A., Lata, C., Verma, A., Singh, D., Rajput, L. S., Joshi, R., Mahesh Kumar Samota, Kumar, S., Kumar, K., Ram, A., Kumar, N., & Arunachalam, A. (2025). Role of biotechnology for shelf-life extension and quality improvement of perishable fruits and vegetables: a comprehensive review. *Food Science and Biotechnology*

Yakubu, A. M., Abdullahi, I., & Sani, A. (2024). Influence of pepper and onion admixture on the microbiological quality of stored tomato paste. Nigerian Journal of Food and Nutrition Sciences, 45(1), 33–41.

Effect of Solar and Cabinet Tray Drying on the Microbial Load of Mango Pulp and Chips

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Abstract

Mango (*Mangifera indica* L.) is a highly perishable fruit in Nigeria, where postharvest losses are largely attributed to microbial spoilage resulting from its high moisture content. Drying is an effective preservation method; however, its influence on microbial safety warrants further assessment. This study evaluated the effect of parabolic shaped solar drying (PSSD) and mechanical cabinet drying (MCD) on the microbial load of mango chips. Fresh mango pulp was processed, dried, and subjected to microbial analysis using serial dilution (10^{-3}) and the pour plate technique. The results revealed a significant reduction ($p < 0.05$) in total bacterial count (TBC) and total yeast count (TYC) after drying. Fresh pulp had the highest microbial load (TBC: 2.40×10^4 CFU/g; TYC: 1.40×10^4 CFU/g), while dried samples showed markedly lower counts. MCD produced the lowest microbial levels (TBC: 8.00×10^3 CFU/g; TYC: 0), followed closely by PSSD (TBC: 1.00×10^4 CFU/g; TYC: 2.00×10^3 CFU/g). No coliform or fungal growth was detected in any dried sample. These results indicate that both drying methods significantly enhance the microbial safety and shelf stability of mango, with MCD showing superior efficacy. The findings highlight the potential of improved drying technologies to reduce postharvest losses, enhance food safety, and promote value addition for small-scale processors, particularly empowering women engaged in fruit processing enterprises.

Keywords: Mango chips; Mechanical cabinet drying; Microbial load; Parabolic solar drying, Postharvest loss; Value addition.

Introduction

Mango (*Mangifera indica* L.) is one of the most widely consumed tropical fruits, valued for its nutritional richness, pleasant flavour, and economic importance in many developing countries, including Nigeria. However, mango is highly perishable due to its high moisture and sugar content, which favour microbial

spoilage during postharvest handling and storage. Postharvest losses of 30-50% have been reported in tropical regions (Mongi, 2023), reducing food availability and limiting income for farmers and processors. Drying is a proven postharvest strategy to extend shelf life by lowering moisture to levels that inhibit microbial activity and enzymatic reactions. Traditional open-sun drying, though inexpensive, exposes products to dust, insects, and microbial contamination, resulting in poor-quality dried products. Improved technologies such as solar dryers and mechanical cabinet or multi-crop dryers have been developed to overcome these limitations (Mohammed, 2020). Solar dryers utilize renewable energy within enclosed systems that minimize contamination, while multi-crop dryers provide controlled temperature and airflow for uniform drying (Salvador et al., 2025).

Despite their growing use, limited studies have compared how these drying systems influence the microbial safety of mango chips under real processing conditions. Most existing works focus on drying kinetics, product colour, or nutrient retention, with few providing quantitative data on microbial reduction efficiency across different dryer types in tropical environments. This lack of comparative microbial data constrains evidence-based recommendations for small-scale processors.

Therefore, this study investigates the microbial load of fresh mango pulp and dried mango chips produced using parabolic shaped solar dryer (PSSD) and mechanical cabinet dryer (MCD). Specifically, it determines the microbial counts of fresh mango pulp, evaluates the reduction achieved by each drying method, and compares their effectiveness in enhancing product safety and shelf stability.

Methodology

Sample collection and preparation

Ripe mangoes (*Mangifera indica* L.) were purchased from a local market in Nigeria and transported to the laboratory within 2 h in clean, insulated boxes. Damaged, overripe, or spoiled fruits were discarded. A total of 90 fruits were used across three experimental runs. Fruits were washed under running potable water, air-dried on sterile trays, peeled with sterile knives, and processed immediately.

Two product formats were prepared:

- **Mango pulp:** The edible portion was aseptically scooped and homogenized in a sterile blender.
- **Mango chips:** Mango flesh was cut into slices of 3–5 mm thickness using a sterile slicer.

No chemical preservatives were applied to ensure the study measured the effect of drying method alone (Engin & Kuşçu, 2023).

Drying systems and operating conditions

Parabolic Shaped Solar Dryer (PSSD)

Drying was carried out using a parabolic shaped solar dryer consisting of a metallic frame covered with transparent polyethylene film, with a parabolic arc design to maximize solar radiation capture. The drying chamber was fitted with mesh trays on which mango slices and pulp samples were spread. The parabolic geometry facilitated greenhouse-type heating, while natural convection enhanced airflow and removal of moisture-laden air (Ajao et al., 2024a). Temperatures within the dryer are typically maintained at an average of 45 – 55 ℃, depending on solar intensity and ambient conditions. The relative humidity inside the chamber was monitored using a digital data logger. Drying continued until constant weight was achieved, defined as two consecutive weight measurements (1/2 h apart) showing no further moisture loss (Bolaji & Olalusi, 2008; Ajao et al., 2024b).

Cabinet Tray Dryer (Multi Crop Dryer, MCD)

A laboratory cabinet tray dryer (forced convection) was used. Samples spread on stainless trays were dried at a temperature range of 50 - 60 °C and ~1.0 $m \cdot s^{-1}$ air velocity until two successive weights (1 h apart) showed no further moisture loss (Kamble et al., 2021).

Sample preparation and dilutions

At each sampling stage, 10 g of sample (pulp or homogenized chips) was aseptically weighed into 90 mL sterile buffered peptone water (BPW) and homogenized for 2 min using a stomacher. Serial dilutions (10^{-1} to 10^{-6}) were prepared in sterile diluent (Mongi, 2023).

Culture media and enumeration

- **Total viable count (TVC):** Plate Count Agar (PCA), incubated at 37 °C for 48 h.
- **Coliforms:** Violet Red Bile Agar (VRBA), incubated at 37 °C for 24 h.
- **Yeasts and moulds:** Potato Dextrose Agar (PDA) acidified to pH 3.5, incubated at 25 °C for 3–5 days.

Plates with 30–300 colonies were counted, and results expressed as $CFU \cdot g^{-1}$ (Mongi, 2023).

Quality control

Sterile blanks and media sterility checks were included. Control organisms (E. coli ATCC 25922, B. subtilis ATCC 6633, Candida albicans ATCC 10231) were used to verify media performance.

Sampling schedule

Microbial analysis was carried out on: Fresh fruit pulp (baseline); Post-processing (before drying); Final dried product. Each stage was analysed in triplicate.

Data Analysis

Microbial counts were log_{10}-transformed before statistical analysis. Mean ± SD were calculated, and reductions expressed as log_{10} difference between fresh and dried samples. One-way ANOVA followed by posthoc multiple comparison (Duncan's test) was used to compare treatments ($p < 0.05$) (Ajao et al., 2024a).

Results and Discussion

Microbial Analysis

Microbial evaluation of the fresh mango pulp and dried mango chips was carried out using the pour plate technique. Appropriate serial dilutions were prepared using sterile distilled water to obtain countable colonies. Aliquots of 1 mL from suitable dilutions were plated on nutrient agar for total bacterial count (TBC), yeast extract agar for total yeast count (TYC), MacConkey agar for coliform detection, and potato dextrose agar for fungi. Plates were incubated at 37 °C for 24–48 h (bacteria) and at 30 °C for 3–5 days (yeast and fungi). Microbial colonies were counted and expressed as Colony Forming Units per gram (cfu/g) of sample. All analyses were performed in triplicate.

Results and Discussion

The microbial analysis of fresh mango pulp and dried mango chips (0-day) revealed significant variations in microbial loads (Table 1). Fresh mango pulp recorded the highest contamination levels, with total bacterial counts ranging between 2.2×10^4 and 2.6×10^4 CFU/g (mean = 2.40×10^4 CFU/g). Yeast counts ranged from 1.2×10^4 to 1.5×10^4 CFU/g, while coliforms and moulds were not detected. The relatively high bacterial and yeast loads in the fresh pulp could be attributed to its high moisture content, which supports microbial proliferation, and possible contamination during handling and peeling (Dereje & Abera, 2020).

In contrast, dried mango chips exhibited substantially lower microbial counts. For parabolic solar-dried (PSSD) chips, bacterial counts decreased to an average of 1.4×10^4 CFU/g, while yeast counts ranged between 7–8 CFU/g. No visible growth (NVG) was observed for coliforms and moulds, indicating effective inhibition of these groups by the drying process. Similarly, mechanically cabinet-dried (MCD) chips showed an average bacterial count of 2.30×10^4 CFU/g, with no visible growth of yeast, coliforms, or moulds. Although both drying methods significantly reduced microbial loads compared to fresh pulp, solar drying appeared slightly more effective in suppressing yeast growth.

The absence of mould contamination in both drying systems is noteworthy, as moulds are often implicated in tropical fruit spoilage. This reduction is likely due to decreased water activity following drying,

which restricts fungal development (FAO, 2021). The results corroborate the findings of Mongi (2023), who reported markedly lower microbial loads in solar-dried mango and pineapple relative to their fresh forms. Furthermore, the non-detection of coliforms across all dried samples reflects good hygienic practices and adequate drying conditions during processing.

For statistical uniformity, microbial counts were $\log_{10}$-transformed prior to analysis to normalize the data; however, the results are presented in CFU/g for ease of interpretation.

Overall, both solar and mechanical drying effectively reduced microbial contamination in mango chips, improving safety and extending shelf-life potential. The marginally lower microbial counts observed in solar-dried samples may be attributed to higher surface temperatures and possible UV exposure during drying. These findings provide useful baseline data for evaluating the storage stability and consumer safety of dried mango products.

Table 1: Microbial load (CFU/g) of fresh mango pulp and dried mango chips

Sample	Total Bacterial Count (CFU/g, mean)	Total Yeast Count (CFU/g, mean)	Coliform	Total Mould Count (CFU/g, mean
Fresh mango pulp	2.40×10^4 [a]	1.40×10^4 [a]	NVG	NVG
Parabolic solar dried (PSSD)	1.40×10^4 [b]	8.00×10^3 [b]	NVG	NVG
Mechanical cabinet dried (MCD)	8.00×10^3 [c]	0 [c]	NVG	NVG

Conclusion

This study has shown that drying significantly reduces microbial load in mango products compared to fresh pulp. Fresh mango pulp had high bacterial and yeast counts, while parabolic solar drying (PSSD) and mechanical cabinet drying (MCD) effectively lowered microbial levels, with no coliform or mould growth detected. ANOVA and Duncan's test confirmed significant differences ($p < 0.05$) among treatments, with microbial load decreasing in the order: fresh pulp > PSSD > MCD. The findings affirm that drying technologies improve the microbial safety and shelf stability of mango chips, thereby supporting postharvest loss reduction and value addition.

Recommendations

- **Adoption of drying technologies:** Both PSSD and MCD are suitable for safe mango processing, but solar drying is more sustainable and cost-effective for rural communities.
- **Capacity building:** Training of women and small-scale processors on hygienic drying practices should be prioritized to enhance product quality and income generation.

- **Policy support:** Government and research institutes (such as NSPRI) should strengthen dissemination of affordable drying technologies to empower farmers, reduce postharvest losses, and enhance food security.
- **Further research:** Long-term storage studies should be conducted to evaluate microbial dynamics and shelf life stability under different packaging condition

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References

Ajao, T. O., Omoniyi S. O., Famakinwa, J. O., Ojo, O. A., Oyewole, S. N., Shotonwa, D., Lawal, Badmus, D. E., Mobolaji., Adedeji, J. A., & Alao, A. O. (2024a). Mathematical modelling of the drying characteristics and economic analysis of Hake fish using Smoking Kiln. *Journal of Research in Agriculture and Food Sciences.* 2(1). doi: 10.5455/JRAFS.20240909085309.

Ajao, T. O., Oyewole, O. S., Famakinwa, J. O., Oyewole, S. N., Shotonwa, A., Zaka, O. K., Kazeem, A. A., and Ajala, O. V. (2024b). Mathematical Modelling of Solar Drying Kinetics and its Effect on Qualities of *Telfaria amygdalina* using NSPRI Parabolic Shaped Solar Dryer. Proceedings of the 24th International Conference and 44th Annual General Meeting of the Nigerian Institution of Agricultural Engineers, Abuja, Nigeria, 14 – 18th October, 2024

Behera, D. D., Mohanty, R. C., & Mohanty, A. M. (2023). Performance evaluation of indirect type forced convection solar mango dryer: A sustainable way of food preservation. *Thermal Science,* 27(2B). pp 1659-1672. https://doi.org/10.2298/TSCI220621154B

Dereje, B., & Abera, S. (2020). Effect of some pretreatments before drying on microbial load and sensory acceptability of dried mango slices during storage periods. *Cogent Food & Agriculture,* 6(1). https://doi.org/10.1080/23311932.2020.1807225

Engin, A. S., & Kuşçu, A. (2023). The Effect of Different Drying Processes on Some Nutritional and Quality Criteria in Tomato Powder. *Gaziosmanpaşa Bilimsel Araştırma Dergisi*, 12(1), 194-204.

Mongi, Richard John (2023). Physicochemical properties, microbial loads and shelf life prediction of solar dried mango (*Mangifera indica*) and pineapple (*Ananas comosus*) in Tanzania, *Journal of Agriculture and Food Research*, 11, https://doi.org/10.1016/j.jafr.2023.100522

Mohammed, S., Edna, M., & Siraj, K. (2020). The effect of traditional and improved solar drying methods on the sensory quality and nutritional composition of fruits: A case of mangoes and pineapples, *Heliyon*, 6(6), https://doi.org/10.1016/j.heliyon.2020.e04163

Vijaya Raghavan. (2007). Drying characteristics of foamed alphonso mango pulp in a continuous type foam mat dryer. *Journal of Food Engineering*. https://doi.org/10.1016/J.JFOODENG.2006.04.027

Salvador, P. V., Phinney, R., Östbring, K., Lucas T., Rayner, M., Galindo, F. G., & Davidsson, H. (2025). Minimizing post-harvest waste of mango in rural Mozambique – The effect of different solar setups in mango drying. *AIMS Agriculture and Food*, 10(1): 58–73. http://www.aimspress.com/article/doi/10.3934/agrfood.2025004

Effect of Biopolymer and Cinnamon-Based Edible Coatings on the Postharvest Quality and Shelf Life of African Grapes (*Lannea microcarpa*)

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Abstract

African grapes (*Lannea microcarpa*) are nutritionally rich but highly perishable fruits that undergo rapid postharvest deterioration, limiting their market potential and contributing to significant food losses. Sustainable approaches such as edible coatings present a promising solution by acting as semi-permeable barriers that regulate respiration, and delay senescence, while also reducing reliance on synthetic packaging. This study evaluated the effectiveness of starch and carboxymethyl cellulose (CMC) coatings, with and without cinnamon extract, on the physicochemical quality of African grapes stored at ambient conditions for 10 days. The fruits were divided into five groups: Group A1, uncoated control; group A2 (starch 2%); group A3 (CMC 1%); group A4 (starch 2% + cinnamon extract); and group A5 (CMC 1% + cinnamon extract). Moisture content, pH, titratable acidity, total soluble solids, and weight loss were monitored at 5-day intervals. Results showed that coated fruits retained significantly higher moisture and acidity compared to the control, A5 exhibited the lowest weight loss (19.92%) and the highest moisture content (76.03%) at the end of the storage period ($p < 0.05$). The control sample (group A1) recorded the highest decrease in TTA (0.146%) and the highest increase in TSS (1.1°Brix). Overall, natural polymer-based coatings, particularly CMC and starch integrated with cinnamon extract, proved effective in extending African grape shelf life under non-refrigerated storage. These findings highlight the potential of eco-friendly coatings as a cost-effective and biodegradable technology for reducing postharvest losses and enhancing the market value of underutilized tropical fruits.

Keywords: African grapes, biopolymers, Cinnamon extract, edible coatings, shelf-life extension.

Introduction

African grapes (*Lannea microcarpa*), often called “desert grapes,” are valued for their unique taste, nutritional benefits, and cultural importance across many African communities (Murtala et al., 2025). However, their soft skin and high sugar content make them highly perishable, with a shelf life of only a few days under ambient conditions. Rapid moisture loss, microbial spoilage, and overripening severely limit their availability and market potential (Blanckenberg et al., 2021).

Sustainable preservation strategies are needed to extend their shelf life, reduce waste, and enhance market value. In recent years, edible coatings have emerged as a sustainable alternative, as they act as semi-permeable barriers that limit respiration, moisture loss, and microbial growth while reducing reliance on synthetic packaging (Lichter et al., 2006; Sonker et al., 2016; Karnwal et al., 2025). Studies have shown that CMC and starch-based coatings can effectively delay senescence and maintain fruit quality by regulating gas exchange and water balance (Tumbarski et al., 2019; Ali et al., 2022). Incorporation of bioactive compounds such as cinnamon extract, with proven antioxidant and antimicrobial activity, further enhances preservation by reducing oxidative and microbial spoilage (Martinelli & Burner, 2024; Bajaj et al., 2023).

Although edible coatings have been widely studied in fruits such as mango, strawberry, and tomato, little is known about their potential in extending the shelf life of African grapes. Addressing this gap is essential to reduce postharvest losses, promote sustainable food preservation, and unlock the economic value of this underutilized fruit. Therefore, this study evaluated the effectiveness of starch and CMC coatings, with and without cinnamon extract, in preserving the physicochemical properties of African grapes during storage. The findings aim to provide a natural, low-cost, and scalable strategy to reduce postharvest losses while contributing to environmental sustainability and food security.

Methodology

Samples collection

Freshly harvested mature unripe African grapes were purchased from Ipata market, Ilorin, Kwara State, Nigeria. The fruits were washed and then allowed to air-dry. Cinnamon sticks were purchased from Yoruba road market, Ilorin. The sticks were cleaned using dry kitchen tissues and ground, after which they were extracted for oil, using a Hydro distillation setup.

Preparation of coatings

Coatings were prepared using the method of Olivas & Barbosa-Cánovas (2005) and Lin & Zhao (2007) with modifications. Exactly 5 g of carboxymethyl cellulose (CMC) and 10 g of soluble starch were dissolved separately in 500 mL of distilled water and stirred on the hotplate using a magnetic stirrer at 60 ^{o}C to obtain a clear solution, with glycerol (1%) added to each solution as plasticizer. Another set of solutions were prepared by dissolving exact weight of both carbohydrates separately in 500 mL of 5% cinnamon aqueous extract and prepared as explained above. All four (4) solutions were labelled, and allowed to cool before use.

Coating of African grapes

The mature green African grapes were divided into five groups (40 grapes each) and treated as:

A1: Control

A2: Coated with Starch 2%

A3: Coated with CMC (1%) in 5% cinnamon extract

A4: Coated with Starch (2%) in 5% cinnamon extract

A5: CMC 1%

The treated samples were kept in uniformly sized paper carton (30 cm×18 cm ×18 cm) at ambient (28 ± 2 ^{o}C and 70% RH) and stored for 10 days with analyses carried out at 5 days interval.

Physicochemical properties

Moisture, ash, pH, and total titratable acidity (TTA) contents were determined according to AOAC (2000). Weight loss and total soluble solids were estimated as described by Lawal et al. (2019). All analyses were done in triplicate. Statistical analysis was done with SPSS software package to determine the analysis of variance (ANOVA) and statistical difference was determined using Duncan range multiple tests at 95% confidence level ($p<0.05$).

Results and Discussion

Physicochemical properties of the stored African grapes

Moisture content declined steadily in all treatments during storage, which is expected due to transpiration and metabolic water loss (Table 1). However, the control (A1) suffered the sharpest reduction, falling from 84.55% on day 0 to 60.96% by day 10. By contrast, coatings substantially minimized these losses, with the CMC treatment (A5) retaining the highest moisture (76.03%) at day 10. Coatings incorporating cinnamon extract, particularly A3 (CMC + cinnamon) and A4 (starch + cinnamon), also outperformed the control. This suggests that the coatings provided effective barriers to water vapor diffusion. Such hydrophobic barrier properties are consistent with the findings of Ali et al. (2022), who reported that CMC coatings effectively delay moisture loss in tropical fruits by forming semi-permeable films that reduce water vapor transmission. The inclusion of cinnamon extract may further contribute to this effect through its antioxidant activity, which not only enhances the structural integrity and stability of the coating film but may also interact synergistically with the CMC matrix to improve its overall barrier performance. This synergistic interaction could explain the reduced weight loss and improved moisture retention observed in the coated samples, aligning with the observations of Pagliari et al. (2023) on the role of natural antioxidants in reinforcing biopolymer films.

The TTA decreased across all samples over time, reflecting the metabolic consumption of organic acids during ripening and senescence. The control (A1) exhibited the most drastic drop, from 0.845% to 0.146%

by day 10. Coated grapes maintained higher acidity, with A3 retaining 0.185% at day 10, significantly ((p<0.05) greater than the control. This indicates that the coatings slowed acid degradation by moderating respiration and enzymatic breakdown. Such retention of organic acids is important for delaying senescence and preserving sensory quality, in agreement with findings by Karnwal et al. (2025), who showed that edible coatings slow ripening by modifying the fruit's internal atmosphere. The antimicrobial effect of cinnamon extract may also have contributed by reducing spoilage organisms associated with acid loss (Martinelli and Burner, 2024).

The pH values showed only modest variation but coated grapes (A3 and A5) sustained slightly higher pH values (2.51) compared with the control (2.48) at day 10. These small differences nevertheless suggest slower acid depletion and lower microbial activity, reinforcing the role of CMC- and cinnamon-based coatings in stabilizing fruit quality (Bajaj et al., 2023).

The TSS, an indicator of sugar accumulation and sweetness, rose in the control from 0.83 to 1.10 °Brix, likely due to concentration effects from water loss and starch hydrolysis. Coated grapes exhibited more moderate increases; A3 reached 1.00 °Brix while A2, A4, and A5 showed even smaller rises. This moderation implies that the coatings slowed starch-to-sugar conversion and respiration, thereby reducing the risk of overripening. Comparable outcomes were reported by Shinga et al. (2025), who noted that coatings reduce respiration rates and help maintain fruit marketability.

Table 1. Physicochemical properties of coated and uncoated African grapes during storage

Sample	Storage days	Moisture content (%)	TTA (%)	TSS (°Brix)	pH
A1	0	84.547±0.367^{a}	0.845±0.017^{a}	0.833±0.058^{a}	2.490±0.000^{a}
A2		84.547±0.367^{a}	0.845±0.017^{a}	0.833±0.058^{a}	2.490±0.000^{a}
A3		84.547±0.367^{a}	0.845±0.017^{a}	0.833±0.058^{a}	2.490±0.000^{a}
A4		84.547±0.367^{a}	0.845±0.017^{a}	0.833±0.058^{a}	2.490±0.000^{a}
A5		84.547±0.367^{a}	0.845±0.017^{a}	0.833±0.058^{a}	2.490±0.000^{a}
A1	5	74.664±0.675^{a}	0.495±0.009^{a}	0.667±0.491^{a}	2.485±0.000^{ab}
A2		74.954±0.390^{a}	0.517±0.013^{c}	0.767±0.029^{a}	2.465±0.000^{a}
A3		78.190±0.355^{b}	0.516±0.008^{c}	0.917±0.029^{a}	2.500±0.000^{b}
A4		77.025±0.383^{c}	0.511±0.014^{ab}	0.717±0.076^{a}	2.475±0.000^{ab}
A5		80.095±0.364^{d}	0.509±0.001^{ab}	0.733±0.058^{a}	2.535±0.000^{c}
A1	10	63.145±1.653^{a}	0.146±0.002^{a}	1.100±0.000^{e}	2.480±0.000^{b}
A2		63.145±1.653^{a}	0.189±0.008^{c}	0.700±0.000^{c}	2.440±0.000^{a}
A3		71.081±0.869^{c}	0.185±0.004^{bc}	1.00±0.000^{d}	2.510±0.000^{c}
A4		71.859±0.253^{c}	0.176±0.010^{bc}	0.533±0.058^{a}	2.460±0.000^{b}
A5		76.027±0.528^{d}	0.174±0.001^{b}	0.633±0.058^{b}	2.460±0.000^{bc}

Result shows mean ± standard deviation (SD) of triplicate values. Means with unshared superscript in the same column for each of the storage days are significantly different (p<0.05). A1= Control (Uncoated); A2= Coated with Starch 2%; A3= Coated with CMC (1%) in 5% cinnamon extract; A4= Coated with Starch (2%) in 5% cinnamon extract; A5= CMC 1%

Weight loss of the stored African grapes

Weight loss, closely associated with moisture decline, was highest in groups A2 and A1 at 34.38% and 32.72% respectively, whereas group A5 recorded the lowest value at 19.92%. These findings are consistent with Ali et al. (2022) and Tumbarski (2019), who reported that CMC reduces moisture loss and delays ripening in fresh produce. The addition of cinnamon extract further improved coating performance due to its antioxidant and antimicrobial properties (Basaglia et al., 2021). By limiting water loss, the coatings effectively preserved overall freshness (Tavassoli-Kafrani et al., 2022).

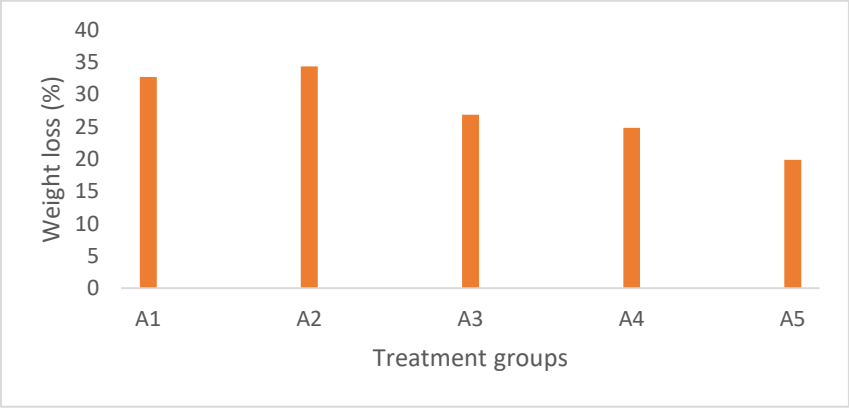


Figure 1: Effect of Coating medium on weight loss of stored African grapes.

Each bar represents mean of triplicate values. Error bars represent Standard error (SE). A= Control (Uncoated); A2= Coated with Starch 2%; A3= Coated with CMC (1%) in 5% cinnamon extract; A4= Coated with Starch (2%) in 5% cinnamon extract; A= CMC 1%

Conclusion

The study demonstrated that carboxymethyl cellulose (CMC)-based edible coatings, with or without cinnamon extract, effectively reduced weight loss, preserved acidity, and maintained the quality of African grapes. Starch coatings offered moderate protection, whereas CMC showed superior barrier properties, enhanced by the antioxidant and antimicrobial effects of cinnamon extract. Edible coatings to extend shelf life, reduce postharvest losses, and support food security in tropical regions.

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References

Ali, S., Anjum, M.A., Khan, A.S., Nawaz, A., Ejaz, S., Khaliq, G., Iqbal, S., Ullah, S., Rehman, R.N.U., Ali, M.M., & Saleem, M.S. (2022). Carboxymethyl Cellulose Coating Delays Ripening of Harvested Mango Fruits by Regulating Softening Enzymes Activities. *Food Chemistry*, *380*, 131804.

AOAC. *Official Method of Analysis*, 17th ed.; Association of Official Analytical Chemists: Washington, DC, USA, 2000.

Bajaj, K., Adhikary, T., Gill, P.P.S., & Kumar, A. (2023). Edible coatings enriched with plant-based extracts preserve postharvest quality of fruits: A review. *Progress in Organic Coatings*, *182*, 107669. https://doi.org/10.1016/j.porgcoat.2023.107669

Basaglia, R. R., Pizato, S., Santiago, N. G., de Almeida, M. M. M., Pinedo, R. A., & Cortez-Vega, W. R. (2021). Effect of edible chitosan and cinnamon essential oil coatings on the shelf life of minimally processed pineapple (Smooth cayenne). *Food Bioscience*, *41*, 100966.

Blanckenberg, A., Opara, U.L., & Fawole, O.A. (2021). Postharvest Losses in Quantity and Quality of Table Grape (cv. Crimson Seedless) along the Supply Chain and Associated Economic, Environmental and Resource Impacts. *Sustainability*, 13, 4450.

Karnwal, A., Kumar, G., Singh, R., Selvaraj, M., Malik, T., & Al Tawaha, A.R.M. (2025). Natural biopolymers in Edible Coatings: Applications in Food Preservation. *Food Chemistry: X*, 102171. https://doi.org/10.1016/j.fochx.2025.102171

Lawal, I. O., Akande, S. A., Adebayo, O. B., Ayanda, I. S., Ibrahim, A. S., & Fashanu, T. A. (2019). Wood by-Product as Storage Material for Post-Harvest Management of Tomato (*Solanum lycopersicum L*.) at Breaker Stage, 22(4), 1–10.

Lichter, A., Gabler, F.M., & Smilanick, J.L. (2006). Control of Spoilage in Table Grapes. *Stewart Postharvest Review,* 2006,6, 1–10. doi: 10.2212/spr.2006.6.1.

Lin, D., & Zhao, Y. (2007). Innovations in the development and application of edible coatings for fresh and minimally processed fruits and vegetables. *Comprehensive Reviews in Food Science and Food Safety*, 6, 60–75. 10.1111/j.1541-4337.2007. 00018.x

Martinelli, M., & Bruner, M. (2024). The Effect of Cinnamon Extract on the Prevention of Fruit Spoilage via Delay in Microbial Growth. *Journal of Student Research* 13(3). https://doi.org/10.47611/jsrhs.v13i3.7071

Murtala, A., Imam, N., Barde, M.I., & Auwal, Y. (2025). Proximate and Mineral Analyses of African Grapes (*Lannea microcarpa*) Roots for Nutritive and Therapeutic Application. *Dutse Journal of Pure and Applied Sciences,* 11(1b), 59–65. https://doi.org/10.4314/dujopas.v11i1b.7

Olivas G.I., & Babosa-Canovas, G.V (2007). Edible coatings for fresh-cut fruits, *Critical reviews in Food Science and Nutrition*, 45(7-8), 657-670. https://doi.org/10.1080/10408690490911837

Pagliari, S., Forcella, M., Lonati, E., Sacco, G., Romaniello, F., Rovellini, P., Fusi, P., Palestini, P., Campone, L., Labra, M., Bulbarelli, A., & Bruni, I. (2023). Antioxidant and Anti-Inflammatory Effect of

Cinnamon (*Cinnamomum verum* J. Presl) Bark Extract after In Vitro Digestion Simulation. *Foods*. 18, 12(3), 452. https://doi.org/10.3390/foods12030452.

Shinga, M. H., Silue, Y., & Fawole, O. A. (2025). Recent Advancements and Trends in Postharvest Application of Edible Coatings on Bananas: A Comprehensive Review. *Plants*, *14*(4), 581.

Sonker, N., Pandey, A.K. & Singh, P. (2016). Strategies to control post-harvest diseases of table grape: A review. *Journal of Wine Research,* 27, 105–122. https://doi.org/10.1080/09571264.2016.1151407.

Tavassoli-Kafrani, E., Gamage, M.V., Dumée, L.F., Kong, L., & Zhao, S. (2022). Edible Films and Coatings for Shelflife Extension of Mango: A review. *Critical Reviews in Food Science and Nutrition*, *62*(9), 2432-2459.

Tumbarski, Y., Nikolova, R., Petkova, N., Ivanov, I., & Lante, A. (2019). Biopreservation of Fresh Strawberries by Carboxymethyl Cellulose Edible Coatings Enriched with a Bacteriocin from *Bacillus methylotrophicus* BM47. *Food technology and biotechnology*, *57*(2), 230-237.

Agronomic Performance of Biofortified Maize Hybrids in Nigeria

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Abstract

Biofortified maize hybrids that are high-yielding are crucial in combating 'hidden hunger', prevalent in regions with high consumption of cereal-based diets. The present study assessed the agronomic performance and stability of micronutrient-rich maize hybrids across multiple environments. Ninety-six yellow and orange endosperm maize hybrids, alongside four checks, were evaluated using a 25 x 4 alpha lattice design across eight environments in Nigeria. The top 20% hybrids for grain yield (GY) were subjected to additive main effects and multiplicative interaction (AMMI) and genotype and genotype environment interaction (GGE) analyses to explain the genotype x environment interaction (GEI) using PB tools 1.4. Significant variability ($p<0.01$) among the hybrids and environments were observed for grain yield (GY) and other agronomic traits. Hybrid x environment interaction effect was significant ($p<0.01$) for GY, plant aspect, and ear aspect. GY ranged from 1.49, obtained from G71 to 6.04t/ha, obtained from G32 across environments, with a mean of 4.33 t/ha. The range for other agronomic traits were 56-64 days for days to anthesis (DA), 59-65 days for days to silking (DS), 1.90-3.50 and 1.69-3.71 for plant aspect (PA) and ear aspect (EA), respectively. Hybrids G30, G46, G47, and G80 were identified to be stable across environments from the AMMI biplot. The ideal genotype GGE biplot depicted G30, 32, 47, and G80 to be the most stable of the high-yielding hybrids across environments. The superior hybrids identified will be useful to farmers in different agroecological zones in Nigeria.

Keywords: Biofortified maize, Hidden hunger, Genotype x Environment Interaction, Grain yield, Stability

Introduction

Maize (*Zea mays* L.) is one of the most widely grown cereals globally. The nutritional profile of maize grain shows that it contains about 70%, 11% and 5% starch, protein and fat, respectively with vitamins C, E and K, and low levels of micronutrients (Ekanem *et al*., 2022). The importance of maize in food security, especially in sub-Saharan Africa (SSA) necessitates its continuous improvement for agronomic and quality traits. Micronutrients deficiencies (MNDs), particularly those of Vitamin A, Zinc (Zn) and iron (Fe) have major health and economic impact, affecting 25% and 48% of global and sub-Saharan African population, respectively (Steven *et al*., 2015). The Maize Breeding Unit at the International Institute of Tropical

Agriculture (IITA) has championed maize biofortification, resulting in the release of several hybrids and open pollinated varieties with enhanced micronutrients content to fight hidden hunger (Udo *et al*., 2023). The goal of biofortification breeding is to develop crop varieties that combine high productivity and increased micronutrients content. Biofortification of maize should not be achieved at the expense of grain yield and relevant agronomic traits, like flowering dates, plant height, ear height, plant and ear aspects. Furthermore, GY of maize which differs across agroecological zones due to variability in temperature, precipitation, and solar radiation is a complex trait influenced by genotype x environment interaction (GEI) (Olayinka, 2025). It is therefore necessary for breeders to evaluate the performance of genotypes across multiple environments to identify the genotypes that are suitable to specific environments and those that are adaptable across the agroecological zones of SSA. This study was conducted to: (i) evaluate the performance of biofortified maize hybrids in multiple environments and (ii) identify stable and high yielding hybrids across environments.

Methodology

Ninety-six (96) experimental biofortified hybrids, developed at IITA with 4 commercial hybrids used as checks were arranged in a 25 x 4 lattice design, replicated twice and planted in four testing sites (Ikenne, Saminaka, Mokwa and Zaria) in Nigeria in 2020 and 2021. The trial in each site was planted in a single 5m row plot with a spacing of 0.75m between rows and 0.50m, two plants per hill to give a plant population of about 53,333 plants/ha. Fields were managed as recommended for each site (Udo *et al*., 2023).

Data collected include days to anthesis (DA), days to silking (DS), anthesis-silking interval (ASI), plant height (PH), ear height (EH), ear aspect (EA) and grain yield (GY). Analysis of variance was performed using Proc GLM procedure SAS 9.4. Each year x location combination was regarded as an environment to give a total of 8 environments as follows: Ikenne 2020 (E1), Saminaka 2020 (E2), Mokwa 2020 (E3), Zaria 2020 (E4), Ikenne 2021 (E5), Saminaka 2021 (E6), Mokwa 2021 (E7), Zaria 2021 (E8). Means were separated using standard error of differences (SED). Top 20% hybrids for GY were subjected to additive main effects and multiplicative interaction (AMMI) and genotype and genotype environment interaction (GGE) analyses to explain the genotype x environment interaction (GEI) using PB tools 1.4.

Results and Discussion

The effect of hybrids was significant at $p<0.01$ for GY and other agronomic traits (**Table 1**). The variability among the hybrids for GY and other agronomic traits indicates genetic differences among the hybrids included in the study. These differences could be exploited during selection for promising hybrids with high GY and desirable agronomic traits. The proportion of the total variation attributed to environment was greater than 70%. This highlighs the importance of environmental effects on the productivity of maize

and the need to evaluate the hybrids in multiple locations. Hybrid x environment interaction was significant at p<0.01 for GY and PA indicating that the performance of the hybrids across environments was not stable, revealing the need to further analyse the genotype x environment interaction observed. Maazou *et al*. (2022) corroborates these findings.

Table 1: Mean Squares from the ANOVA for Agronomic Traits and Grain Yield for 96 Hybrids and 4 Checks Evaluated in Eight Environments in Nigeria

Source	DF	DA	DS	PH	EH	PA	EA	GY
Envt	7	158.13**	151.27**	748.81**	552.82**	6.71**	6.73**	28.98**
Rep (Envt)	8	4.32**	3.64*	57.60**	24.99*	0.32**	0.74**	0.77
Block (Envt*Rep)	384	2.33**	2.53**	216.45**	118.24*	0.17**	0.17**	0.97**
Hybrid	99	19.77**	21.50**	201.65**	110.94**	1.34**	1.47**	5.08**
Hybrid*Envt	693	1.75*	1.76	187.44**	94.01	0.20**	0.20**	0.87**
Error	376	1.53	1.64	122.00	96.06	0.12	0.13	0.62
CV%		2.10	2.07	5.37	9.71	13.17	14.29	16.16

DA: days to anthesis, PA: plant aspect, DS: days to silking, PH: plant height (cm), EA: ear aspect, EH: ear height (cm), GY: grain yield (t/ha), Envt: Environment, DF: degree of freedom, *: significant at p<0.05, **: significant at p<0.01.

Among the eight environments, highest GY, best PA and EA were obtained from Zaria 2020 (E4), followed by Zaria 2021 (E8). Lowest grain yield accompanied by late flowering was obtained in Mokwa 2021 (E7) **(Table 2)**. According to (Shehu, 2019), the Northern Guinea Savannah where Zaria falls is the most suitable zone for maize production in Nigeria. Highest grain yield across environments was obtained from G32 (6.04 t/ha), while the lowest was obtained from G71 (1.49 t/ha) with a mean of 4.88t/ha which is higher than the values obtained from previous studies by Iseghohi et al, 2020. The range for other agronomic traits were 56-64 days for DA, 59-65 days for DS, 1.90-3.50 and 1.69-3.71 for PA and EA, respectively **(Table 3).**

Table 2. Environment Means for Agronomic Traits and Grain Yield of 96 Hybrids and Checks Evaluated in Eight Environments in Nigeria

	ENVIRONMENTS								Mean	SED
TRAIT	1	2	3	4	5	6	7	8		
DA	53.02	57.59	57.17	61.70	52.56	57.67	81.02	61.39	60.26	6.40
DS	55.02	58.54	59.17	63.14	54.34	59.49	83.02	62.45	61.90	6.44
ASI	2.00	0.96	2.01	1.45	1.78	1.82	2.00	1.06	1.63	0.30
PH	184.20	231.6	190.2	199.4	201.2	241.4	199.3	196.8	205.51	14.24
EH	92.10	107.80	94.75	101.80	103.30	106.40	102.30	98.61	100.87	3.86
PA	2.42	2.48	2.48	2.42	2.83	2.76	2.70	2.86	2.62	0.14
EA	2.57	2.40	2.26	2.26	2.61	2.76	2.62	2.71	2.52	0.14
GY	4.51	5.74	3.69	6.45	4.49	5.47	2.78	5.94	4.88	0.70

1: Ikenne 2020, 2: Saminaka 2020, 3: Mokwa 2020, 4: Zaria 2020, 5: Ikenne 2021, 6: Saminaka 2021, 7: Mokwa 2021,8: Zaria 2021, SED:Standard error of difference. DA: days to anthesis, PA: plant aspect, DS: days to silking,

PH: plant height (cm), EA: ear aspect, EH: ear height (cm), GY: grain yield (t/ha),

Table 3. Mean values for Agronomic traits and Grain Yield of the of Top 10% of Hybrids Evaluated Across Eight Environments in Nigeria

Hybrid	DA	DS	ASI	PH	EH	PA	EA	GY
G32	60.83	62.65	1.83	234.4	121.0	2.09	2.16	6.04
G29	60.86	62.50	1.63	217.1	114.6	2.16	2.55	6.00
G80	61.47	63.09	1.62	211.7	110.6	2.19	1.96	6.00
G86	58.06	59.26	1.20	216.9	98.22	2.37	2.16	5.92
G31	61.66	63.41	1.75	209.0	100.3	2.57	2.20	5.91
G15	59.97	61.39	1.42	205.6	97.42	2.51	2.75	5.86
G24	61.00	62.32	1.31	220.9	111.4	1.92	1.70	5.82
G1	60.90	62.75	1.84	197.8	103.9	2.45	2.20	5.80
G8	61.74	63.40	1.66	213.2	108.8	2.45	2.12	5.79
Min	56.00	59.00	0.90	176.2	82.3	1.90	1.69	1.49
Max	66.00	65.00	2.40	238.2	124.9	3.50	3.70	6.04
Mean	60.20	61.80	1.63	205.5	100.9	2.60	2.50	4.88
SED	0.34	0.34	0.17	5.09	3.52	0.17	0.16	0.37

SED: Standard error of difference, DS: days to silking, EH: ear height (cm), ASI: anthesis silking interval,
EA: ear aspect, DA: Days to anthesis, PA: plant aspect, PH: plant height (cm), GY: Grain Yield(t/ha)

The AMMI biplot for GY revealed that principal component axes (PCA) 1 and 2 explained 38.6% and 35.7% of total GEI variability (Fig. 1a). Hybrids G30, G46, G47, and G80 were stable across environments with low GEI as they were plotted closest to the origin of the AMMI PC1 vs. PC2 biplot **(Fig. 1a)**. The AMMI biplot also revealed that E1 and E5 were positively correlated and suited for hybrids G1, G31, G38 and G60. E3 and E7, which were low yielding environments were grouped together, ideal for G29, G46 and G77. E4 and E8 were also closely associated and suited to G4, G8, G32 and G47. G38 was best suited to E1, whereas G4 and G17 were best adapted to E2. The ideal genotype GGE biplot which ranked hybrids based on both mean and stability relative to the ideal hybrid for grain yield **(Fig. 1b)**, depicts hybrids 30, 32, 47 and G80 to be the most stable of the high-yielding hybrids across environments (Fig 1b). The high-yielding biofortified hybrids identified by the AMMI and GGE analysis to have stable performance across environment could be utilized directly or used to develop parents of genotypes enriched with micronutrients.

Conclusion

The study revealed genetic variability among the micronutrient-rich hybrids. The best performing and stable hybrids identified across eight environments would benefit biofortification breeding.

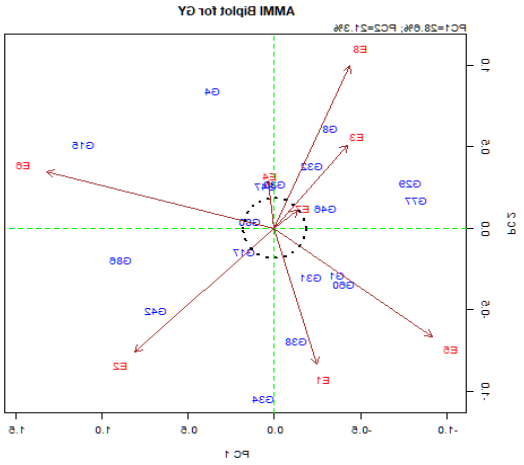


Fig 1a: AMMI biplot PC1 vs. PC2 for GY

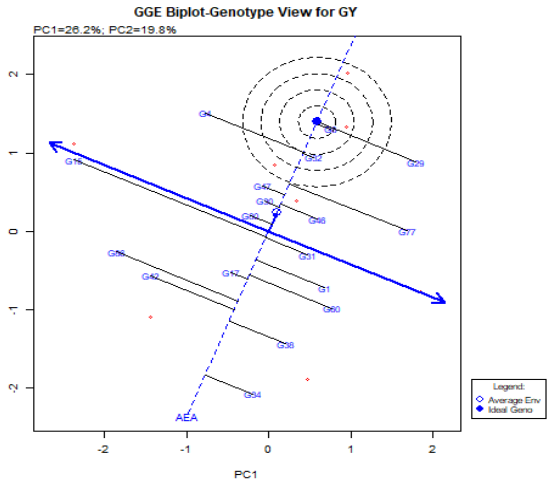


Fig 1b: The ideal genotype plot of hybrids for GY in the GGE biplot in 20% top hybrids

References

Ekanem, S. F., Audu, A. A., & Lieberman, M. (2022). Proximate analysis of grain samples from strategic grain reserve facilities in Nigeria. *Journal of Chemical Society of Nigeria*, *47*(3), 592-602.

Stevens, A., Bennett, E.J., Hennocq, Lu, Y., & Rogers, L. (2015). Trends and mortality effects of vitamin A deficiency in children in 138 low-income and middle-income countries between 1991 and 2013. *The Lancet Global health* 3(9),528-536.

Udo, E., Abe, A., Meseka, S., Mengesha, W., & Menkir, A. (2023). Genetic Analysis of zinc, iron and provitamin A content in tropical maize (Zea mays L.). *Agronomy*, *13*(1), 266.

Olayinka, A. O. (2025). Field Performance of Extra-Early Maturing Pro-Vitamin A Maize (Zea mays L.) Hybrids under Optimal Rainfed Conditions in the Derived Savanna Agroecology Zone. *Crop Breeding, Genetics and Genomics*, *7*(3).

Shehu, B. M., Lawan, B. A., Jibrin, J. M., Kamara, A. Y., Mohammed, I. B., Rurinda, J., ... & Merckx, R. (2019). Balanced nutrient requirements for maize in the Northern Nigerian Savanna: Parameterization and validation of QUEFTS model. *Field Crops Research*, *241*, Iseghohi, I., Abe, A., Meseka, S., Mengesha, W., Gedil, M., & Menkir, A. (2020). Assessing effect of marker-based improvement of maize synthetics on agronomic performance, carotenoid content, combining ability and heterosis. *Agronomy* 10(11), 1625. 107585.

Maazou, A. R. S., Adetimirin, V. O., Gedil, M., Meseka, S., Mengesha, W., & Menkir, A. (2022). Suitability of testers to characterize pro-vitamin A content and agronomic performance of tropical maize inbred lines. *Frontiers in Genetics 13*:955420.

Survey of Aflatoxins Contamination in Dried Fish, Maize And Melon Sold Across Major Markets In Lagos State

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Abstract

This study examined the prevalence, awareness, and handling practices regarding aflatoxins contamination in dried fish, maize and melon sold across various markets in Lagos State. Data from 132 traders of these commodities were analyzed. Results showed that 53% were aware of aflatoxins, though many lacked adequate knowledge. Major contamination drivers included high moisture, inadequate drying and poor storage. While 27.3% of traders discarded contaminated goods, others employed unsafe coping methods such as washing, aeration, or animal feeding. Preventive practices were limited to moisture avoidance (50%) and proper drying (35.6%). These findings underscore the need for targeted training, improved infrastructure, and stronger regulatory enforcement to mitigate risks. Strengthening awareness, handling, drying, and storage systems can enhance food safety, protect public health, and support Nigeria's compliance with international trade and food safety standards.

Keywords: Aflatoxins contamination, awareness, food safety, open market, postharvest handling

Introduction

Aflatoxins are naturally occurring toxic compounds produced by certain strains of the *Aspergillus* fungus, particularly *A. flavus* and *A. parasiticus*, which thrive in hot and humid environments (Bunny et al., 2024). They contaminate staples such as maize, groundnuts, sorghum, and other cereals when drying and storage are inadequate. In Nigeria, these conditions foster widespread contamination with serious health and economic impacts (Abdurrazaq & Oluwafemi, 2022). Chronic exposure causes liver cancer, immune suppression, and child stunting, while acute cases can be fatal (Aflasafe, 2020). Low awareness, poor enforcement, and weak food safety systems exacerbate the problem (NPFSIS, 2014). Aflatoxins cause about 5,000 deaths annually and cost Nigeria roughly USD 155 million in lost exports (PACA, 2020). Strengthening national food control systems, aligning standards with the Codex Alimentarius, and

investing in traceability, regulation, and awareness are essential to safeguard health and trade (FAO, 2025). Ensuring safe food supports Sustainable Development Goals 2 and 3, demanding urgent coordinated national action. Understanding the importance of food safety among the commodity traders is very key to guaranteeing availability of safe food commodities in the open market. Therefore, this study was aimed at assessing the awareness of commodity traders in Lagos markets on effects of aflatoxins contamination in some selected open-market traded food commodities.

Methodology

A cross-sectional survey was conducted in four purposively selected major Lagos markets: Mushin, Agege, Ido and Mile 12. From a sampling frame of market traders dealing in dried fish, maize and melon, 132 consenting traders were interviewed using a structured questionnaire implemented via KOBO Toolbox for real-time data capture. Questionnaire modules covered socio-demographics, commodity handling, visual contamination indicators (mould, caking, insect damage, discolouration), and coping/preventive practices. Collected descriptive data were summarized with frequencies and percentages.

Table 1: Analysis of Commodities Collected

Commodity	Frequency	Percent (%)
Fish	45	34.1
Maize	46	34.8
Melon	41	31.1

Source: Field Survey, 2025

Results and Discussion

Demographic Characteristics of Respondents

The majorities of the study respondents (Table 2) were male, aged around 44 years, and have completed secondary education. The average business experience of the respondents was 18.3 ± 11.0 years, with household size averaging 5.9 ± 3.4 members, indicating long-term engagement in commodity trading with moderate educational attainment.

Awareness of Aflatoxin

The results show that 53% (70 respondents) of the traders are aware of aflatoxins, while 47% (62 respondents) are not aware of this dangerous toxin (Table 3). Despite the relatively high percentage of awareness, 47% of the traders are not familiar with aflatoxins. This knowledge gap threatens public health and undermines control efforts. Findings highlight the need for targeted education and awareness programs to teach traders the risks of aflatoxins and practical measures for improved handling, drying and storage of food commodities.

Table 2: Demographic Distribution of Respondents

Variable	Mean	Standard Deviation (SD)
Age	44	12.11
Years of selling commodity	18.27	10.998
Household members	5.95	3.42
Variable	**Frequency**	**Percentage**
Educational Level		
Non-formal education	40	30.3
Primary education	33	25.0
Secondary education	54	40.9
Tertiary education	5	3.8
Gender		
Male	110	83.3
Female	22	16.7

Source: Field Survey, 2025

Factors Contributing to Aflatoxin Contamination in Food Commodities

The survey identified key factors contributing to aflatoxin contamination (Table 4). Most traders (80.3%) reported observing mould on stored commodities, a strong indicator of fungal growth. Among them, 52.8% saw mould occasionally, 7.5% often, and 39.7% rarely. Another common issue was product caking, caused by excess moisture and fungal activity — 51.4% experienced this occasionally, 5.7% often, and 42.9% rarely. Major drivers of these contaminations include high moisture, inadequate drying and poor storage (Abdurrazaq et al., 2022). These findings align with previous studies linking moisture and clumping to increased mycotoxin development in stored commodities.

Table 3: Awareness of Aflatoxin

Response	Frequency	Percent (%)
No	62	47.0
Yes	70	53.0
Total	132	100

Source: Field Survey, 2025

Traders in Lagos use both safe and unsafe methods to manage aflatoxin-contaminated goods. About 27.3% discard affected products, some sell cheaply (22.7%), 21.2% of the respondents wash and aerate, while others use them as animal feed (17.4%); all ineffective against the toxins. Fewer traders mix, consume, or give away contaminated items. Preventive practices are limited; 50% avoid moisture accumulation and 35.6% ensure proper and adequate drying, while only 12.1% use proper storage.

Traders' Responses on Handling and Preventing Aflatoxins Contamination in Commodities

These gaps show traders balance safety with livelihood pressures. Strengthening resilience requires training, affordable testing, efficient drying and improved storage facilities, and economic incentives to promote adoption of safer, aflatoxin-preventive practices.

Table 4: Factors Contributing to Aflatoxin Contamination in Food Commodities

Factor	Agree (%)	Disagree (%)	Strongly Agree (%)	Strongly Disagree (%)	Undecided (%)
High moisture content	47.0	9.8	34.1	0.8	8.3
Low temperature and high humidity	41.7	16.7	25.0	0.0	16.7
Structural condition of the storage house	51.5	17.4	19.7	0.8	10.6
Improper handling and storage conditions	52.3	5.3	34.1	0.0	8.3
Drought	22.0	27.3	1.5	2.3	47.0
Inappropriate harvesting time	41.7	16.7	18.9	1.5	21.2
Method of harvesting	41.7	19.7	12.9	1.5	24.2
Frequent insect attacks	45.5	27.3	11.4	5.3	10.6
Inappropriate drying technique	35.6	3.0	52.3	0.8	8.3
Inappropriate drying of product	34.8	5.3	54.5	0.8	4.5
Use of inappropriate transport system	53.8	14.4	22.0	1.5	8.3

Source: Field Survey, 2025

Table 5: Traders' Responses on Handling and Preventing Aflatoxins Contamination in Commodities (N = 132)

Methods	Frequency	Percentage
Handling Method		
Throw away	36	27.3
Sell at reduced price	30	22.7
Wash and aerate for sale	28	21.2
Use as animal feed	23	17.4
Mix with uncontaminated products before sale	9	6.8
Family consumption	3	2.3
Add chemicals	2	1.5
Give it out	1	0.8
Total	**132**	**100.0**
Prevention Method		
Keep away from moist/wet environment	66	50.0
Ensure proper drying	47	35.6
Proper storage	16	12.1
Careful handling of commodities	3	2.3
Total	**132**	**100.0**

Source: Field Survey, 2025

Conclusion

Aflatoxins contamination poses a persistent challenge in food commodities sold in Lagos markets. The study conducted among 132 traders across four major markets on three commodities (dried fish, maize and melon), revealed that 53% were aware of aflatoxins, while nearly half lacked adequate knowledge. Major drivers include high moisture, poor storage, and inadequate drying. Most traders adopted unsafe coping measures such as selling at reduced prices or washing contaminated products, while preventive practices like proper storage were limited. These findings emphasize the need for awareness creation, improved infrastructure, and capacity building for traders on strengthening of food safety systems.

Recommendations

To reduce aflatoxin contamination, there is a need for intensified public education and traders-focused capacity-building programs. Provision of low-interest loans and incentives will help traders adopt efficient drying and storage technologies. Market-level monitoring and affordable testing kits should be introduced to ensure compliance and early detection. Additionally, integrating aflatoxins education into school curricula and promoting media-based awareness will enhance food safety culture. Strengthening institutional collaboration and enforcement will protect public health and promote Nigeria's food trade competitiveness.

References

Abdurrazaq, S.A., & Oluwafemi, A.B. (2022). Awareness and prevalence of aflatoxin contamination in staple food commodities in Nigeria. *Journal of Food Safety, 42(3), 1–10.*

Abdurrazaq, S. A., Tijjani, H., & Atta, S. (2022). Assessment of aflatoxin contamination in maize and groundnuts during storage in Giwa community, Kaduna State, Nigeria. *UMYU Journal of Microbiology Research, 7(1), 12–20.*

Aflasafe, (2020). Fighting aflatoxin contamination in Africa: Country progress report – Nigeria. International Institute of Tropical Agriculture (IITA).

Bunny, S. M., Umar, A., Bhatti, H. S., Javed, S., & Suleria, H. A. R. (2024). Aflatoxin risk in the era of climatic change: A comprehensive review. *CABI Agriculture & Bioscience, 5(105)*. https://doi.org/10.1186/s43170-024-00388-0

Food and Agriculture Organization of the United Nations (2025). Strengthening food control systems for safer food and trade competitiveness. FAO.

NPFSIS. (2014). National Policy on Food Safety and Its Implementation Strategy. Federal Ministry of Health, Abuja, Nigeria.

PACA. (2020). The cost of aflatoxin contamination to African economies. Partnership for Aflatoxin Control in Africa, African Union Commission.

Salisu, B., Anua, S. M., Ishak, W. R. W., & Mazlan, N. (2020). Review on the aflatoxins' contamination of foods and public health effects among Nigerian population. *UJMR Journal of Microbiology Research, 5(2), 33–49.*

Biocompositional Potentials of Functional Cookies from Blends of Wheat Flour, Kersting Ground Nut and Date

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Abstract

This research was carried out to investigate the formulation and bio-compositional characteristics of cookies from the blends of wheat, kersting groundnut and date fruit flours. Fresh date fruits were sorted, washed, drained, de-seeded, diced into 5 mm thickness, oven dried at 50 ^{o}C for 8 hours, and converted into flour. Kersting groundnut was sorted, cleaned, de-husked, blanched for 40 minutes, oven dried at 50 ^{o}C for 9 hours, and converted into flour. Flour blends were formulated in the ratios 0:0:100, 10:10:80, 20:15:65, 30:20:50, and 40:25:35 for kersting groundnut, date fruit, and wheat flours, respectively; and coded as WKD1, WKD2, WKD3, WKD4 and WKD5, respectively. The obtained flour blends were processed into cookies and evaluated for bio-active compound and sensory evaluation using gas chromatography mass spectrometry (GC-MS) and 9-point hedonic scale, respectively. The bio-active compounds characterization showed the presence of 17 organic compounds, which include fatty acids and derivatives (associated with cardiovascular), fatty acid esters and carboxylic esters (contributed to antimicrobial activity), and aldehydes (such as 9-octadecenal associated with oxidative stability). The sensory evaluation study showed a significant difference within samples in respect to appearance, color, flavor, texture, taste, aftertaste, therefore making WKD1, WKD2 and WKD3 the preferred samples with an overall acceptability of 7.44, 7.78, and 7.33 respectively, with sample WKD2 leading with (7.78) making it the most preferred sample. Conclusively, the study showed profile that highlighted the functional potentials of the cookies, which, combine nutritional quality with bioactive, and consequently showcased the suitability as a functional food.

Keywords: Bio-compositional, Cookies, Functional food, Kersting groundnut

Introduction

Cookies and other bakery products have become loved portable fast foods products for all age group because they are tasty to eat, cholesterol free, containing digestive and dietary principles and they are reasonably cheap (Farheena et al., 2015). Baked cookies are sweet, individually baked foods made primarily from flour and sugar, often combined with ingredients like butter, eggs, and various flavorings. They can have diverse textures, ranging from chewy to crispy, and are typically flat and round. Cookies have a long history (Dhal et al., 2023), dating back to ancient times, and are enjoyed worldwide in various

forms, including chocolate chip, oatmeal, and sugar cookies Wheat flour (*Triticum aestivum*) is a powder made from grinding and sieving of wheat grain used for human consumption. It is also the most commonly used flour for baking worldwide. Date fruit is domestically known as Debino in the Northern part of Nigeria. It is a fruit known for its sugary taste (Hamza et al., 2014). It consists of more than 70% sugar mainly glucose and fructose. It is high in energy value and a good replacement for sugar (sucrose) in the cookies production. Date fruit is rich in fiber, antioxidants and is an excellent source of minerals (iron, copper, calcium) and vitamins (Farheena et al., 2015). Date fruit has great nutritional benefits as it prevents the risks of increased blood sugar level in diabetic patients. Kersting Groundnut, scientifically known as *Macrotyloma geocarpum*, is a legume crop native to West and Central Africa. It thrives in semi-arid regions and is valued for its high nutritional content, providing approximately 21.3 grams of protein per 100 grams, along with essential amino acids and vitamins. The crop is primarily used for food, animal feed, and traditional medicine. Despite its benefits, it remains underutilized and faces threats of extinction due to low yields and limited research efforts. Recently the rise of functional foods has gained global recognition, as more people now know how nutrition impacts their health. These foods offer benefits that go beyond just nutritional content. In terms of baked foods, cookies have stand out as a favorite snack. Wheat flour used in making cookies gives more texture and flavor to the products, but it often falls short of essential nutrients. Vital elements like dietary fiber, minerals, and high-quality protein, are typically missing from these classic treats, which are important for a balanced diet. Increasingly, bakers are turning to composite flour mixes as a solution to this nutritional gap. Therefore, this research was carried out to investigate the formulation and bio-compositional characteristics of cookies from the blends of wheat, kersting groundnut and date fruit flours.

Methodology

Wheat flour, date fruits and kersting groundnut of good quality and other ingredients for the cookie production such as sugar, salt, milk, baking powder, and fat were purchased from ogige market in Nsukka, Enugu state, Nigeria. Fresh date fruits were sorted, washed, drained, de-seeded, diced into 5 mm thickness, oven dried at 50^{o}C for 8 hours, and converted into flour. Kersting groundnut was sorted, cleaned, de-husked, blanched for 40 minutes, oven dried at 50 ^{o}C for 9 hours, and converted into flour. Flour blends were formulated in the ratios 0:0:100, 10:10:80, 20:15:65, 30:20:50, and 40:25:35 for kersting groundnut, date fruit, and wheat flours, respectively; and coded as WKD1, WKD2, WKD3, WKD4 and WKD5, respectively. The obtained flour blends were processed into functional cookies and evaluated for bio-active compound contents and sensory evaluation using standard analytical methods.

Analytical methods

Bio-active compounds were determined using the method of Azmir et al. (2013), while sensory evaluation of the samples was carried out for consumer acceptance and preference

Result and Discussion

Identified bioactive compounds and their potential activities

Table 1 presents the identified compounds in cookies along with their proportions and potential bioactivities. 1-Butoxy-1-isobutoxy-butane increases from 3.18% to 6.49% among the samples. This compound may contribute to the preservation of cookies and its overall bioactivity (Gopu et al., 2021). The proportion of 2-propenal increases from 2.51% to 12.00% among the samples. 2-Propenal is known for its antibacterial properties. It is likely to contribute to the antimicrobial effect observed in cookies, particularly as it increases with sample proportion (Momodu et al., 2022). It was noted that upon addition of kersting groundnut and date fruit there were an increase in most of the bioactive compounds among sample A to E. These compounds have been reported to induce apoptosis, reduce inflammation, and have antiatherogenic effects. It also acts as a bacterial xenobiotic metabolite (Oni et al., 2023). Oleic acid is a monounsaturated omega-9 fatty acid with proven benefits in reducing inflammation. It is often associated with improved cardiovascular health and could play a role in enhancing the nutritional profile of cookies. The chemicals in epoxy resin systems can affect the health when they come in contact with the skin, or if they evaporate or form mist or dust in the air you breathe. n-Hexadecanoic acid is known for its antioxidant, antimicrobial, and anti-inflammatory effects. It can contribute to the preservation and nutritional benefits of cookies (Momodu et al., 2022). This is also known as palmitric acid, which helps in brain function and immune regulation. It serves as an additive in the cookies.

Sensory quality of wheat, kersting groundnut and date composite cookies

The sensory evaluation study showed a significant difference within samples in respect to appearance, color, flavor, texture, taste, aftertaste, therefore making WKD1, WKD2 and WKD3 the preferred samples with an overall acceptability of 7.44, 7.78, and 7.33 respectively, with sample WKD2 leading with (7.78) making it the most preferred sample.

Table 1: Bioactive compounds and potential biological activity in cookies produced from blends of wheat flour, kersting groundnut flour and date flour.

Compound	Proportion (%)					Reported Bioactivity[a]
	WKD1	WKD2	WKD3	WKD4	WKD5	
1-Butoxy-1-isobutoxy-butane	-	3.18	3.89	5.70	6.49	Antimicrobial
2-Propenal	2.51	4.59	6.10	7.74	12.00	Antibacterial
9,12-Octadecadienoic acid (Z,Z)- / linoleic acid	-	2.74	4.59	5.01	6.04	Antioxidant activities, hepatoprotective, antihistaminic, anti-inflammatory
Hexadecanoic acid, 1,1-dimethylethyl ester	0.84	1.15	1.69	2.35	3.00	Anti-inflammatory, anticancer
Z-(13,14-Epoxy)tetradec-11-en-1-ol acetate	-	1.35	1.86	2.56	3.46	Antioxidant, haemolytic.
9-Octadecenal, (Z)-	1.65	2.31	2.46	2.90	3.38	Antimicrobial
cis-11-Hexadecenal	0.60	1.30	2.00	2.40	2.78	Antimicrobial
Oleic acid	1.03	1.54	2.11	2.76	3.99	Lowering cholesterol and reducing inflammation
17-pentatriacontene	-	5.28	7.74	9.81	10.05	Anti-inflammatory, anticancer, antiarthritic
n-Hexadecanoic acid	1.68	3.14	3.78	4.88	5.66	Antioxidant, antimicrobial, anti-inflammatory
Total	**8.31**	**26.56**	**36.21**	**46.11**	**56.84**	

Key: WKD1 = 100% of wheat flour, WKD2 = 10% kersting Groundnut flour + 10% date flour +80%wheat flour, WKD3 20% kersting groundnut flour + 15% date flour +65% wheat flour, WKD4 = 30% kersting groundnut flour + 20% date flour + 50% wheat flour, WKD5 = 40% kersting groundnut flour + 25% date flour + 35% wheat flour.

Table 2: Sensory Properties of Cookies Produced from Blends of Wheat, Kersting Groundnut and Date Flour

Samples	Appearance	Colour	Flavour	Taste	Texture	Aftertaste	Overall acceptability
WKD1	$6.89^{c} \pm 0.9$	$6.72^{c} \pm 0.96$	$5.44^{ab} \pm 1.42$	$5.67^{bc} \pm 1.28$	$5.06^{abc} \pm 1.21$	$5.11^{b} \pm 1.32$	$5.44^{ab} \pm 2.36$
WKD2	$5.78^{b} \pm 1.52$	$5.72^{b} \pm 1.45$	$6.11^{b} \pm 1.45$	$5.83^{c} \pm 1.89$	$5.56^{c} \pm 1.46$	$5.56^{b} \pm 1.72$	$5.78^{b} \pm 2.26$
WKD3	$5.56^{b} \pm 1.20$	$5.56^{b} \pm 0.92$	$5.44^{ab} \pm 1.15$	$5.56^{bc} \pm 1.38$	$5.44^{bc} \pm 1.20$	$5.22^{b} \pm 1.26$	$5.33^{ab} \pm 1.75$
WKD4	$5.23^{b} \pm 0.89$	$5.00^{ab} \pm 1.14$	$4.72^{a} \pm 1.41$	$4.00^{a} \pm 1.03$	$4.33^{a} \pm 1.14$	$3.78^{a} \pm 0.88$	$4.22^{a} \pm 1.44$
WKD5	$4.00^{a} \pm 1.57$	$4.28^{a} \pm 1.49$	$5.50^{ab} \pm 1.10$	$4.72^{ab} \pm 1.53$	$4.67^{ab} \pm 1.03$	$4.83^{b} \pm 1.38$	$4.72^{ab} \pm 1.49$

Values are mean ± SD of duplicate determination. Samples with different superscripts within the same column were significantly ($p<0.05$) different. WKD1 = 100% of wheat flour, WKD2 = 10% kersting Groundnut flour + 10% date flour +80%wheat flour, WKD3 20% kersting groundnut flour + 15% date flour +65% wheat flour, WKD4 = 30% kersting groundnut flour + 20% date flour + 50% wheat flour, WKD5 = 40% kersting groundnut flour + 25% date flour + 35% wheat flour

Conclusion

This study has shown that quality cookies could be produced from the blends of wheat, date fruit and kersting groundnut flour. It also shows that date fruit flour can be an ideal replacement for sugar in cookie recipes. The result shows that protein content was increased as a result of kersting groundnut which has a high protein content (21% to 40%). Therefore, the study showed diverse profile that highlighted the functional potentials of the cookies, which, combine nutritional quality with bioactive (health-promoting compounds), and consequently showcased the suitability as a functional food.

References

Azmir, J., Zaidul, I. S. M., Rahman, M. M., Sharif, K. M., Mohamed, A., Sahena, F., ... & Omar, A. K. (2013). Techniques for extraction of bioactive compounds from plant materials: A review. *Journal of food engineering*, *117*(4), 426-436.

Dhal, S., Anis, A., Shaikh, H. M., Alhamidi, A., & Pal, K. (2023). Effect of mixing time on properties of whole wheat flour-based cookie doughs and cookies. *Foods,* 12(5), 941 - 949.

Farheena, I., Avanish, K., & Uzma, A. (2015). Development and quality evaluation of cookies fortified with date paste (Phoenix dactylifera L.). *International journal of science and technology*, *3*(4), 975-978.

Gopu, C., Chirumamilla, P., Daravath, S. B., Vankudoth, S., & Taduri, S. (2021). GC-MS analysis of bioactive compounds in the plant parts of methanolic extracts of Momordica cymbalaria Fenzl. *J. Med. Plants Stud*, *9*(3), 209-218.

Hamza, A. M., Collins, A., Ado, S. G., Ikuenobe, C. E., Ataga, C. D., & Odewale, J. O. (2014). Proximate compositions evaluation and variability among cultivars of date palm (Phoenix dactylifera L.) in Nigeria. *International Journal of Plant & Soil Science*, 3(3), 248-259.

Momodu, I. B., Okungbowa, E. S., Agoreyo, B. O., & Maliki, M. M. (2022). Gas chromatography–mass spectrometry identification of bioactive compounds in methanol and aqueous seed extracts of Azanza Garckeana fruits. *Nigerian Journal of Biotechnology*, *38*(1), 25-38.

Uchegbu, N. N., Fasuan, T. O., & Onuoha, N. L. (2023). Quantification of phytochemicals, and compounds' identification in functional tea from Ficus capensis and Justicia secunda. Journal of Food Science, 88(3), 1004-1018.

Effectiveness of *Lantana camara* Leaf Powder as Biopesticide against *Callosobruchus maculates* F. (Coleoptera Chrysomelidae) in Stored Cowpea.

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Abstract

The continuous application of chemical pesticides on stored grains causes significant risks to various life forms and the environment. This study aimed to assess the impact of *Lantana camara* leaves on *Callosobruchus maculatus* infestation in stored cowpea seeds and their germination potential. Fresh, mature leaves of *L. camara* were harvested, washed, air-dried, ground into fine powder using an electric blender, and sieved through a 450 mm mesh. The experiment investigated the effects of different dosage levels of the leaf powder (10g, 7.5g, 5.0g, and 2.5g) mixed with 200g of cowpea seeds, alongside a control group with no treatment. The mixtures were placed in Kilner jars, shaken for two minutes, and then each jar was infested with 20 unsexed *C. maculatus* adults, five days old. The experiment was setup in a completely randomized design, with three replicates for each treatment. Insect mortality was recorded on days 3, 5, and 7, while the emergence of offspring was monitored after 21 days. Statistical analysis was performed using SPSS version 25. Findings revealed that the 7.5g dose of *L. camara* powder achieved an 85% mortality rate of *C. maculatus* and completely suppressed progeny emergence at the 5.0g dose. These results indicate that *Lantana camara* could serve as an effective biopesticide in integrated pest management strategies for stored grain protection.

Keywords: biopesticide, *Lantana camara*, *Callosobruchus maculatus*, stored cowpea

Introduction

Insect pests remain a major cause of postharvest grain losses, contributing to 30–40% reduction in quantity and quality (Kolappamban et al., 2024). Despite long-standing control efforts, these losses continue to hinder food quality and security (Dhaliwal et al., 2015 ; Ayalew, 2020).

Lantana camara is widely distributed in tropical, subtropical, and temperate regions. Its leaves have been identified as a source of insecticidal activity and bioactive compounds (Dhaliwal et al., 2015; Singh et al., 2021). Studies demonstrate their potential as novel biopesticides for stored-product protection. Rajashekar et al. (2014) reported over 80% efficacy of L. camara leaf extracts against Sitophilus oryzae,

Tribolium castaneum, and *Callosobruchus chinensis*. Other botanicals and essential oils have similarly shown ovicidal, repellent, antifeedant, and toxic effects against storage pests (Mobolade et al., 2019; Singh et al., 2021).

The extensive use of synthetic pesticides has created serious challenges in agriculture, the environment, and public health. Their application has led to pest resistance, resurgence, and toxic residues in food products, while also posing hazards to humans and non-target organisms such as pollinators, natural enemies, fish, and birds. Inorganic insecticides contaminate soil, water, and food, reduce biodiversity, and may bioaccumulate in the food chain, causing lethal effects (Mobolade et al., 2019; Singh et al., 2021). In addition, these chemicals are costly and require skilled handling.

The adverse effects associated with synthetic pesticides in stored-product protection have necessitated the exploration of plant-based alternatives. Botanical biopesticides are biodegradable, environmentally benign, and possess high selectivity with reduced persistence, thereby minimizing risks of resistance, contamination, and residue accumulation in food (Singh et al., 2021). They are also cost-effective and readily available, as many source plants can be cultivated locally. Therefore, this study investigates the insecticidal efficacy of *Lantana camara* leaves against the cowpea weevil (*Callosobruchus maculatus*), focusing on adult mortality and subsequent effects on F1 progeny emergence.

Methodology

Cultured Insects

The study was conducted in the Entomology Laboratory of the Nigerian Stored Products Research Institute (NSPRI), Ilorin, Kwara State. White cowpea grains, sourced locally, were disinfested by freezing at −4 °C for 72 h and later aerated at room temperature before use. Adult *Callosobruchus maculatus* were obtained from laboratory cultures maintained on cowpea. For colony establishment, twenty pairs of adults were introduced into 200 g of cowpea (four replicates) and allowed to oviposit for 14 days before removal. Cultures were maintained under ambient laboratory conditions (30.7 °C; 74.5% RH) for 25 days, after which progeny emergence was assessed. Insects from these cultures were used in subsequent bioassays (Nwaubani et al., 2020).

Collection and preparation of *Lantana camara* leaves

Mature *Lantana camara* leaves were collected around the metropolitan stadium, Asa Dam Road Ilorin, Kwara State. The leaves were washed, cut, and shade-dried for seven days, then briefly exposed to sunlight before grinding (Singh et al., 2021, with slight modification). The dried leaves were pulverized, sieved (70 µ mesh), and stored in airtight containers until use. The powder was assessed for insecticidal activity through contact toxicity bioassays.

Treatments application

The treatments consisted of *Lantana camara* leaf powder at four dosages (10 g, 7.5 g, 5 g, and 2.5 g per 200 g cowpea) and a control without treatment. Each dosage was thoroughly mixed with cowpea seeds in kilner jars, after which 20 unsexed, 5-day-old *Callosobruchus maculatus* adults were introduced. The experiment followed a completely randomized design with three replicates per treatment (Singh et al., 2021).

Insect mortality

Insect mortality was assessed at 3, 5, and 7 days after treatment by sieving the treated seeds and recording the numbers of live and dead adults. Percentage mortality was then calculated using the formula:

$$\% \text{ Mortality} = \frac{\text{Number of Dead Insects}}{\text{Total Number of Insects}} \text{X}100$$ (Ayalew, 2020).

F1 Progeny Emergence

After 21 days of incubation, the jars were monitored for adult emergence (at 3,5, and 7 days). Newly emerged progeny was collected and counted using a sieve or aspirator. The number of F_1 adults in treated samples was compared with the control, and percentage reduction in progeny was calculated using the following formula (Ayalew, 2020).

$$\% \text{ Progeny Reduction} = \frac{\text{C} - \text{T}}{\text{C}} \text{X}100$$

Where C = mean number of progenies in control, T = mean number in treatment

Data Analysis

Data obtained were subjected to analysis of variance (ANOVA) using Statistical Package for Social Scientists (SPSS 25.0) and significant means were separated using Duncan Multiple Range Tests (DMRTs) (Nwaubani et al., 2020).

Results and Discussion

Table 1: Effect of *Lantana camara* leave powder on *C. maculatus* mortality (%)

TREATMENT/ DAYS	3	5	7
CONTROL	50.0 ± 0.0a	50.0 ± 0.0a	68.33 ± 16.073ab
LC 10g	50.0 ± 0.0a	73.33 ± 7.638ab	80.0 ± 5.0b
LC 7.5g	51.67±7.638a	55.0 ± 5.0a	85.0 ± 5.0b
LC 5.0g	55.0 ± 15.0a	61.67 ± 5.774ab	78.33 ± 2.887ab
LC 2.5g	53.33 ± 5.774a	73.33 ± 12.583ab	83.33 ± 12.583b
Sig	F(8,18)=1.565, p=0.204	F(8,18)=3.985, p=0.007	F(8,18)=3.492, p=0.013

LC= is *Lantana camara,* Sig= significant, p= percentage probability (0.05)

Table 1 above, the treatments with *Lantana camara* is shown to have done better compared to the control. The treatment with the best performance is LC7.5g (85.0%) at 7 days, followed by LC2.5g (83.33%) and LC10g (80.0%) respectively. The contact toxicity bioassay demonstrated that *Lantana camara* leaf powder significantly affected *Callosobruchus maculatus* during storage. Resulting in insect mortality of 85.0% (at LC 7.5g), supporting earlier reports of the insecticidal potential of *L. camara* against storage pests (Rajashekar *et al*., 2014; Kolappamban *et al*., 2024). this could be due to the Variations in toxicity may depend on insect species, phytochemical composition, volatile compounds and dosage (Singh et al., 2021).

Table 2: effect of *L.camara* leaves powder on *C. maculatus* progeny emergence (F1)

TREATMENT/ DAYS	3	5	7
CONTROL	3 ± 2.082a	3 ± 2.082ab	3 ± 1.528a
LC 10g	1 ± 0.0a	7 ± 0.0b	2 ± 0.0a
LC 7.5g	2 ± 2.0a	1 ± 0.577a	3 ± 1.0a
LC 5.0g	0 ±0.577a	2 ± 1.528ab	3 ± 0.0a
LC 2.5g	1 ± 0.577a	2 ± 1.155a	4 ± 2.887a
Sig	F(8,18) =2.042 p=0.099	F(8,18)=3.261, p=0.018	F(8,18)=1.022, p=0.455

LC= is *Lantana camara,* Sig= significant, p= percentage probability (0.05)

From table 2 above, although statistically there are no significant difference between the treatments except for LC10g (7 ± 0.0b). The results show that *L. camara* treatments on the grains gave zero emergence for LC 5.0g at three days while other treatments had minimal emergence. The treatments were found to deter Progeny emergence and development compared with to control; with LC 10 g showing the greatest suppression. This suggests possible oviposition deterrent and ovicidal effects of *L. camara*, consistent with findings that *L. camara* extracts can exert repellent, antifeedant, and toxic actions on insects (Rajashekar et al., 2014).

Conclusion

Although *Lantana camara* treatment caused a temporary green taint on cowpea grains, the findings demonstrate that *L. camara* leaf powder is effective against *Callosobruchus maculatus*, reducing adult survival and limiting progeny emergence, likely through oviposition deterrence or ovicidal activity. As a readily available weed, *L. camara* has strong potential as a low-cost biopesticide for integrated pest management in stored products, thereby enhancing agricultural productivity and offering economic benefits to smallholder farmers. Further research is recommended to fully establish its ovicidal and anti-oviposition properties.

References

Ayalew, G. (2020). Evaluation of plant powders for the control of storage pests in cereals and legumes. *Journal of Stored Products and Postharvest Research, 11*(3), 45–53. https://doi.org/10.5897/JSPPR2020.0301

Dhaliwal, G.S., Jindal, V. & Mohindru, B. (2015). "Crop losses due to insect pests: global and Indian scenario" Indian Journal of Entomology, volume 77, no. 2, pp. 165–168, 2015.

Kolappamban, V., *et al*. (2024). Contact toxicity of *Lantana camara* leaf extracts against major storage pests. *Journal of Biopesticides, 17*(1), 33–41.

Mobolade, A. J., Bunindro, N., Sahoo, D. & Rajashekar, Y. (2019). Traditional methods of food grains preservation and storage in Nigeria and India. *Annals of Agricultural Sciences* 64 (2), 196-205, 2019.

Nwaubani, S., Otitodun, O. G., Ajao, S. K., Opit, G. P., Ala, A. A., Mobolaji, O. O., Ogwumike, J. C., Abel, G. I., Ogundare, M. O., Braimah, J. A. Gbenga, B. S., Olenloa, A. E., Kolayemi, O. R., McNeill, S. G. & Ileleji, K. E. (2020). Assessing efficacies of insect pest management methods for stored bagged maize preservation in storehouses located in Nigerian markets. *Journal of stored products Research* 86, 101566, 2020.

Rajashekar, Y., Ravindra, K. V., Bakthavatsalam, N., & Shivanandappa, T. (2014). Insecticidal activity of the plant extracts of *Lantana camara* against three storage insect pests. *Journal of Food Science and Technology,* 49(5), 589–593. https://doi.org/10.1007/s13197-011-0464-3

Singh, K. D., Mobolade, A. J., Bharali, R., Sahoo, D. & Rajashekar, Y. (2021). Main plant volatiles as stored grain pest management approach: A Review. *Journal of Agriculture and food Research* 4, 100127, 2021.

Awareness Level of Aflatoxin Contamination in Commodities Sold in some Selected Markets in Oyo State

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Abstract

Aflatoxin contamination presents a significant public health and economic challenge in Sub-Saharan Africa, particularly in Nigeria and awareness level of this toxin is limited. This study therefore, assessed the socio-economic characteristics, postharvest handling practices, and awareness levels of aflatoxin contamination among traders of maize, melon, and fish commodities in Bodija, Gbagi and Orita-Merin market, using a Kobotool box Application to deploy the structured questionnaires. Data obtained from 165 respondents were analyzed descriptively. The socio-economic analysis revealed a strong female dominance (80.6%), Middle-aged traders from 41-50 of about 33.9% had secondary education (49.1%). Ninety eight percent (98%) are full time commodity traders. Majority of the traders (50.6%) store their commodities in bags for just one month (35.8%). Findings revealed that more than half of respondent (55.9%) experience commodity mouldiness, however their level of aflatoxin awareness was found to be low (37.6%), and about 77.0% pointed at lack of adequate storage facilities and unsafe handling of contaminated commodities. Most traders lacked access to regulatory services and diagnostic tools. The results highlight critical gaps in knowledge, infrastructure, and policy enforcement. Strengthening education, regulatory systems, and capacity building is vital to mitigate aflatoxin risks and safeguard food security and public health.

Keywords: Aflatoxin, Contamination, Awareness, Markets

Introduction

Aflatoxins, a toxic secondary metabolite produced mainly by *Aspergillus flavus* and *Aspergillus parasiticus*, are among the most dangerous food contaminants globally (IARC, 2020). Their occurrence is particularly prevalent in warm, humid regions like Sub-Saharan Africa, where food preservation, storage, and

regulatory systems remain inadequate (Ezekiel et al., 2019; Gnonlonfin et al., 2020). Some food crops such as maize, groundnut, sorghum, melon and fish are central to the Nigerian diet and economy, yet they remain highly susceptible to aflatoxin contamination, especially under poor postharvest management. Aflatoxins, produced by Aspergillus species, proliferate in tropical climates with inadequate drying and storage, contributing to chronic health issues, such as liver cancer, immune suppression, and stunted growth in children (Adetunji et al., 2022).

Specifically, maize, melon, and fish are part of widely consumed staples in Nigeria, they are frequently exposed to aflatoxin contamination due to poor postharvest practices, improper drying, and prolonged storage (Matumba et al., 2021; Kamala et al., 2020). Despite growing global concern, awareness level of aflatoxins and their implications remain low among local traders and consumers (Johnson et al., 2022). Poor infrastructure, weak policy enforcement, and limited educational interventions further compound the problem, allowing contaminated food to reach consumers and livestock (Omotayo et al., 2021; Udomkun et al., 2019). These issues are worsened by the lack of reliable testing equipment and the general misconception about visible moulds being the sole indicator of contamination (Hell et al., 2022).

The consequences of aflatoxin exposure are severe ranging from liver cancer, immune suppression, to stunted growth in children (IARC, 2020; Milani, 2020). Yet, many traders unknowingly engage in risky behaviors such as selling contaminated produce at reduced prices or mixing them with good products, further undermining food safety (Oluwafemi et al., 2020). These challenges highlight the need for detailed local studies to understand the socio-demographic characteristics and knowledge gaps influencing aflatoxin management. This study highlights that contamination is not just a food safety concern but also a socio-economic burden that reduces marketability and limits export potentials for smallholder farmers (Ogunmola et al., 2023). Addressing aflatoxin risks in these food crops is therefore vital for safeguarding public health and achieving food security in Nigeria.

This study aimed to assess the level of awareness, handling practices and knowledge gaps among commodity traders in relation to aflatoxin contamination. Additionally, it focused on traders within a specific locality; Bodija, Gbagi and Orita Merin markets respectively, which may affect the generalizability of findings. By revealing the underlying knowledge and behavioral gaps among traders, this research contributes to the body of evidence guiding policy, education, and interventions aimed at aflatoxin mitigation in Nigeria and similar agro-ecological regions (FAO, 2021; Mutegi et al., 2019).

Methodology

The study adopted a descriptive survey design targeting commodity traders involved in maize, melon, and fish handling. A structured questionnaire was administered to 165 respondents selected through

purposive sampling across major markets: Bodija, Gbagi and Orita Merin markets. The instrument captured socio-demographic variables, postharvest handling practices, awareness level of aflatoxins, perceived health hazards, and behavioral responses to contamination.

Data were analyzed using descriptive statistics including frequencies and percentages. The approach was suitable for identifying trends, gaps, and behavioral patterns regarding aflatoxin contamination. While the study did not include laboratory confirmation of aflatoxin presence, the self-reported indicators provided a strong base for assessing the level of awareness and handling practices.

Results and Discussion

Socio-Economic Characteristic of the respondents

The socio-economic analysis revealed a strong female dominance (80.6%) in the trade of maize (38.8%), fish (34.5%), and melon (26.7%), which are all highly susceptible to aflatoxin contamination (Okoth & Kucia, 2020). These are vulnerable to fungal infection due to their oil and starch content (Ezekiel et al., 2019). Middle-aged traders (41–60 years) dominated, often with limited education, only 6.7% had tertiary education and 10.3% had none affecting comprehension of aflatoxin risks (Waliyar et al., 2015; Ezekiel et al., 2019). Trading was the major occupation (98.2%) with most respondents having less than 20 years' experience.

Awareness Status of Respondents on Aflatoxin Contamination

In terms of awareness, only 37.6% had heard of aflatoxins, while 62.4% had never come across the term. Nonetheless, visible symptoms like caked commodities (32.1%), moulds (20.6%), and insect infestations (30.3%) were common but often misinterpreted due to low awareness (Misihairabgwi et al., 2017). Radio (46.8%) and extension agents (37.1%) were primary information channels, highlighting the importance of outreach efforts (Kolosova & Stroka, 2011). Encouragingly, 69.7% expressed willingness to attend aflatoxin training. Trader behavior towards contaminated goods further complicates the scenario. While 35.8% discarded them, 17.0% sold them at lower prices and 8.5% mixed them with clean commodities, practices that pose serious public health risks (Ilesanmi et al., 2022). Preventive actions were inconsistent, as only 4.2% used moisture meters and 43.6% checked goods regularly. Despite these lapses, 59.4% of respondents did not link aflatoxins to any health issue, and only 1.2% connected it with cancer (Miller, 2020).

Table 1: Socio-Economic Characteristic of the Respondents

Variables	Frequency	Percent
Commodity		
Fish	57	34.5
Maize	64	38.8
Melon	44	26.7
Gender of respondent		
Female	133	80.6
Male	32	19.4
Age Category		
21-30years	19	11.5
31-40years	28	17.0
41-50years	56	33.9
51-60years	51	30.9
61years and above	11	6.7
Marital Status		
Divorce/separated	11	6.7
Married	129	78.2
Single	15	9.1
widow/widower	10	6.1
Educational Level		
Non formal education	17	10.3
Primary	56	33.9
Secondary	81	49.1
Tertiary	11	6.7
Years of experience		
less than 10years	67	40.6
11-20years	52	31.5
21-30years	31	18.8
31-40years	10	6.1
41-50years	5	3.0
Household size		
less than 5	64	38.8
6-10	85	51.5
11-15	16	9.7
Primary occupation		
Civil Servant	1	.6
Commodity trading	162	98.2

Fish farming	2	1.2
	165	**100**

Table 2: Awareness Status of Respondents on Aflatoxin Contamination

Variables	Frequency	Percent
Experience of caked commodities		
No	112	67.9
Yes	53	32.1
Moulds on the commodities		
No	131	79.4
Yes	34	20.6
Rate of Moulds in commodities		
Occasionally	19	55.9
Often	2	5.9
Rarely	13	38.2
Presence of insects on commodities		
No	115	69.7
Yes	50	30.3
Regular presence of insects		
Occasionally	35	70.0
Often	8	16.0
Rarely	7	14.0
colour particles on the commodities		
No	127	77.0
Yes	38	23.0
Awareness of aflatoxin		
No	103	62.4
Yes	62	37.6
Source of information on aflatoxin		
Extension officer/Government agents	23	37.1
Internet	2	3.2
NGOs	3	4.8
Radio	29	46.8
Television	5	8.1
Aflatoxin, as a cause of cancer/terminal diseases		

No	124	75.2
Yes	41	24.8
Awareness of limit of aflatoxin on human body		
No	135	81.8
Yes	30	18.2
Willingness to participate in any training on aflatoxin/other postharvest management activities		
No	50	30.3
Yes	115	69.7

Awareness Status of Respondents on Danger of Aflatoxin

Institutionally, 79.4% of traders believed market laws were not enforced, and 77.0% pointed at lack of adequate storage facilities, demonstrating systemic failures (Atehnkeng et al., 2014). These findings underscore the need for strong policy action and investment in storage infrastructure. Unsafe responses included mixing contaminated goods (8.5%) and selling at reduced prices (17%). Only 35.8% discarded affected commodities. Most did not link health issues like vomiting or diarrhea to aflatoxins. 95.2% never used testing kits, and only 43.6% checked commodities. Only 47.3% maintained moisture free environments using wooden slabs; 40% never did. 79.4% cited market law inadequacy, while 77% noted insufficient storage services (Gnonlonfin et al., 2020). The study thus highlights the interplay between socio-economic conditions, knowledge gaps, behavioral patterns, and institutional inefficiencies that collectively perpetuate aflatoxin contamination across markets.

Table 3: Awareness Status of Respondents on Danger of Aflatoxin

Variable	Frequency	Percent
Handling the commodities contaminated with aflatoxin		
add chemicals	7	4.2
family consumption	12	7.3
Give it out	9	5.5
mix it with others before selling	14	8.5
sell at reduced price	28	17.0
Throw away	59	35.8
Use as animal feed	6	3.6
wash and aerated for sale	30	18.2
Perceived health hazard link to aflatoxin		
Abdominal pain	22	13.3
Cancer	2	1.2
Death	6	3.6

Diarrhea	18	10.9
I do not Know	98	59.4
Suppression of immune system	2	1.2
Vomiting	17	10.3
Use of moisture meter/ other kits		
Always	7	4.2
Never	157	95.2
Occasionally	1	.6
I check my commodities periodically		
Always	72	43.6
Never	32	19.4
Occasionally	61	37.0
Environment moisture free use wooden slab in my store		
Always	78	47.3
Never	66	40.0
Occasionally	21	12.7
Availability of market law/services		
Adequately used	34	20.6
Inadequately used	131	79.4
Adequacy of storage		
Adequately used	38	23
Inadequately used	127	77

Conclusion

This study underscores knowledge and infrastructural gaps contributing to aflatoxin risks. Many traders are unaware of aflatoxins and the danger it posed to health. Inadequate storage, policy enforcement and testing further increase contamination risks. Improved education, access to test kits, modern storage and policy reforms are crucial for mitigation.

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References

Adetunji, M. C., Alimi, B. A., & Atanda, O. O. (2022). Aflatoxin contamination in staple foods and its implications for food safety in Sub-Saharan Africa. Food Control, 134, 108724. https://doi.org/10.1016/j.foodcont.2021.108724

Ezekiel, C. N., Sulyok, M., Warth, B., & Krska, R. (2019). Fusarium and Aspergillus mycotoxins in locally grown Nigerian maize. Food Additives & Contaminants: Part A, 36(5), 682–691. https://doi.org/10.1080/19440049.2019.1571114

FAO. (2024). Reducing mycotoxin risks in food systems: Integrated approaches for safer food in Africa. Food and Agriculture Organization of the United Nations. https://www.fao.org/documents/card/en/c/FAO2024mycotoxins

Hell, K., Mutegi, C., & Njapau, H. (2022). The potential of testing tools for aflatoxin detection among traders in Africa. *World Mycotoxin Journal,* 15(1), 23–31. https://doi.org/10.3920/WMJ2021.2714

Ilesanmi, O. S., Adebayo, A. M., & Adewuyi, K. A. (2022). Behavioral responses to aflatoxin risk among food traders in Southwest Nigeria. *BMC Public Health,* 22(1), 1–12. https://doi.org/10.1186/s12889-022-12789-7

Mutegi, C., Wagacha, J. M., & Hoffmann, V. (2019). Aflatoxin contamination in Africa: The role of storage and climate. *African Journal of Agricultural Research,* 14(1), 1–10. https://doi.org/10.5897/AJAR2018.13699

Ogunmola, O. O., Adeyeye, S. A. O., & Fashina, A. B. (2023). Economic impact of aflatoxin contamination in Nigerian agricultural value chains. *Journal of Food Safety and Security*, 9(2), 45–56. https://doi.org/10.32738/JFSS.2023.902.45

Udomkun, P., Mutegi, C., & Maziya-Dixon, B. (2019). Innovative technologies to manage aflatoxins in foods. Trends in Food Science & Technology, 91, 85–93. https://doi.org/10.1016/j.tifs.2019.07.007

Functional Properties and Sensory Evaluation of Powdered Ogi made from Malted Sorghum-Soybean Blends

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Abstract

Malnutrition, particularly protein-energy malnutrition, remains a major public health challenge among children under five years of age. This study investigated the functional properties of malted sorghum-soybean powdered *ogi* and sensory attributes of the re-constituted pap. Three formulations were prepared: control (100% malted sorghum flour (MSF)), 70:30 malted sorghum–roasted soybean and 60:40 malted sorghum–roasted soybean. Functional properties showed no significant differences ($p > 0.05$) in swelling capacity, water absorption capacity (WAC), and oil absorption capacity (OAC) among the blends, whereas dispersibility increased significantly ($p < 0.05$) with higher soybean inclusion, reaching 74.50% in the 60:40 blend. Sensory evaluation revealed that all formulations were generally acceptable. These findings suggest that malted sorghum roasted soybean *ogi*, is functionally suitable, and organoleptically acceptable, and can help reduce protein-energy malnutrition among children under five.

Keywords: Complementary food, Infant nutrition, Protein-energy malnutrition, Sensory evaluation

Introduction

Malnutrition, particularly protein-energy malnutrition (PEM), remains a major public health challenge in many developing countries, especially among children under five years of age (WHO, 2024). PEM occurs when the intake of energy and protein is inadequate to meet the body's requirements, leading to conditions such as marasmus, kwashiorkor, wasting, stunting, impaired immunity, and increased child mortality (Zhang et al., 2022). Addressing PEM requires affordable, nutrient-dense food formulations based on locally available crops. Among such crops, cereals like sorghum and legumes such as soybean offer complementary nutritional benefits when combined.

Sorghum (*Sorghum bicolor*) is a drought-tolerant cereal and one of the most important staple foods in sub-Saharan Africa, where it provides a major source of dietary energy (Legesse et al., 2019). Its grains are rich in carbohydrates and dietary fiber, with moderate amounts of protein and essential minerals such as

iron, zinc, and phosphorus. Sorghum also contains bioactive compounds, including phenolic and antioxidants, which support overall health (Baye et al., 2019). However, sorghum proteins are limited in lysine and threonine, tryptophan and total sulfur amino acid, which reduces their biological value and makes sorghum-based diets insufficient as a sole protein source (Tasie & Gebreyes, 2020). This nutritional limitation contributes to the high burden of PEM in populations that rely heavily on sorghum as a staple. Consequently, sorghum is increasingly being used in complementary food formulations in combination with protein-rich legumes such as soybean to improve both energy and protein quality for children at risk of undernutrition (WHO, 2024).

Soybean (*Glycine max*) is a nutrient-dense legume containing 35–40% high-quality protein with a complete profile of essential amino acids, making it one of the best plant-based protein sources (Hagos & Bekele, 2018). It is also rich in healthy fats, calcium, iron, folate, and bioactive compounds such as isoflavones, all of which support growth and development in children (Aanchal, 2023). Soybean is abundant in lysine, an essential amino acid often lacking in cereal-based diets. When combined with other cereals, soybean enhances protein quality, resulting in a balanced, cost-effective complementary food suitable for addressing protein energy malnutrition in children (Aanchal, 2023).

Processing methods such as malting and roasting are widely employed to improve the nutritional and sensory qualities of food ingredients. Malting of sorghum enhances nutrient digestibility, reduces anti-nutritional factors such as tannins and phytates, and improves flavor (Ranini et al., 2025). Roasting of soybean improves its sensory attributes by reducing the characteristic beany flavor and effectively inactivates trypsin inhibitors, thereby enhancing protein quality (Yang et al., 2023). Cereal-legume blends are widely explored for their potential to improve nutritional quality of complementary foods. However, sensory limitation associated with soybean, particularly its beany flavor often reduces consumer acceptance. Therefore this study evaluated the functional and sensory properties of malted sorghum–roasted soybean blends. The goal was to determine the most suitable formulation for pap preparation as an affordable complementary food for reducing protein-energy malnutrition among children.

Methodology

Source of materials

Sorghum (*Sorghum bicolor)* and soybean (*Glycine max)* were purchased from Oja-oba market, Ibadan, Oyo state, Nigeria.

Preparation of malted sorghum flour

Malted sorghum flour was prepared following the method described by Sotunde et al. (2021) with slight modification. The sorghum grains were sorted to remove stones, dirt, and other unwanted materials. The

cleaned grains were thoroughly washed and steeped in water for 6 hours. After soaking, the hydrated grains were spread on trays and allowed to germinate for 72 hours. The germinated grains were then dried using a NSPRI Parabolic Shaped Solar Dryer (NSPRI PSSD) for 8 hours until uniform dryness was achieved. Finally, the dried malted grains were milled, sieved to pass through a 0.25 mm sieve size, cooled and packaged in a moisture and air-proof re-sealable plastic bag.

Preparation of soybean flour

Soy flour was prepared following the method described by Ndife et al. (2011) with a slight modification. The beans were thoroughly cleaned to remove dirt and foreign materials such as stones and sticks. They were then washed then spread on trays in NSPRI PSSD to dry out the water. After drying, the soybeans were roasted at 150°C for 30min, de-hulled, winnowed, milled and sieved (through a 0.25 mm sieve) into fine flour. The flour was packed in a moisture and air-proof re-sealable plastic bag under uniform storage conditions.

Formulation of the powdered *ogi*

The malted sorghum flour was blended with the soybean flour in the ratio of 70:30 and 60:40, where a control was used containing only the malted sorghum (100% malted sorghum).

Functional Properties

The bulk densities of the flour were determined using the method described by Mpotokwane et al. (2008). Swelling capacity was determined by Oyewole et al. (2024) method while the procedure of Umoh and Iwe (2023) was used to compute Water Absorption Capacity and Oil Absorption Capacity. Dispersibility was determined using the method described by Asma et al. (2006).

Preparation of gruel from the formulated Complementary food

The complementary food sample (100g) was reconstituted with clean water (100ml). The reconstituted complementary formula was poured in boiling (100°C) water (150ml) in a pot and stirred for 5 mins to obtain a smooth gruel.

Sensory evaluation of the pap produced from the *ogi* powder

Reconstituted pap from the malted sorghum-soybean flour blends (100:0, 70:30 and 60:40) was evaluated by 20 semi-trained panelists consisting of women who had children under the age of five. They were requested to score the samples according to their degree of likeness using 9 point hedonic scale, where 9 is like extremely and 1 is dislike extremely. The products were evaluated for their color, taste, flavor, texture, appearance and overall acceptability qualities.

Ethical Considerations

Ethical standards governing research involving human participants were observed. Participation in the sensory evaluation was voluntary, and informed consent was obtained from all panelists. The samples were hygienically prepared and certified safe for consumption.

Statistical analysis

All data obtained in this study were analyzed using SPSS (Statistical Package for Social Sciences) Version 16. One way ANOVA and Duncan's New Multiple Range Tests was used to compare and separate means ($P<0.05$).

Results and Discussion

Functional properties of the *ogi* powder blends

The functional properties of the powdered *ogi* blends are presented in Table 1. Bulk density ranged from 0.69 to 0.74 g/mL, showing slight but statistically significant differences ($p < 0.05$) among the blends. Although the variation was small, the 100% sample exhibited a marginally higher value, indicating that soybean inclusion had little practical effect on packing characteristics. This result disagrees with the findings of Agume et al. (2017), that roasting of soybean can slightly increase bulk density due to moisture loss and particle. Swelling capacity, water absorption capacity (WAC), and oil absorption capacity (OAC) showed no significant differences ($p > 0.05$) among the blends, suggesting that soybean inclusion and roasting had minimal effect on these properties, possibly due to similar starch–protein interactions across formulations (Raigar & Mishra, 2021; Hatamian et al., 2020). Dispersibility improved significantly ($p<0.05$) with higher soybean inclusion reaching 74.5% in the 60:40 blend. These results indicate roasted soybean improved reconstitution and dispersibility without affecting water or oil absorption, while the slight increase in swelling capacity was likely due to the hydrophilic proteins and soluble carbohydrates in soybean that enhance water uptake. The ogi blends showed good functional suitability for infant feeding. Moderate bulk density and high dispersibility promoted smooth reconstitution and desirable mouth-feel, while improved oil absorption improved energy density (FAO/WHO, 2003; Tasie & Gebreyes, 2020).The findings agree with earlier reports that legume-cereal blends maintain functional quality while improving ease of reconstitution (Tasie & Gebreyes, 2020).

Table 1: Functional properties of the powder *ogi* blends

MSF:SF	Bulk density g/mL	Swelling capacity %	WAC ml/g	OAC ml/g	Dispersibility %
100:0	0.74±0.00[b]	16.50±0.50[a]	246.50±0.50[a]	205.00±2.50[a]	68.00±0.00[a]
70:30	0.69±0.24[ab]	24.00±2.00[a]	248.00±3.00[a]	207.00±5.00[a]	70.50±0.50[b]
60:40	0.70±0.00[a]	24.50±2.50[a]	269.00±11.00[a]	203.00±3.00[a]	74.50±0.50[c]

Values are means ± standard error. Means with different superscripts within the same column are significantly different ($p<0.05$).
MSF: Malted sorghum flour, SF: Soybean Flour

Sensory evaluation of the re-constituted pap produced from the *ogi* powder

The sensory evaluation of the re-constituted pap (Table 2) revealed that all formulations were generally acceptable to the panelists, with no significant differences ($p>0.05$). However, 70:30 blend consistently obtained higher rating for aroma, taste, texture and overall acceptability, compared 100% MSF and 60:40 blend. Higher aroma and taste scores of the 70:30 blend may be attributed to roasting which reduced beany flavor. The relatively lower score of the 60:40 formulation may be linked to the more pronounced beany flavor associated with higher soybean content as previously noted in cereal-legume blends (Adebo et al., 2022). Roasting has been shown to improve sensory properties by significantly decreasing objectionable green and beany flavors, while increasing sweet taste, viscosity, and roasted aroma in soybean-based products (Willard et al., 2018).

Soybean inclusion did not significantly alter color perception confirming earlier reports that legume supplementation in cereal-based complementary foods minimally influences color acceptability (Kaunda et al., 2025).

Table 2: Sensory evaluation of the re-constituted pap produced from the *ogi* powder

MSF:SF	Color	Aroma	Texture	Taste	Overall acceptability
100:0	6.25±0.35[a]	6.10±0.28[a]	5.80±0.40[a]	5.45±0.43[a]	5.95±0.39[a]
70:30	6.95±0.18[a]	6.50±0.22[a]	6.35±0.27[a]	6.40±0.31[a]	6.50±0.32[a]
60:40	6.95±0.22[a]	5.59±0.23[a]	5.85±0.33[a]	5.40±0.38[a]	5.95±0.39[a]

Values are means ± standard error. Means with different superscripts within the same column are significantly different ($p<0.05$).
MSF; Malted sorghum flour, SF: Soybean Flour

Conclusion

This study demonstrated that the incorporation of roasted soybean flour into malted sorghum flour considerably improved the functional properties of the complementary food formulations and improved taste quality and acceptability. Functional properties such as bulk density, water absorption capacity, swelling, and dispersibility were either maintained or improved, supporting the preparation of energy-dense and easily re-constitutable powdered *ogi*. Sensory evaluation indicated that all formulations were acceptable, with the moderate. The findings suggest that malted sorghum–roasted soybean complementary foods, particularly at moderate soybean inclusion, have the potential to serve as a nutritionally rich and organoleptically acceptable complementary food for children under age five, thereby contributing to the prevention of protein-energy malnutrition.

Conflicts of interest: There was no conflict of interest between the authors.

References

Aanchal. (2023). Nutritional and health benefits of soybean and soybean-developed food. *The Pharma Innovation Journal, 12*(6), 4991–4999.

Adebo, J. A., Njobeh, P. B., Gbashi, S., Oyedeji, A. B., Ogundele, O. M., Oyeyinka, S. A., & Adebo, O. A. (2022). Fermentation of cereals and legumes: Impact on nutritional constituents and nutrient bioavailability. *Fermentation, 8*(2), 63. https://doi.org/10.3390/fermentation8020063

Raigar, R. K., & Mishra, H. N. (2021). Impact of Pilot Scale Roasting Treatment on Physical and Functional Properties of Soybean (Glycine max L.). *Journal of the Institution of Engineers (India): Series A, 102(4), 489–495.*

Ranini, A. A., Ayu, A. M., Anjani, G., Syauqy, A., Noer, E. R., & Ayustaningwarno, F. (2025). The role of malting in grains and legumes for the development of high-functionality medical foods. *Journal of Agriculture and Food Research, 22*, 102031. https://doi.org/10.1016/j.jafr.2025.102031

Tasie, M. M., & Gebreyes, B. G. (2020). Characterization of nutritional, antinutritional and mineral contents of thirty-five sorghum varieties grown in Ethiopia. *International Journal of Food Science, 2020*, 1–11. https://doi.org/10.1155/2020/8243617

World Health Organization (WHO). (2024). *Joint child malnutrition estimates (JME)*. WHO.

Yang, L., Xie, Y., & Wang, J. (2023). Control of beany flavor from soybean protein raw material in plant-based meat analog processing. *Foods, 12*(5), 923. https://doi.org/10.3390/foods12050923

Efficacy of Lemon Peel Powder (*Citrus limon*) as a Protectant against *Demestes maculatus* Fed on Smoked *Claria gariepinus*

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Abstract

Efficacy of Lemon peel Powder (*Citrus limon*) as a Protectant against *Demestes maculatus* fed on smoked *Claria gariepinus* was conducted to determine the proximate composition of Clarias gariepinus treated with lemon peel powder, weight loss of treated *Clarias gariepinus* during storage and to investigate the efficacy of lemon peel powder on the mortality of *Dermestes maculatus*. The lemon peels, obtained from lemon merchants at Maiduguri were air dried, grinded and sieved into powder. *Dermestes maculatus* was obtained from infested smoked fish (*Clarias gariepinus*) in Baga road fish market, Maiduguri. Nigeria. The Lemon peel powder was thoroughly mixed with 100g of disinfected dried fish (*Clarias gariepinus*) at rate of 0g (control) lg. 2g, and 4g in separate transparent bottle. Five larvae of *Dermestes maculatus* were introduced into each transparent bottle and covered with muslin cloth. Each treatment was arranged in a completely Randomized Design (CRD), replicated three times and observed daily. The mortality of beetles at each treatment was observed at a 24-hour interval. Results reveal that lemon peel powder improved proximate composition of the treated *Clarias gariepius*. Weight loss of the fish during storage reduced as the concentration of lemon peel powder increased. The lowest weight loss was recorded at the highest concentration of (4g). Lemon peel powder at 4g produced 100% of hide beetle (*Dermestes maculatus*) at six days post treatment. This study showed that lemon peel powder is effective in controlling *Dermestes maculatus.*

Keywords: Lemon, Proximate, Weight loss and *Clarias*

Introduction

Fish are an important part of a healthy, well-balanced diet. They provide a good source of protein and vitamins and are a primary dietary source of heart-healthy omega-3 fatty acids (OEHHA. 2016). Omega-3 fatty acids can lower risk of heart disease, lower triglyceride levels, slow the growth of plaque in your arteries, and slightly lower blood pressure. Omega-3 fatty acids may also provide health benefits to developing babies. The relevance of the fisheries sector to the Nigeria economy and benefits derived by Nigerians from fish and other fish products have led to the high consumption and hence the increased

demand for fisheries products. In 2016, 14.3 million people in Nigeria were classified as undernourished (FAO STAT, 2017).

Catfish like any other fish species could result in significant economic loss due to its perishable nature, if adequate preservation techniques are not adopted. The most common method of fish preservation employed in the tropics is smoking. Smoking increases fish shelf life, gives the product a desirable taste and odour, provides antibacterial and oxidative effects, lowers pH, imparts colour as well as accelerates the drying process and acts as an antagonist to spoilage agents (Akintola *et al*., 2013).

The extension of the storage life of smoked fish can result from a combination of lowered water activity and the uptake by the product of bactericidal and antioxidant components of wood smoke (Piggott, 2015). Smoke-dried *Clarias gariepinus* is highly susceptible to insect infestation, mainly hide leather beetle. Attack on smoked catfish can significantly reduce the quantity and quality of fish flesh meant for human consumption and economic purposes. And their infestation can also predispose the infected fish to microbial attacks. FAO (2019) reported that insect infestation on smoked dried fish during storage can cause economic loss to fishmongers and loss in the qualitative and quantitative composition of the fish. To reduce of insecticides, researchers have employed alternative, ecofriendly and cheaper insect-pest management measures involving plants and plant products such as, powders and extracts. Many Nigerian medicinal plant species have proven to be very important in pest management of stored grains, legumes and dried smoked fish (Ajao, 2012).

Lemon (*Citrus limon*) L, native to South Asia is an evergreen small tree belonging to the family *rutaceae* with nutritional and medicinal property. The lemon peel is a significant antimicrobial agent along within a stringent property. The objectives of this research were to determine the proximate composition of both fresh and lemon-treated smoke-dried *Clarias garipinus*) to assess the weight loss caused by *Dernestes maculatus* on stored smoke-dried *Clarias gariepinus* after infestation, and evaluate the efficacy of lemon peel powder as control against *Dermestes maculatus* on stored smoked-dried *Clarias gariepinus*.

Methodology

The study was conducted at the processing laboratory, Department of Fisheries, University of Maiduguri, which lies in the semi-arid zone of Nigeria within latitude$11^0 49^0$ 59.99" N and Latitude 130 08' 60.00" (GPS EM90). It is characterized by a short rainy season (3-4 months) with a long dry season period.

Collection and preparation of plant product

The Lemon peel (*Citrus limon*) was obtained from Monday market, this material was air dried for one week and grinded and sieved through a 40 holes/mm^2 mesh. The powder was then kept in a clean plastic container and placed in a cool place for use in the experiment (Obiakor *et al*., 2013).

Procurement and processing of *Clarias gariepinus*

A total of 1200 grams (1.2 kg) of *Clarias gariepinus* was procured from Baga road fish market. Maiduguri, Borno state. Nigeria. The fish was transported in an ice-bowl to the Fish Post-harvest unit of the Department of Fisheries, University of Maiduguri. The fish was de-gutted and washed several times till they were cleaned. Wood was used as the energy source for smoking.

Collection and of insect (*Dermestes maculatus)*

The beetles (*D. maculatus*) were obtained from the infested smoked dried catfish at Baga road fish market, Maiduguri, Borno state, Nigeria. Insects collected were identified based on their morphological features and were kept in plastic jars covered with muslin cloth with disinfected dried fish in the containers for continues production of newly emerged adults of *D. maculates* (Akinwumi, 2011).

Proximate and weight loss analysis of Smoked and Fresh Fish

The proximate compositions of the fresh and smoked fish were analyzed according to guidelines of the Association of Official Analytical chemist procedure (AOAC, 2012). The protein content (%), moisture content (%), ash content (%), and fat (lipid) content (%) were determined. Weight loss was measured by weighing the smoked fish weekly to access the level of damage done. Percentage weight loss was calculated by initial weight to divide the difference of initial weight and final weight multiply by 100.

% Weight loss=initial weight - final weight x 100

Experimental design

The fish samples were allocated into four (4) treatments 0g. lg, 2g and 4g respectively. Each treatment was triplicate. Each replicate has hundred (100) grams of fish in a transparent glass bottle. Five (5) new larvae (3-5 days) of *Dernestes maculatus* were introduced to each replicate. The lemon peels powder was added to each of the different treatments at varying dosage 1.0g, 2.0g, 4.0g and 0g for control.

Data analysis

The data obtained were subjected to one-way analysis of variance (ANOVA) in a completely Randomized design (CRD) using software Statistix 8.0 package and the means were separated using Least Significant Difference (LSD) at 5% level of confidence.

Results and Discussion

Proximate composition of fresh *Clarias gariepinus*

The proximate composition of fresh African catfish was presented in Table 1. The parameters are moisture content. Crude protein, ether extract, ash, crude fiber and nitrogen free extract. The value of each parameter was recorded. The means of were 68.22±1.59, 18.82±42.45, 14.02±42.32, 2.67±0.69 and

6.27±0.65 for moisture content, crude protein, ether extract, ash, crude fiber and nitrogen free extract, respectively.

Table 1 Proximate composition of fresh *Clarias gariepinus*

Moisture content %	Crude protein %	Ether extract %	Ash content %	NFE%
68.22±1.59[a]	18.82±2.45[a]	14.02±2.32[a]	2.67±0.69[a]	6.27±0.65[a]

Note: Means with same superscript are not significantly different P>0.05

The use of plant parts has been reported by several researchers as an alternative to chemical insecticides in controlling insect pests. Don-Pedro (1985) reported the toxicity of Citrus peel powder to *Dermestes maculatus*. Nwaehujor and Olatunii (2011) reported that orange peel powder and its extracts gave adequate protection to stored cowpea seeds, Dawit and Bekelle (2010) reported that orange peel powder protected the grains from damage by hundred percent strongly suggesting the presence of physical interfering agents in orange peel powder. Owoede (2008) used *Zingiber officinale* powder to control *Dermestes maculatus* infestation. There is a general increase in moisture content as the inclusion level of both lemon peel powder increased. This could be attributed to the prevailing ambient temperature and relative humidity around the smoked-dried fish sample. Protein tends to increase with the increase in the quantity of the lemon peel powder (Table 2). This is so because fish is a good source of protein as reported by Tidwell. (2011). The fat content tends to decrease as the inclusion level of lemon peel powder increases. Therefore, 4g of lemon peel powder treated sample had the lowest fat content. This disagreed with the findings of Compaoré *et al*. (2011), who reported that the fish fat content increased with increased inclusion level of *Moringa oleifera* seed. There was a decrease of ash content in smoke-dried fish treated with different levels of lemon peel control the ability of *D. maculatus* to perpetuate on cowpea seeds during storage. Lemon As the level of inclusion of lemon peel powder increased the ash content reduced this is an agreement with Ibrahim (2017). Weight loss of smoke-dried *Clarias gariepinus* treated with different rates of lemon peel powder was recorded at Table 3. Highest weight loss was recorded (3.00+0.65) at 0g inclusion level of lemon peel powder and the lowest weight loss was recorded (0.67+0.60) at 4g inclusion level of lemon peel powder.

Percentage weight loss of smoked fish treated with lemon peel powder infested with *D.maculates* during storage is shown in Table 3. Weight loss in smoked fish due to insect attack drastically reduced ($p< 0.05$) in the treated sample. Smoked fish without inclusion of any other plant materials (control treatment) gave the highest percentage of weight loss due to insect attack for the 9 days storage period. The percentage weight loss could be a good index of assessing spoilage and fish waste during storage. Such phenomena often affect the nutritional quality and consumers' acceptability of the fish products, a substantial number

of smoked fish has been reported to be wasted due to insect pest attack during storage (Odeyemi *et al*. 2000). The effectiveness of lemon peel powder in reducing damage and of *Dermestes maculatus* in smoked fish during storage are found to be encouraging and a possible means of ensuring a steady supply of good quality smoked fish.

Table 2 Proximate Composition of Smoked-dried *Clarias gariepinus* after Treatment with Lemon Peel Powder (%)

Conc (g)	Moisture content	Crude protein	Ether extract	Ash content	NFE
Control	7.64±0.93^{b}	56.04±5.23^{b}	12.74±1.62^{b}	3.07±0.16^{a}	19.84±4.97^{a}
1	8.11±1.32^{a}	56.65±7.41^{b}	13.51±2.29^{a}	3.15±0.22^{a}	18.58±7.03^{b}
2	7.39±0.43^{b}	57.51±4.40^{b}	13.39±2.28^{a}	3.10±0.39^{a}	18.60±7.28^{b}
4	7.70±1.02^{b}	62.91±5.40^{a}	10.32±1.50^{c}	2.89±0.36^{b}	16.17±5.62^{c}

Means in a row are significantly different at p<0.05

Table 3: Weight Loss of Treated Smoked-dried *Clarias gariepinus* after Storage for Nine Days

Weight of fish (g)	0	1	2	4
Initial weight	100.00±.1.12^{a}	100.00±1.58^{a}	100.00±0.43^{a}	100.00±1.10^{a}
Final weight	97.00±0.47^{b}	99.00±0.67^{a}	98.33±0.23^{b}	99.33±0.50^{a}
Weight loss	3.00±0.65^{a}	1.00±0.91^{b}	1.67±0.20^{ab}	0.67±0.60^{b}

The effects of lemon peel powder on the mortality of Dermestes maculatus is shown in Table 4. All the concentration of the lemon peel powder used was effective in controlling infestation by *Dermestes maculatus* when compared with the untreated control. The mortality of the beetles increased with lemon-peel concentration and the duration of storage. 4g of lemon peel powder was found to have 100% mortality of the insects at six-day post-treatment. The results of this study shows that smoke-dried *Clarias gariepinus* treated with varying concentrations of lemon peel powder has effect on the development of *Dermestes maculatus*. The efficacy of the lemon peel powder on hide beetle (*Dermestes maculatus*) mortality was higher when the treatment dosage was higher (Table 4). 4g of the lemon peel powder was found to have 100% mortality of the insects within six days post treatment, 33.3% of mortality was observed after eight days for untreated control of lemon peel powder (Table 4). This study also indicated that almost all the concentration of the lemon peel powder used was effective in controlling infestation by *Dermestes maculatus* when compared with the untreated control due to the facts that the mortality of the beetle increased with an increase of the treatment and the duration of the days (Table 4). This study is in agreement with the work of (Shuaibu *et al*. 2017) who reports that the highest dose of Citrus peel powders recorded the highest mortality of insects after every 24 hours interval of exposure, this indicates that the Citrus peel powder has some toxic factors which are negatively impacted on the survival of insects.

Table 4 Effect of lemon peel powder on the mortality of *Dermestes maculatus*

Parameters				
Days	**Control**	**1**	**2**	**4**
1	0	0	13.3	13.3
2	0	13.3	26.6	26.6
3	0	33.3	33.3	33.3
4	0	40	46.6	60
5	6.6	46.6	60	80
6	13.3	53.3	80	100
7	26.6	60	100	100
8	33.3	80	100	100
9	46.6	100	100	100

Table 4 shows that smoke-dried *Clarias gariepinus* treated with 4g of the lemon peel powder was found to have 100% mortality of the insects within six days post treatment, 100% mortality was observed at day seven post treatment for smoke-dried *Clarias gariepints* treated with 2g of lemon peel powder. 100% mortality also found at day nine post treatment for smoke-dried *Clarias gariepinus* treated with lg of lemon peel powder and untreated control recorded 46.6% beetle mortality after nine days of treatment.

Conclusion

This study shows that lemon peel powder treatment improved the proximate composition, reduced storage weight loss and increased the mortality of Hide beetles (*Dermestes maculatus)* in smoke-dried *Clarias gariepinus*. Lemon peel powder is recommended for fish processors for the control of *Dermestes maculatus* pests of smoke-dried fish and serves as a good alternative to synthetic insecticides in food fish protection.

References

Akinrotimi, O.A., Gabriel, U.U., Owhonda, K.N., Onunkwo, D.N., Opara, J.Y., Anyanwu. P.E., & Cliffe. P.T. (2007). Formulating an Environmentally Friendly Fish Feed for Sustainable Aquaculture Development in Nigeria. *Agricultural Journal*, 2(5), 606-612.

Federal Department of Fisheries. (2008). Fisheries Statistics of Nigeria Projected I Human Population, Fish Demand and Supply in Nigeria, 2000-2015, 56.

Food and Agriculture Organization (FAO). (2007). Fisheries Development in Nigeria: Paper Presented by The Honourable Minister of State for Agriculture to The Fisheries Society of Nigeria (FISON). Lagos State. 23 :2. Bruchidae). MEJS Vol. 2 (1): 61-75

Ibrahim., B.U. (2017). Assessment of mutritional quality of smoked catfish (Clarias gariepinus) 1m Lapai. Niger State, Nigeria. Science World Journal. 12(1): 18-21.

Nwachujor, I.U & Olatunji., G.A. (2011). Orange peel powder and its extracts as preservative aginst *Callosobruchus maculatus* (*Coleoptera: Bruchidae*) attack on Cowpea. Journal of Science and Technology, Vol.31 No. 2: 21-26

Otang. W.M. & Afolayan, A.J. (2016). Antimicrobial and Antioxidant Efficacy of Citrus Limon L. Peel Exĺracts Used for Skin Diseases by Xhosa Tribe of Amathole District. Eastern Cape South Africa, S. Afr:. J. Bot, 102:46-49.

Shuaibu, T. Bandiya, H.M., Sufi, D.A., Idris, M.A & Jibrin. M.M. Efficacy of Citrus peel powder against the Hide *heetle Dermestes* maculatus fed on Smoked Afirican Cat fish *Clarias gariepinus. Dutse Journal of Pure and Applied Sciences* (DUJOPAS) Vol. 3 No. I June 2017 229.

Antibiotic Susceptibility Profile of *Escherichia coli* and *Salmonella Species* Isolated from Leafy Vegetables Sold in Ilorin, Kwara State, Nigeria

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Abstract

Salmonella spp and *Escherichia coli* can contaminate vegetables through soil and water contaminated with animal manure, contact with contaminated surfaces or hands during handling and processing and cross contamination from raw meat and other contaminated foods. This study investigated the antibiotic susceptibility profiles of *E. coli* and *Salmonella* species isolated from vegetables sold in selected markets across Ilorin, Nigeria. A total of 40 vegetable samples were collected from four major markets: Ganmo (A), Mandate (B), Oja-Oba (C), and Oja-Titun (D). Isolation and identification of the bacterial species were conducted using standard microbiological techniques. Antibiotic susceptibility testing was performed using the disk diffusion method in accordance with Clinical and Laboratory Standards Institute (CLSI) guidelines. The findings revealed that streptomycin was the most effective antibiotic, showing sensitivity in 52.9% of isolates, followed by Septrin and chloramphenicol, each with 47.1% sensitivity. In contrast, Tarivid and ciprofloxacin exhibited the highest resistance rates, with 88.2%.Among the *E. coli* isolates, strain EC7 demonstrated the highest resistance level (90%), resistant to SFX, PEF, OFX, CPX, SPT, CHF, AMC, GTC, and STM. The least resistant *E. coli* strain was EA3, with a resistance rate of 50%. For *Salmonella* species, strain SB1 showed the highest resistance (80%), resistant to SFX, PEF, OFX, CPX, AUG, CHF, AMC, and STM, while strain SC4 had the lowest resistance (30%). These results highlight the need for improved hygiene practices throughout the vegetable supply chain. Implementing effective control measures to reducemicrobial contaminationofvegetables and limit the spread of resistance is essential for protecting public health and ensuring food safety.

Keywords: Antibiotics, Vegetables, Nutrition

Introduction

The rising popularity of leafy vegetables, celebrated for their nutritional value, also brings forth significant public health concerns due to the potential presence of food-borne pathogens. Among these, *Escherichia coli* and *Salmonella species* are of particular importance, as they are commonly associated with food-borne illnesses that can lead to severe health complications. (Kaba and Rolon, 2020) These pathogens

often find their way onto fresh produce through contaminated water, soil, or during handling and processing, (Lienen et al., 2022) raising concerns over food safety. The susceptibility of vegetables to contamination throughout the production process, from cultivation to consumption, prompts a reevaluation of the potential transmission of resistant bacteria along the food chain.

In Ilorin, Kwara-State, Nigeria, the demand for fresh, locally sourced leafy vegetables continues to grow, which has amplified focus on the microbiological quality of these products. Recent studies suggest that these vegetables may harbor antibiotic-resistant strains of *E. coli* and *Salmonella species*, highlighting the pressing issue of antibiotic resistance, which complicates treatment options in clinical settings and poses a serious risk to public health (Szczuka et al., 2022).

This study aimed to investigate the antibiotic susceptibility profiles of *E. coli* and *Salmonella species* isolated from leafy vegetables sold in Ilorin. The resistance patterns of these pathogens can be examined through their prevalence in the local food supply and identifying their protential sources of contamination. The insights gained from this research will be crucial for informing public health strategies, improving food safety standards, and guiding best practices for agricultural management in the region. Ultimately, this work seeks to safeguard consumer health and promote safer food practices within the community.

Methodology

Sample Collection

Forty (40) samples of leafy vegetables were collected from 4 different markets in Ilorin, Kwara State. Ten (10) leafy vegetables namely dandelion greens, bitter leaf, African spinach, Lagos spinach, water leaf, Malabar spinach, African basil, Yoruba bologi, fluted pumpkin leaf and jute leaf were collected into sterile vegetable baskets and transported to the Microbiology Laboratory ofthe Nigerian Stored Products Research Institute, Ilorin, for analysis.

Isolation and Identification of Isolates

The leafy vegetable samples were homogenized separately, 1g of the homogenized sample was taken for serial dilution after which diluent 10^{-2} was selected as aliquot and inoculated on differential medium, Eosin Methylene Blue (EMB) Agar for isolation of *Escherichia coli*, and Salmonella Shigella (SSA) agar for isolation of *Salmonella spp* which were prepared according to the manufacturer's prescription and then incubated at 37°C for 24 to 48h for the isolation of *E. coli* and *Salmonella spp.* respectively. The isolates were sub-cultured after 24 to 48 hours, the pure cultures obtained were transferred into slant bottles for storage at 4^0C. (Ihum et al., 2023).

Antimicrobial susceptibility profile of *E. coli* and *Salmonella species Isolated from leafy vegetable*

The antimicrobial susceptibility profile was conducted on Mueller–Hinton agar using the disk diffusion technique, in accordance with the Clinical and Laboratory Standards Institute (CLSI, 2022) guidelines. Inhibition zone diameters were measured and interpreted as resistant (≤14 mm), intermediate (15–19 mm), or sensitive (≥20 mm), based on the breakpoint values for Enterobacteriaceae (CLSI, 2022)The commercial antibiotic discs used were: Septrin (SEP) 30µg, Amoxicillin (AM) 25µg, Chloraphenicol (CHL)30µg, Sparfloxacin (SPX) 10µg, Ciprofloxacin (CIP) 10µg, Augmentin (AU) 30µg, Gentamicin (CN) 10µg, Tarivid (OFX)10µg, Streptomycin (STM) 30µg.To quantify resistance across multiple antibiotics, the Multi-Antibiotic Resistance (MAR) index was calculated for each isolate using the formula:

MAR Index = Number of antibiotics to which the isolate is resistant / Total number of antibiotics tested. (Singh et al., 2010).

Results and Discussion

The antibiotic susceptibility profile of *E. coli* and *Salmonella spp* obtained from leafy vegetables in Ilorin markets is presented in Table 1, and the percentage susceptibility of the isolates to the ten selected antibiotics is presented in Table 2. In this study, it was observed that the most sensitive antibiotic is streptomycin (52.9%). Septrin (47.1%) and Chloraphenicol (47.1%) are moderately effective. Tarivid and Ciprofloxacin recorded the highest resistance at 88.2% (15/17). The result is in contrast with the finding of Alimi et al., 2023, where *Escherichia coli* and *Salmonella spp* were sensitive to Ciprofloxacin. These antibiotics belong to the class, fluoroquinolones as highly promising option for treatment. They are broad-spectrum antibiotics that are effective against a variety of bacterial infections by inhibiting DNA replication and synthesis in susceptible bacteria. However, abuse may lead to an increase in fluoroquinolone-resistant strains, a serious concern for both animal and human health. (WHO, 2019)

The resistance profiles and the multi-antibiotic resistance (MAR) index revealed that all the isolates examined are resistant to three or more antibiotics as presented in Table 3. The *Escherichia coli* isolate from Oja-oba sample (EC7), had the highest percentage resistance (90%), while the lowest (50%) was EA3 isolate from Ganmo market. The Salmonella spp isolated from Mandate market sample, (SB1) had the highest percentage resistance (80%), while the lowest was SC4 (30%) isolated from Oja oba market sample. Antibiotic resistance could be attributed to chromosomal or plasmid resistance of the microorganism cell constituents.

Table 1: Antibiotic susceptibility profile of *E. coli* and *Salmonella spp* from leafy vegetables from some selected markets in Ilorin, Kwara-State

	(Zone of inhibition in mm)									
Isolate	**SPX**	**PEF**	**OFX**	**CPX**	**AUG**	**SPT**	**CHF**	**AMC**	**GTC**	**STM**
EA2	10	14	13	9	17	16	12	12	16	11
ED2	13	18	10	12	9	9	17	11	18	15
EA3	12	16	17	13	10	16	12	9	17	19
ED5	18	11	13	9	12	10	18	19	11	20
EB7	14	14	14	16	10	9	9	13	16	11
EC7	13	0	0	0	16	9	12	11	13	14
ED7	11	9	12	9	13	16	15	13	11	17
EB8	10	12	19	16	0	9	16	10	10	12
ED8	12	13	10	15	10	11	13	17	9	10
EC10	18	18	11	13	9	17	19	10	12	17
SB1	9	12	11	11	13	16	11	10	19	14
SD3	13	16	10	9	10	12	13	19	12	20
SC4	18	18	10	13	11	16	15	16	16	19
SA5	20	11	12	14	16	17	18	11	13	10
SB7	13	0	0	0	11	16	13	17	10	16
SB8	16	0	0	0	18	14	17	11	9	12
SA9	14	12	12	12	17	10	13	12	17	20

Keys: Sparfloxacin – SPX, Pefloxacin – PEF, Tarivid – OFX, Ciprofloxacin –CPX, Augmentin – AUG, Septrin – SPT, Chloraphenicol – CHF, amoxicillin-AMC, Gentamycin – GTC, Streptomycin STM. E- ***E. coli, S-Salmonellaspp,*** A- Ganmo market, B- Mandate market, C- Oja oba, D- Oja titun

Table 2: Susceptibility profile (%) of *E. coli* and *Salmonella spp* isolates to selected antibiotics

ANTIBIOTICS	**SENSITIVE**	**INTERMEDIATE**	**RESISTANT**
	No/%of isolates	**No/ % of isolates**	**No/ % of isolates**
Sparfloxacin (SPX)	1 (5.9)	4 (23.5)	12 (70.6)
Pefloxacin (PEF)	0	5 (29.4)	12 (70.6)
Tarivid (OFX)	0	2 (11.8)	15 (88.2)
Ciprofloxacin (CPX,)	0	2 (11.8)	15 (88.2)
Augmentin (AUG)	0	5 (29.4)	12 (70.6)
Septrin (SPT)	0	8 (47.1)	9 (52.9)
Chloraphenicol (CHF)	0	8 (47.1)	9 (52.9)
Amoxicillin (AMC)	0	5 (29.4)	12 (70.6)
Gentamycin (GTC)	0	7 (41.2)	10 (58.8)
Streptomycin (STM)	3 (17.6)	6 (35.3)	8 (47.1)

Table 3: Resistance profile, multi-antibiotic resistance (MAR) index and percentage resistance of *E. coli* and *Salmonella spp* from leafy vegetables

ISOLATES	RESISTANCE PROFILE	MAR INDEX	PERCENTAGE RESISTANCE (%)
EA2	SFX, PEF, OFX, CPX, CHF, AMC, STM	0.7	70
ED2	SFX, OFX, CPX. AUG, SPT, AMC	0.6	60
EA3	SFX, CPX, AUG, CHF, AMC	0.5	50
ED5	PEF, OFX, CPX, AUG, SPT, GTC	0.6	60
EB7	SFX, PEF, OFX, AUG, SPT, CHF, AMC, STM	0.8	80
EC7	SFX, PEF, OFX, CPX, SPT, CHF, AMC, GTC, STM	0.9	90
ED7	SFX, PEF, OFX, CPX, AUG, AMC, GTC	0.7	70
EB8	SFX, PEF, AUG, SPT, AMC, GTC, STM	0.7	70
ED8	SFX, PEF, OFX, AUG, SPT, CHF, GTC, STM	0.8	80
EC10	OFX, CPX, AUG, AMC, GTC	0.5	50
SB1	SFX, PEF, OFX, CPX, AUG, CHF, AMC, STM	0.8	80
SD3	SFX, OFX, CPX, AUG, SPT, CHF, GTC	0.7	70
SC4	OFX, CPX, AUG,	0.3	30
SA5	PEF, OFX, CPX, AMC, GTC, STM	0.6	60
SB7	SFX, PEF, OFX, CPX, AUG, CHF, GTC	0.7	70
SB8	PEF, OFX, CPX, SPT, AMC, GTC, STM	0.7	70
SA9	SFX, PEF, OFX, CPX, SPT, CHF, AMC	0.7	70

This result is corroborated with the report of Eniola *et al*. (2021) who also reported that isolated *E.coli* from leafy vegetables in Osun State market were resistant to two or more antibiotics. This research is therefore important for understanding the level of antibiotic resistance in food-borne pathogenic bacteria present in leafy vegetables consumed in the Ilorin, Kwara State.

Conclusion

The leafy vegetables purchased from the various markets harbored multi antibiotic-resistant *Escherichia coli* and *Salmonella species*. This research highlights the need for improved hygiene practices throughout the vegetable supply chain. Implementation of effective control measures to reduce contamination and limit the spread of resistance is essential for protecting public health and ensuring food safety in the selected markets

References

Alimi J. O., Ogunbanwo S. T. & Alimi J. P. (2023). Antimicrobial Effects of Lactic Acid Bacteria on Food-Borne Pathogens Isolated from Some Fruits Sold in Ibadan, Nigeria. 15, 4, 38-45, Article no. SAJRM.100654 ISSN: 2582-1989.DOI: 10.9734/SAJRM/2023/v15i429

Clinical and Laboratory Standards Institute. (2022). Performance Standard for Antimicrobial Susceptibility Testing; 32nd ed. CLSI supplement M100, Wayne.

Eniola, O., Adeyemi, A., & Alabi, O. (2021). Antibiotic resistance profiles of *Escherichia coli* isolated from leafy vegetables in Osun State, Nigeria. *Journal of Food Safety and Quality Assurance*, 11(4), 543-550.

Ihum T. A., Kurrah, I. A., Olalekan, M. R., & Oledibe C. F. (2023) Inhibitory activity of orobiotics against microbial contaminants of packed and exposed soy beans flour. *Timbou-Africa Academic Journal,* 14, 1, 3438-2901S

Keba, H., & Rolon, A. (2020). Emerging concerns regarding antimicrobial-resistant bacteria in vegetables: Implications for food safety and human health. *International Journal of Food Microbiology*, 321, 108529.

Lienen, K., Müller, H., & Schneider, J. (2022). The relationship between food production systems and the spread of antibiotic-resistant bacteria: A review. *Food Control*, 131, 108405. .

Szczuka, E., Porada, K., Wesołowska, M., & Łęska, B. (2022) Occurrence and Characteristics of *Staphylococcus aureus* Isolated from Dairy Products. *Molecules, 27*, 4649.

Singh S., Yadav A.S., Singh S. M., & Bharti P. (2010). Prevalence of Salmonella in chicken eggs collected from poultry fatrms and marketing channels and their antimicrobial resistance. *Food Research International*, 43(8), 2027-30. http://dol. org/10.1016//j.foodres 2010.06.001

World Health Organization. (2019). Global action plan on antimicrobial resistance. Available at: https://www.who.int/docs/default-source/documents/global-action-plan-on-amr.pdf

Antioxidant and Molecular Docking Inhibitory activity of *Phyllanthus Amarus* Extract against Fungal Enzyme, Lanosterol-14-Alphademethylase

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Abstract

The antioxidant activity of *P. amarus* leaf ethanolic extract and the molecular docking of 10,13-diethoxydibenzo (a,c) phenazine, a phytoconstituent of the GC-MS analysis of the leaf extract was assessed in this study. The dried leaves of *P. amarus* were grinded and extracted with ethanol by means of soxhlet extraction. The antioxidant activity of the extract was investigated via 1,1-diphenyl 2-picryl-hydrazyl (DPPH), Ferric Reducing Antioxidant Potential (FRAP), Hydroxyl Radical Scavenging and Superoxide Radical Scavenging Assays. The DPPH scavenging ability of *P. amarus* leaf extract affirms that *P. amarus* leaf extract respond to DPPH scavenging in dose dependent manner. Similar trend is obtained for hydroxyl and superoxide scavenging ability except for FRAP where the activity is not in dose dependent trend. The antioxidants analysis revealed that the crude extract is potent on scavenging free radicals. The results of the molecular docking of 10,13-Diethoxydibenzo(a,c)phenazine against lanosterol-14-alpha demethylase (4LXJ), an important enzyme crucial for fungi growth and responsible for the synthesis of the essential component of the cell membrane ergosterol, showed higher binding affinity compared to the standard antifungal agent, propiconazole. 10,13-Diethoxydibenzo(a,c)phenazine exhibited a higher binding energy (-9.5 Kcal/mol) with lanosterol 14-alphademethylase compared to propiconazole (-7.5 Kcal/mol). The findings of this study indicate that *Phyllanthus amarus* contains antioxidants and phyto-constituents with antifungal properties and the potential to inhibit fungal growth which is promising for the control of fungi infestation in stored grains.

Keywords: 10,13-Diethoxydibenzo(a,c)phenazine, Fungal infestation, Lanosterol-14alpha-demethylase, *Phyllanthus amarus*, Propiconazole

Introduction

The rising rate of pest resistance, high pesticide residues in food and other health related risks associated with the miss-use of synthetic pesticides have become a source of public concern (Juniad *et al*., 2023). Numerous studies have evaluated the efficacy of *Phyllanthus amarus* extracts against a wide range of pests. The efficacy has been evaluated through laboratory bioassays and field trials, indicating the potential of *Phyllanthus amarus* as a biopesticide in different agricultural systems (Doumbia *et al*., 2014; Okonkwo and Onyeji, 2018). *Phyllanthus amarus* Schum and Thonn (Euphorbiale: Euphobiaceae) is a leafy herbal plant found in tropical regions in Africa, the Americas, China, India and South East Asia. Secondary metabolites that have been successfully isolated from *P. amarus* include alkaloids, flavonoids, tannins, lignin, sterol, triterpenes and volatile oils (Bahar et al., 2011). Methanolic extracts of leaf, roots and fruits of *Phyllanthus amarus* showed significant concentration-dependent antibacterial activity *in vitro* against a range of gram-positive and gram-negative bacteria; leaf extracts showed the highest activity (Ravikumar et al., 2011). Plant extracts have been shown to exhibit significant molecular docking activity against the fungal enzyme, lanosterol-14α-demethylase (Ajayi *et al*., 2024; Ajayi *et al*., 2025).

Methodology

Antioxidant Assay

DPPH Antioxidant Assay

This was assayed according to the method described by Ademoye et al., (2018).

Ferric Reducing Antioxidant Potential (FRAP)

The method of Boulebd (2022), was used to determine the FRAP.

Hydroxyl Radical Scavenging Assay

The hydroxyl radical scavenging activity was measured by the method of Biondi et al., (2018).

Superoxide Radical Scavenging Assay

The method of Gulcin *et al*., (2009) was used to determine the superoxide scavenging activity of the sample.

Ligand Selection and Preparation

The isomeric smile of 10,13-diethoxydibenzo (a,c) phenazine, propiconazole and was retrieved from PubChem compounds database (https://pubchem.ncbi.nih.gov). The retrieved isomeric smile was concatenated and converted to the MDF-SDF file format using Open Babel. The MDF-SDF File format was converted from the two-dimensional form (2D-form) to the three-dimensional form (3D form) using Data Warrior, and the 3D-form was converted to the PDBQT file format using PyRx. The PDBQT file format was taken through energy minimization using the optimization algorithm at force field mmff94 on PyRx.

Accession and preparation of the protein target

The 3D crystal structure of the protein target, lanosterol-14α-demethylase(PDB:4LXJ) was retrieved from RCSB PDB (https://www.rcsb.org/pdb/home/home.do). The co-crystalized ligand and non essential water molecules were removed from the retrieved protein target using Pymol tool and exported as a PDB file format.

Results and Discussion

The antioxidant activity obtained for *P. amarus* leaf extract is presented in Table 1.

Table 1: Antioxidant Activity of *P. amarus* Leaf Extract

DPPH (% inhibition)

Sample/Standard	100 µg/mL	200 µg/mL	300 µg/Ml	400 µg/mL	500 µg/mL
Crude Extract	$85.27^{u} \pm 1.019$	$87.67^{v} \pm 0.1132$	$88.07^{v} \pm 0.0$	$89.75^{w} \pm 0.1132$	$90.71^{x} \pm 0.1132$
Ascorbic Acid	$86.63^{u} \pm 0.2265$	$87.75^{v} \pm 0.2265$	$90.79^{w} \pm 0.2265$	$91.91^{x} \pm 0.4529$	$93.92^{y} \pm 0.5661$
FRAP (µM)					
Sample	$68.48^{u} \pm 0.5439$	$58.78^{v} \pm 0.3839$	$45.23^{x} \pm 0.1600$	$46.47^{x} \pm 0.4479$	$46.95^{x} \pm 0.1600$
OH^{-} (% Scavenging)					
Sample	$15.91^{u} \pm 0.4592$	$31.17^{v} \pm 0.9183$	$32.79^{v} \pm 0.4592$	$34.42^{v} \pm 0.0$	$35.71^{w} \pm 0.9183$
Ascorbic Acid	$78.57^{x} \pm 0.9183$	$84.74^{y} \pm 1.377$	$88.31^{z} \pm 0.9183$	$89.94^{z} \pm 0.4592$	$87.34^{z} \pm 1.377$
Superoxide (% Scavenging)					
Sample	$12.77^{u} \pm 0.3009$	$31.28^{v} \pm 0.6018$	$43.83^{w} \pm 2.708$	$46.81^{x} \pm 0.3009$	$49.15^{y} \pm 0.6018$
Ascorbic Acid	$48.94^{z} \pm 1.204$	$54.47^{a} \pm 1.204$	$62.55^{b} \pm 3.611$	$64.89^{b} \pm 5.717$	$71.91^{c} \pm 0.6018$

The antioxidants results are reported as mean of duplicate determination ± standard deviation. Values with same superscript across each column shows that there is no significant difference between the means (p value > 0.05) while values with different superscript across and between columns shows there is significant difference (p value < 0.05) between the mean values

Binding Affinities and Molecular Interactions of 10,13-Diethoxydibenzo(a,c)phenazine Docked against Lanosterol 14-alpha Demethylase (4LXJ)

Docking 10,13-Diethoxydibenzo(a,c)phenazine, from the ethanol extract of *Phyllanthus amarus* leaves, against lanosterol 14-alpha demethylase (4LXJ) showed higher binding affinity compared to propiconazole (-9.5 Kcal/mol). The binding affinity of the standard antifungal agent propiconazole was observed to be -7.5 Kcal/mol. The visualization study demonstrated that 10,13-Diethoxydibenzo(a,c)phenazine interacted

with lanosterol-14-alpha demethylase through eight hydrophobic bonds and one hydrogen bond (Figure 1, Table 2).

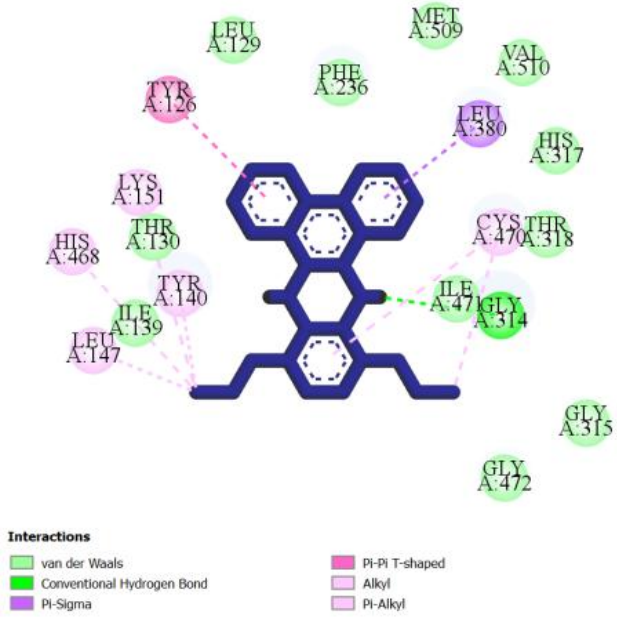


Figure 1: Two-dimensional Interaction of Amino Acid Residues of Lanosterol 14-alpha Demethylase (4LXJ) with 10,13-Diethoxydibenzo (a,c) phenazine

Table 2: Analysis of the Interaction of 10,13-Diethoxydibenzo(a,c)phenazine with the Binding Pocket of Lanosterol 14-alpha Demethylase (4LXJ)

Name	Category	Types	Distance
10,13-Diethoxydibenzo(a,c)phenazine - A:GLY314:O	Hydrogen Bond	Conventional Hydrogen Bond	2.74186
A:LEU380:CD2 - 10,13-Diethoxydibenzo(a,c)phenazine	Hydrophobic	Pi-Sigma	3.97547
A:TYR126 - 10,13-Diethoxydibenzo(a,c)phenazine	Hydrophobic	Pi-Pi T-shaped	4.72849
10,13-Diethoxydibenzo(a,c)phenazine - A:CYS470	Hydrophobic	Alkyl	4.47954
10,13-Diethoxydibenzo(a,c)phenazine - A:LEU147	Hydrophobic	Alkyl	4.3009
10,13-Diethoxydibenzo(a,c)phenazine - A:LYS151	Hydrophobic	Alkyl	4.89515

A:TYR140 - 10,13-Diethoxydibenzo(a,c)phenazine	Hydrophobic	Pi-Alkyl	5.37646
A:HIS468 - 10,13-Diethoxydibenzo(a,c)phenazine	Hydrophobic	Pi-Alkyl	4.88054
Diethoxydibenzo(a,c)phenazine-A:CYS470	Hydrophobic	Pi-Alkyl	5.46335

Enzyme inhibition plays an important role in fungal drug discovery and treatment, particularly through targeting lanosterol 14-alpha demethylase (CYP51), a key enzyme in the pathway of ergosterol biosynthesis of fungi. This enzyme converts lanosterol to ergosterol, an important component of cell membranes in fungi that influences membrane permeability and fluidity (Istiqomah *et al*., 2023; Korkut *et al*., 2017). Inhibiting CYP51 leads to the depletion of ergosterol and accumulation of lanosterol, resulting in impaired fungal cell growth and viability (Korkut et al., *2017)*.

Conclusion

From the outcome of this study, 10,13-Diethoxydibenzo(a,c)phenazine exhibited much significant inhibitory activity against lanosterol-14alpha demethylase, a very crucial enzyme in the fungi cell membrane. The antioxidant activity of the plant extract also indicated a potency to scavenge free radicals. As such, the plant presents a promising ability to be harnessed for the control of fungi infestation in stored grains.

References

Ajayi, O.A., Babatunde, O.T., Atanda, S.A., Jibrin, A.F., Salako, M.O., Odutola, S.B., Okparavero, F.N. & Otenaike, O.E (2024). Molecular docking of Cholesta-3,5-diene from *Megaphrynium macrostachyum* as Potent Inhibitory Agent against Fungal Enzyme, Lanosterol-14α-demethylase. *Proceedings of the 48th NIFST Conference*, Kano.

Ajayi, O.A., Oyeyipo, S., Ihum, T.A., Ariyo, O.D., Babatunde, O.T., Adediran, B.I., Ahmed, T. & Zubair A.O. (2025). Biochemical Constituent and Enzyme Inhibitory Activity of *Thaumatococcus daniellii* Methanolic Extract against Fungi Isolates of Maize. *Journal of Renewable Agricultural Technology Research* 8. http://doi.org/10.70382/sjratr.v8il.005

Bahar, L., Sarker, S.D. & Delazar, A. (2011). "Phytochemistry of the genus Phyllanthus,"in Phyllanthus Species Scientific Evaluation and Medicinal Applications, R. Kuttan and K.B. Harikumar, Eds., 119-138. Taylor and Francis Group CRC Press, London, UK.

Doumbia, M., Yoboue, K., Kra, K.D., Klimaszewski, J., Kwadjo, E.K., Douan, G.B. & Dagnogo, M. (2014). Testing of insecticidal extract from *Mitracarpus scaber* Zucc. (Rubiale: Rubiaceae)

against four stored food products insect pests in Ivory Coast. *International Journal of Entomological Research*, 02(02): 81-86.

Istiqomah, N., Fatikasari, S. & Hutuba, A.H. (2023). Kajian in Silico Daun Sungkai (Peronema canescens) dalam Menghambat Enzim lanosterol 14-α demethylase Jamur Candida albicans. *Indonesian Journal of Pharmaceutical Education* 3(1).

Junaid, A.S., Ruidong, F., Hira, N., Bamisope, S.B., Muhammad, H., Muhammad, I.G., Yiming, W., Yijuan, X & Xiaoyulong, C. (2023). *Front. Physiol*. 13 http://doi.org/10.3389/fphys.2022.1112278.

Korkut, B., Çevik, U.A., Özkay, Y. & Atlı, Ö. (2017). Design, Synthesis Molecular Docking Study and Antifungal Activity Evaluation of New Benzimidazole-Triazole Derivatives. *Proceedings*, 1(6).

Evaluation of Stress Tolerance and Antimicrobial Activity of *Lactobacillus plantarum* NRIC 0383 for Postharvest Biopreservation of Oil Seeds

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Abstract

Post-harvest microbial spoilage of oil seeds poses a significant challenge to food quality and storage stability. This study evaluated the stress tolerance and antimicrobial activity of *Lactobacillus plantarum* NRIC 0383 for potential application in post-harvest bio preservation. The strain was cultured in MRS broth, and its cell-free metabolites were tested against *Bacillus subtilis*, *Bacillus cereus*, and *Pseudomonas aeruginos*a using the agar well diffusion method. Stress tolerance was assessed under varying concentrations of bile (0.05–0.3%), NaCl (2–8%), pH (5.0–7.0), and temperature (25–45°C). The strain exhibited strong tolerance to bile (0.3%) and salt (6%) with OD_{600} values of 0.654 ± 0.15 and 0.761 ± 0.13, respectively. Optimal metabolite production occurred at 35°C and pH 6.5. The metabolites showed significant inhibitory activity against *B. subtilis* (15 ± 0.93 mm), *B. cereus* (13 ± 0.76 mm), and *P. aeruginosa* (14 ± 1.20 mm), with no inhibition observed in the control. These findings indicate that *L. plantarum* NRIC 0383 and its metabolites possess substantial potential as natural, eco-friendly bio preservatives for minimizing microbial spoilage and reducing post-harvest losses in oil seeds.

Keywords: Postharvest, oil seeds, spoilage bacteria, Lactic acid metabolites

Introduction

Post-harvest losses in oil seeds and grains continue to threaten food security and agricultural sustainability. These losses are largely due to microbial spoilage, particularly from fungi and bacteria that produce toxins, deteriorate food quality, and shorten shelf life (Mpeluza et al. 2023). Conventional preservation approaches such as chemical fumigation and synthetic preservatives have raised health and environmental concerns. Consequently, research has increasingly focused on natural preservation methods using beneficial microorganisms.

Lactic acid Bacteria, especially *Lactobacillus plantarum*, have gained attention for their probiotic potential and their ability to produce antimicrobial compounds, including bacteriocins, hydrogen peroxide, and organic acids. These metabolites inhibit the growth of spoilage and pathogenic microorganisms, including *Bacillus cereus*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*, which are commonly implicated in oil seed deterioration, making LAB suitable for application in post-harvest bio preservation. Moreover,

their tolerance to environmental stresses such as variations in temperature, salt, pH, and bile enhances their stability and survival in food systems (Garin-Murguialday et al. 2024).

Oil seeds such as groundnut, soybean, sesame, sunflower, and melon seeds are highly susceptible to microbial spoilage during storage, handling, and processing (Wajahat, 2023). While fungi are the main spoilage organisms, lipase-producing bacteria also contribute to deterioration, rancidity, and nutritional loss (Garin-Murguialday et al., 2024). Traditional measures such as proper drying, hermetic storage, and hygienic handling help minimize spoilage, but the use of eco-friendly bio preservatives like lactic acid bacteria (LAB) and their bacteriocins offers additional protection. LAB metabolites inhibit microbial growth by lowering pH, generating inhibitory compounds, and competing for nutrients (Mpeluza et al., 2023). Understanding LAB growth dynamics, stress tolerance, and metabolite production under varying conditions is essential for optimizing their application in reducing post harvest microbial losses (Wajahat, 2023). This study therefore evaluates the stress tolerance and antimicrobial efficacy of *Lactobacillus plantarum* NRIC 0383, highlighting its potential role in minimizing post-harvest losses of oil seeds through bio preservation.

Methodology

Microbial Strains and Culture Condition

Lactobacillus plantarum NRIC 0383 used in this study was obtained from the Culture Collection of the Microbiology Laboratory of the Nigerian Stored Products Research Institute (NSPRI) and maintained in de Man, Rogosa, and Sharpe (MRS) broth. The strain was incubated at 37°C for 24 hours and used for subsequent analyses. The test organisms (*Pseudomonas aeruginosa*, *Bacillus subtilis*, and *Bacillus cereus*) which are known to cause deterioration in stored oil seeds were also sourced from the same laboratory.

Stress Tolerance Assays

Tolerance of *L. plantarum* to bile and salt was assessed using MRS broth supplemented with 0.05–0.3% bile salt and 2–8% NaCl, respectively. Optical density (OD600 nm) readings were recorded at 4-hour intervals up to 60 hours. pH tolerance was determined in media adjusted to pH 5.0–7.0, while temperature tolerance was evaluated at 25°C, 30°C, 35°C, 40°C, and 45°C (Singhal et al., 2021).

Preparation of CFS and Determination of the Antimicrobial Activity of *L. plantarum*

Cell-free supernatant (CFS) of *Lactobacillus plantarum* was obtained by centrifuging a 20 mL culture grown in MRS broth (12 hours) at 10,000 rpm for 10 minutes to separate the bacterial cells from the supernatant. The resulting supernatant was filtered through a sterile 0.22 µm syringe filter. Neutralized cell-free supernatant (NCFS) was prepared by adjusting the pH of the CFS to neutrality and adding 1 mL of catalase,

following the method of Ihum et al. (2024). Activity of the resulting metabolite was evaluated against test organisms and zones of inhibition measured after incubation at 37°C for 24 hours (Ihum et al., 2024).

Statistical Analysis

All experiments were conducted in triplicate. Data were analyzed using two-way ANOVA, and mean separation was performed using Tukey's HSD test at $p < 0.05$.

Results and Discussion

Bile and Salt Tolerance

Lactobacillus plantarum NRIC 0383 demonstrated substantial tolerance to bile and salt stress. The strain maintained growth up to 0.3% bile salt and 6% NaCl concentration, with optical density (OD600) ranging between 0.654 ± 0.15 and 0.761 ± 0.13, respectively (Figure 1 and 2). These findings indicate its ability to survive harsh storage and processing environments, a prerequisite for potential application in food systems. Statistical analysis revealed that bile salt concentration had a significant effect on growth ($F = 9.508$; $p < 0.001$), consistent with previous reports on the resilience of *L. plantarum* under gastrointestinal and food processing stresses Singhal et al. (2021).

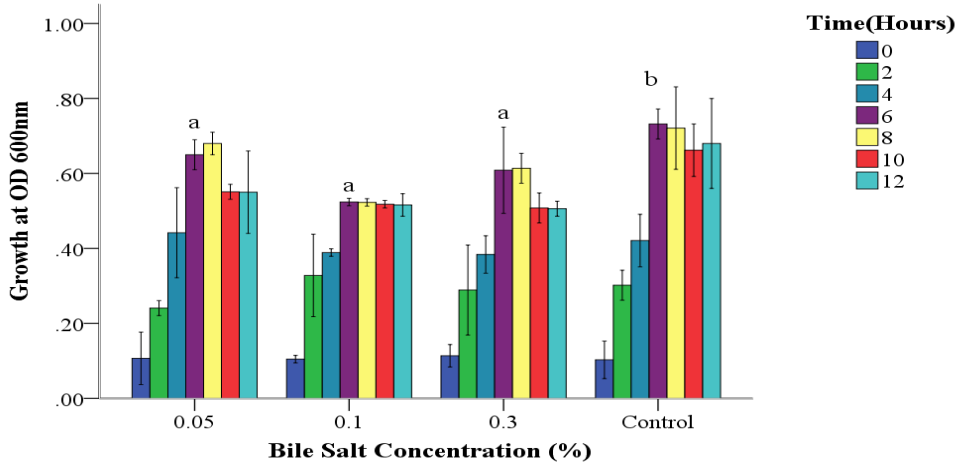


Figure 1: Effect of Different Bile Salt Concentrations on the Growth of *Lactobacillus plantarum*

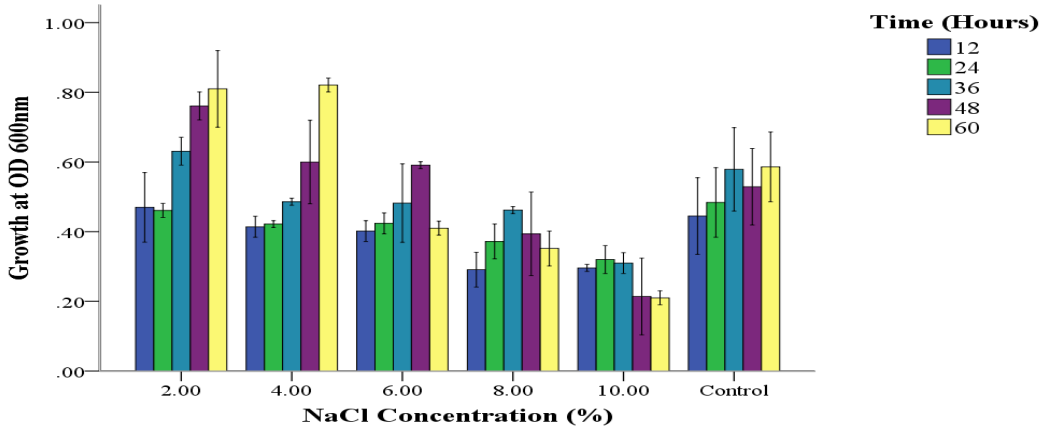


Figure 2: Effect of Different Salt Concentrations on the Growth of *Lactobacillus plantarum* NRIC 0383

Effect of Environmental Factors on Metabolite Production

Temperature and pH significantly influenced *L.plantarum* metabolite production ($F = 8845.429$; $p < 0.001$). Maximum production occurred at 35°C and pH 6.5, with reduced activity at higher or lower levels (Figure 3 and 4). These findings are in line with earlier studies by Singhal et al. (2021). Which reported optimal LAB metabolite production under similar conditions.

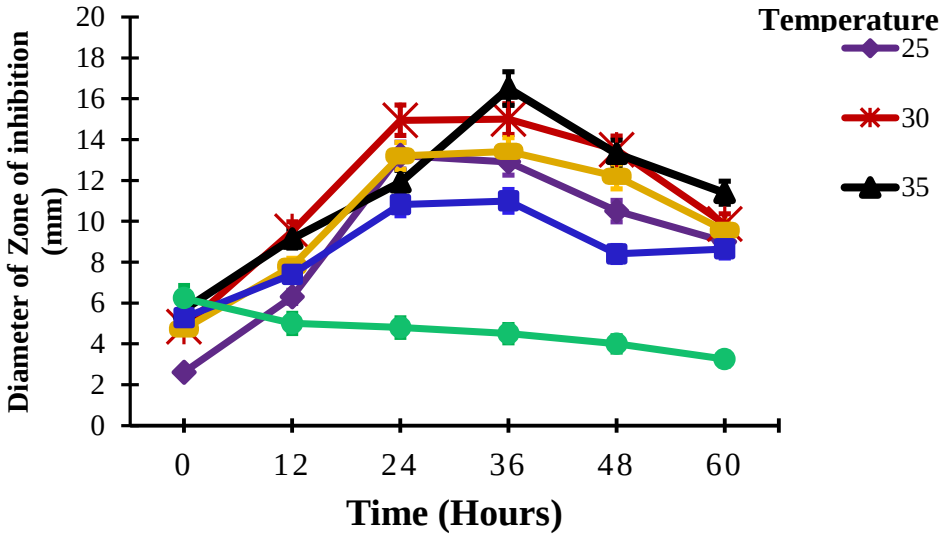


Figure 3: Effect of Different Temperatures on *L.plantarum* metabolite Production

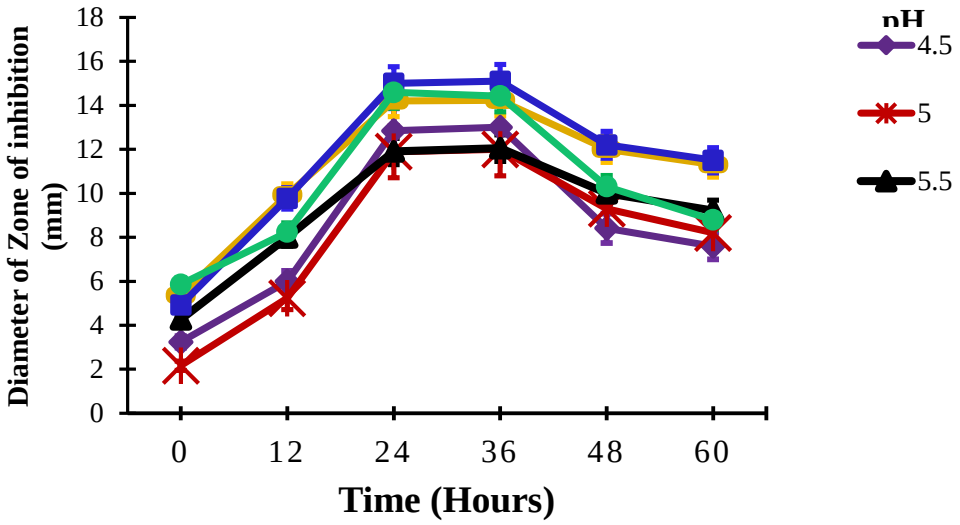


Figure 4: Effect of Different pH on *L.plantarum* metabolite Prodution

Inhibitory activity of *L.plantarum* metabolite against the test isolates

The inhibition zones ranged from 13 ± 0.76 mm to 15 ± 0.93 mm, indicating significant antimicrobial activity across both Gram-positive and Gram-negative bacteria ($p < 0.05$). No inhibition zones were observed in the control (sterile MRS broth), confirming that the antagonistic effect was solely due to the antimicrobial substances produced by *Lactobacillus plantarum* NRIC 0383 rather than the growth medium itself (Singhal et al., 2021). This finding supports the potential of *L. plantarum* as a natural biopreservative to mitigate microbial spoilage and maintain quality during postharvest storage (Rahman et al., 2025). Incorporating this LAB strain or its metabolites into postharvest systems such as seed coatings, hermetic storage bags, or inert-atmosphere silos could minimize microbial spoilage, extend shelf life, and enhance food safety. Its natural origin further aligns with the global shift toward sustainable, eco-friendly, and chemical-free postharvest preservation technologies (Singhal et al., 2021).

Table 1: Antimicrobial Spectrum of *L.plantarum* metabolite

L.plantarum(100 (µg /ml)	*Bacillus subtilis*	*Bacillus cereus*	*Pseudomonas aeruginosa*
	15 ± 0.93	13 ± 0.76	14 ± 1.2
Control	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Control: MRS broth; Values represent mean ± standard deviation (mm)

Conclusion

This study demonstrates that *L. plantarum* metabolites exhibits significant stress tolerance and bacteriocin-mediated antimicrobial activity against key spoilage bacteria. Optimal bacteriocin production was achieved at 35°C and pH 6.5, with enhanced activity in lactose-supplemented medium. The ability of this strain to thrive under stress and inhibit spoilage organisms highlights its potential as a natural biopreservative for postharvest loss reduction in oil seeds and other agricultural products. Future work should focus on incorporating this strain into real storage systems to assess its efficcy in maintaining product quality and safety over extended periods.

References

Garin-Murguialday, N., Espina, L., Virto, R., & Pagán, R. (2024). *Lactic acid bacteria and Bacillus subtilis as potential protective cultures for biopreservation in the food industry. Applied Sciences, 14*(10), 4016. https://doi.org/10.3390/app14104016

Ihum, T. A., Adediran, B. I., Jimoh, M. O., Adegbola, R. Q., Okunlade, A. F., & Udoh, J. (2024). Antibacterial Activity of Bacteriocin-Like Inhibitory Substance Produced by Lactic Acid Bacteria against Staphylococcus aureus and E. coli of Sesame Seeds. *FUOYE Journal of Pure and Applied Sciences (FJPAS)*, *9*(3), 160-174.

Mpeluza, A. S., Akinola, S. A., Shoko, T., Remize, F., & Sivakumar, D. (2023). *Efficacy of lactic acid bacteria as a biocontrol agent against anthracnose (Persea americana Miller) decay in avocado (Persea americana cv. Fuerte fruit). Agriculture, 13*(2), 269. https://doi.org/10.3390/agriculture13020269

Rahman, M. S., Soltani, S., LaPointe, G., Karboune, S., & Fliss, I. (2025). *Lactic acid bacteria: Beyond fermentation to bio-protection against fungal spoilage and mycotoxins in food systems. Frontiers in Microbiology, 16,* 1580670. https://doi.org/10.3389/fmicb.2025.1580670

Singhal, N., Singh, N. S., Mohanty, S., Kumar, M., & Virdi, J. S. (2021). Rhizospheric Lactobacillus plantarum (*Lactiplantibacillus plantarum)* strains exhibit bile salt hydrolysis, hypocholestrolemic and probiotic capabilities in vitro. *Scientific Reports*, *11*(1), 15288.

Wajahat, S. S. (2023). *Emerging trends and advancements in the biopreservation of fruits. Journal of Horticultural Research, 31*(1), 1–24. https://doi.org/10.2478/johr-2023-0006

Exploration of Fungal Diversity in the Rhizosphere of Maize (*Zea mays* L.) in Osun State, Nigeria

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Abstract

Maize is a major staple crop in Osun State, with significant contribution to food security. Maize rhizosphere hosts different microbes, with fungi species that are vital for plant development, soil conditions and nutrients' status. There are no or little information on the diversity and distribution of fungi associated with maize rhizosphere. This study therefore, investigated the diversity and distribution of fungi in the rhizosphere of maize in 15 towns of the State. Soil samples were collected randomly using standard microbiological procedures. Fungi species were isolated and identified at genus level using the morphological features and photomicrographs. Data were taken on colony counts for fungal distribution. The findings revealed a high fungal diversity across the State, with notable differences in species composition, abundance, and colony counts among the locations. *Aspergillus* spp. emerged as the dominant genus, detected in 14 out of the 15 towns and representing 79% of the total fungal community, thereby highlighting the potential risk of aflatoxin contamination in maize from these areas. In contrast, *Mortierella* sp. was detected only in a location where *Aspergillus* spp. was absent, suggesting distinct ecological niche. Other major fungal genera identified included *Rhizopus*, *Trichoderma*, *Penicillium*, *Purpureocillium*, and yeasts, each playing important roles in plant and soil health. This study underscores the need to monitor harmful fungi such as *Aspergillus* spp. while promoting beneficial groups like *Trichoderma* spp. to enhance soil quality. The baseline data generated serve as foundation for future research and development of microbial management strategies for sustainable agriculture and food safety.

Keywords: Fungal diversity, Maize rhizosphere, mycotoxin contamination

Introduction

Agricultural ecosystems are intricately linked to the microorganisms inhabiting the rhizosphere, the region surrounding plant roots. Fungi are crucial in influencing plant health, nutrient cycling, and overall soil ecology. Understanding the fungal communities associated with specific crops is fundamental for

sustainable agricultural practices. In the context of Osun State, Nigeria, a region renowned for its maize cultivation, the dynamics of fungal diversities in the maize rhizosphere remain a relatively unexplored area. Rhizosphere of maize plants, characterized by complex interactions between plant roots and soil microorganisms, serves as hotspot for microbial diversity (Zhang *et al*., 2024). To optimize maize cultivation, for targeted interventions that promote crop health and sustainable agricultural practices in Osun State, this study therefore aimed to identify different types of fungal species, present in the soil around maize roots; and to determine the distribution of fungal populations in the rhizosphere of maize fields in Osun State.

Materials and Methods

Osun State, nestled in the southwestern region of Nigeria, and lies on the latitude 7.5629° N and longitude 4.5200° E. The farms in which in which soil samples were collected are located in the following towns; Ikire, Apatere, Aragba Olupona, Osogbo, Ilesha, OAU farms Ile Ife, Aruwaja, Ada, Gbongan, Alapata Akanda, Opa Ile Ife, Ayedaade Ode Omu, Olupona, Irogbin, and Apara village. Soil samples were collected randomly using standard microbiological procedures (Singh, Gupta, & Sharma, 2020). The laboratory analysis was carried at the Pathology laboratory of IAR&T, Ibadan. Soil samples were serially diluted to isolate mycoflora. Streptomycin-supplemented sterilized Potato Dextrose Agar was used as growth medium, poured into plates, and the plates were incubated at 25°C for 5-7 days to allow fungal growth (Singh, Gupta, & Sharma, 2020).

Fungal species were identified at genus level using the morphological features and photomicrographs. Photomicrograph was carried out at the Soil Microbiology laboratory, Department of Soil Science and Land Resource Management, OAU, Osun State. Descriptive statistics, incidences in percentage were used to summarize the data. The percentage incidence was calculated thus:

$$\text{Mean colony count} = \frac{\text{Sum of colony count in all replicates}}{\text{No of replicates}}$$

$$\%\ \text{Incidence for colony count} = \frac{\text{Mean colony count}}{\text{Sum of mean colony count}} \times 100$$

Data collected were subjected to one-way analysis of variance (ANOVA) using the statistical Analysis system (SAS 2000). Means were separated using LSD at 0.05 level of probability.

Results and Discussion

Varying colony counts were observed in each location, indicating differences in the abundance and composition of fungi communities. The colony counts which serve as an indicator for the abundance of fungi within the rhizosphere, varied significantly across the 15 locations. Locations with higher colony

counts, such as Ikire OS14 and Apatere OS09 (Table 1), exhibited a rich and dense fungal community, suggesting a conducive environment for fungal proliferation.

The mean colony counts ranged from 50.50 in Ikire with sample code OS14 to 9.50 in Apara village with sample code OS17 (Table 1), highlighting the diversity in fungal population density within the maize rhizosphere at all locations. Factors such as soil moisture, organic matter content, pH, and the presence of plant exudates likely contributed to the thriving fungal populations in these areas (Oyedele et al., 2024). In contrast, locations with lower colony counts, such as Apara village OS17 and Olupona OS04 (Table 1), may have environmental or soil conditions less favourable for fungal growth.

Table 1: Mean Colony Count of Fungi Abundance in Maize Rhizosphere across Fifteen Locations in Osun State

Sample Location Name	Sample Location code	Mean Colony Count of Fungi
Ikire	OS14	50.50
Apatere	OS09	38.17
Aragba Olupona	OS11	33.00
Osogbo	OS20	32.17
Ilesha	OS06	26.50
OAU Ile ife	OS10	24.83
Aruwaji	OS05	19.83
Ada	OS19	19.83
Gbongan	OS13	14.83
Alapata akanda	OS12	14.83
Opa Ile Ife	OS03	14.50
Ayedaade	OS08	13.17
Olupona	OS07	11.83
Irogbin	OS04	11.33
Apara village	OS17	09.50
	LSD (0.05)	**11.219**

Source: this study

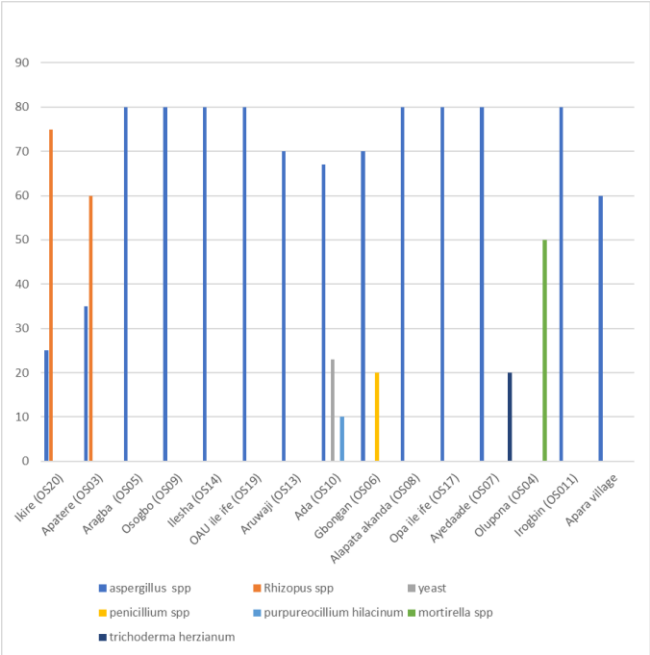
The implications of these lower colony counts could be as a result of reduced nutrient cycling efficiency, lower plant health, and diminished soil ecosystem services, ultimately leading to decreased agricultural productivity (Nyandi & Pepó, 2024). Differences in soil properties, climate, and agricultural practices across Osun State contribute to the observed diversity in fungal communities, which in turn affects maize health and productivity.

One of the most important findings of this study was the prevalence of *Aspergillus* spp. across almost all the sampled locations (Fig.1). *Aspergillus* spp was detected in 14 out of the 15 towns, with 8 of these

locations exhibited an all-time high incidence rate of this genus. The widespread presence of *Aspergillus* spp. suggests that it is a dominant component of the maize rhizosphere fungal community in Osun State. When compared to other fungi found in the study, *Aspergillus* spp. had the highest percentage incidence, constituting 79% of the total fungi discovered (Fig. 2). This high incidence is significant given that certain species within this genus, such as *Aspergillus flavus* and *Aspergillus niger,* are known to produce mycotoxins that can contaminate maize crops and pose serious health risks to consumers (Nyandi & Pepó, 2024).

Given the well-documented risks associated with *Aspergillus-produced* mycotoxins, particularly aflatoxins, the high incidence of this genus across multiple locations (Fig.3) highlights the need for targeted interventions to monitor and manage these fungal populations. The absence of *Aspergillus* spp in one location, replaced by *Mortierella* spp (4%), suggests that specific environmental factors or microbial interactions in the soil may inhibit the growth of *Aspergillus* sp., providing a potential area for further research to explore natural control mechanisms.

The identification of beneficial fungi such as *Trichoderma* (1.6%) and *Penicillium* (1%), in some locations indicate the presence of natural biocontrol agents that could help in managing soil-borne diseases and enhancing soil health (Kabir *et al*., 2024). The coexistence of multiple fungal species within the rhizosphere suggests that the maize plants in Osun State benefit from a complex and interactive microbial community that supports their growth and resilience (Charoen, Sun, & Xu, 2024).



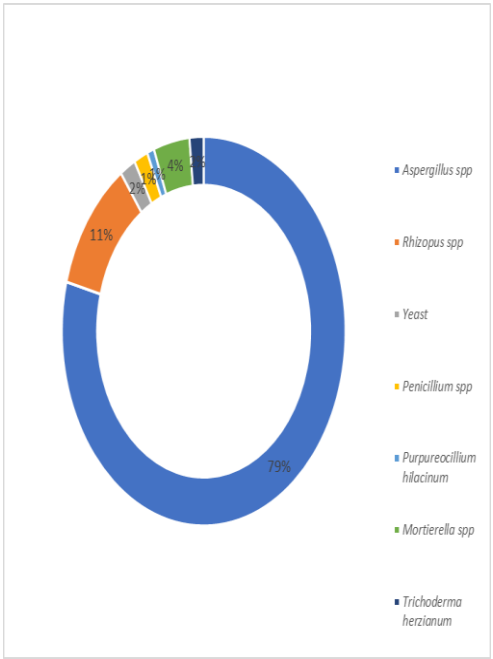


Fig.1: Percentage incidence of fungi diversity across fifteen towns in Osun State, Nigeria

Fig.2: Percentage incidence of fungi species found in all sampled soils at the locations

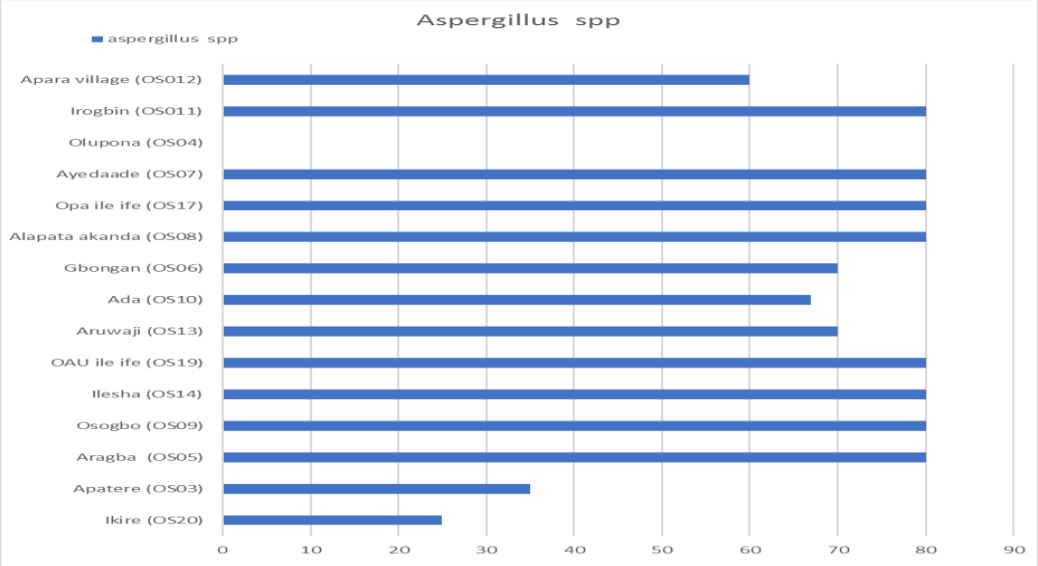


Fig.3. Percentage incidence of *Aspergillus* spp in each sample location

Source: From this study

Conclusion

Locations such as like Ikire and Apatere exhibited variation in colony counts, higher fungal densities due favorable environmental conditions for fungal growth. In contrast, towns such as Apara and Olupona had lower colony counts, likely due to less favorable soil conditions, such as lower fertility and higher compaction.

References

Charoen, S. J., Sun, Y., & Xu, Q. (2024). Maize–soybean rotation and intercropping increase maize yield by influencing the structure and function of rhizosphere soil fungal communities. *Microorganisms,* 12(8), 1620.

Kabir, Z., Sarker, R. H., Islam, M. M., Rahman, M., & Hossain, A. (2024). Trichoderma gets by with a little help from Streptomyces: fungal–bacterial symbiosis in plant growth promotion. *Journal of Experimental Botany*, 75 (22), 6893-7916.

Nyandi, M. S., & Pepó, P. (2024). Aspergillus and Fusarium mycotoxin contamination in maize (*Zea mays* L.): The interplay of nitrogen fertilization and hybrids selection. *Toxins*, 16 (7), 318.

Oyedele, A. O., Ezaka, E. & Taiwo, L. B. (2024). Microbial biosynthesis of the classical phytohormones by plant growth-promoting microorganisms in plants. In P.S. Chauhan, N. Bisht, & R. Agarwal (Eds.), *Microbial Biostimulants for plant growth and abiotic stress amelioration* (pp.345-366).

Singh, P., Gupta, A., & Sharma, R. (2020). Standard microbiological methods for isolation and characterization of soil microorganisms. *Methods in Microbiology*, 47, 25–45.

Zhang, C., Liu, Y., Wang, X., Li, L., Zhang, J., & Chen, Y. (2024). Nitrogen input differentially shapes the rhizosphere microbiome diversity and composition across diverse maize lines. *Biology and Fertility of Soils*, 60(4), 713–727.

Agroforestry as Friend and Foe of Forest Conservation: A Review

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Abstract

Agroforestry, the integration of trees and shrubs into agricultural landscapes, presents a complex relationship with forest conservation efforts. This paper explores the dichotomy of agroforestry as both a friend and foe to forest conservation, considering its various impacts on biodiversity, ecosystem services, and socioeconomic dynamics. On one hand, agroforestry systems can act as allies in forest conservation by promoting biodiversity, mitigating climate change, and enhancing ecosystem resilience. By stimulating natural forest ecosystems, agroforestry practices provide habitat for wildlife, protect soil health, and contribute to carbon sequestration. Furthermore, they offer economic incentives for farmers, thereby reducing pressure on natural forests for agricultural expansion. On the other hand, certain forms of agroforestry may pose challenges to forest conservation efforts. Intensive agroforestry systems, such as monoculture plantations or high-input agroforestry, can displace native forests, degrade soil quality, and reduce overall landscape diversity. By adopting a refined approach that integrates ecological, economic, and social considerations, stakeholders can harness the potential of agroforestry as a powerful tool for both sustainable agriculture and forest conservation. Moreover, the commercialization of agroforestry products may promote deforestation in regions where profit outweighs environmental concerns. While agroforestry holds promise as a sustainable land-use practice, its effectiveness in supporting forest conservation goals depends on careful planning, adaptive management, and holistic decision-making processes. Balancing the benefits and trade-offs of agroforestry systems is essential for realizing their full potential in promoting biodiversity conservation, mitigating climate change, and fostering resilient landscapes in a rapidly changing world.

Keywords: Agroforestry, conservation, foe, forest, friends

Introduction

Agroforestry, the intentional integration of trees and shrubs within agricultural landscapes, has garnered significant attention in recent years as an integrated strategy to sustainable land use (Raihan, 2023; Zhang et al., 2023; Hasan et al 2025). This practice represents a departure from conventional agricultural methods by recognizing the ecological benefits of incorporating woody perennials into agricultural systems. As the global population continues to rise and the demand for food, fiber, and fuel escalates,

agroforestry has emerged as a potential solution to address the dual challenges of food security and environmental sustainability (Nair, 2018). The relationship between agroforestry and forest conservation is complex and nuanced, with divergent perspectives on its impact. On one hand, proponents of agroforestry tout its potential to contribute positively to forest conservation efforts by enhancing biodiversity, restoring degraded landscapes, and providing alternative livelihoods for rural communities (Perfecto & Vandermeer, 2015).

By integrating trees into agricultural settings, agroforestry systems can mimic the structural complexity and ecological functions of natural forests, thereby supporting a wide array of plant and animal species (Schroth et al., 2016). Furthermore, agroforestry practices have been shown to improve soil fertility, regulate water flow, and mitigate climate change by sequestering carbon in biomass and soil organic matter (Jose, 2009, Hasan et al 2025). On the other hand, critics argue that certain forms of agroforestry may pose risks to forest conservation goals, particularly when implemented at scale or inappropriately designed. For example, monoculture plantations of fast-growing tree species, often promoted for their economic benefits, can displace native forests and lead to the loss of biodiversity and ecosystem services (Lamb et al., 2005). Additionally, the commercialization of agroforestry products such as palm oil, coffee, and cocoa may drive deforestation in regions where market demand promotes land conversion for agricultural purposes. (Kalischek et al, 2023).

This paper highlight some of the role of agroforestry in forest conservation, synthesizing existing literature to elucidate the complexities and trade-offs associated with this land-use practice. By analyzing case studies, empirical research, and theoretical frameworks, we seek to explore the extent to which agroforestry serves as both a friend and a foe to forest conservation objectives. Through a nuanced understanding of the ecological, economic, and social dimensions of agroforestry, we endeavor to inform policy and management decisions aimed at maximizing its potential contributions to sustainable development and biodiversity conservation. More so, some ecological benefits and socioeconomic implications of agroforestry, including its role in enhancing biodiversity, conserving soil and water resources, and mitigating climate change and its effects on livelihoods, land tenure, and market dynamics were highlighted. Finally, we will discuss key challenges and opportunities for integrating agroforestry into forest conservation strategies, highlighting the need for context-specific approaches that balance ecological integrity with socioeconomic viability.

Methodology

Secondary data was derived to get information from textbooks, journals, proceedings, guides bulletins and some national dallies.

Results and Discussion

Potentials of Agroforestry as a Friend to Forest Conservation

Agroforestry offers significant potential to contribute positively to sustainable land management and biodiversity conservation. Here are some of the potentials of agroforestry:

Habitat Creation and Connectivity: Agroforestry systems, when designed and managed thoughtfully, can serve as important habitat corridors and stepping stones, enhancing landscape connectivity and facilitating species movement between fragmented forest patches (Perfecto & Vandermeer, 2015). By providing diverse microhabitats within agricultural landscapes, agroforestry can support a wide range of plant and animal species, including those with specialized habitat requirements.

Ecosystem Services Provision: Agroforestry systems offer a suite of ecosystem services that benefit both agricultural production and environmental conservation. These services include soil fertility improvement, water regulation, erosion control, pollination support, and pest regulation (Schroth et al., 2016). By harnessing ecological processes and biological interactions, agroforestry can enhance ecosystem resilience and productivity while reducing reliance on external inputs.

Carbon Sequestration and Climate Change Mitigation: Trees and perennial vegetation in agroforestry systems play a crucial role in carbon sequestration, helping to mitigate climate change by capturing and storing atmospheric carbon dioxide (Jose, 2009). Agroforestry practices that prioritize the establishment of long-lived tree species and the maintenance of diverse vegetation cover can contribute to carbon sequestration at both the landscape and global scales.

Livelihood Diversification and Poverty Alleviation: Agroforestry provides opportunities for diversifying rural livelihoods and enhancing economic resilience, particularly in marginalized and resource-constrained regions (Nair, 2018). By integrating trees with crops or livestock, agroforestry systems offer multiple income streams, reducing vulnerability to market fluctuations and environmental shocks. Smallholder farmers and indigenous communities can benefit from increased food security, income generation, and improved access to ecosystem resources.

Cultural and Traditional Knowledge Preservation: Agroforestry practices often draw upon traditional knowledge systems and indigenous land management practices, fostering cultural continuity and preserving biodiversity-rich landscapes (Perfecto & Vandermeer, 2015). By integrating modern science with indigenous wisdom, agroforestry initiatives can promote cultural diversity, community empowerment, and participatory decision-making processes.

Restoration of Degraded Landscapes: Agroforestry holds promise as a tool for restoring degraded ecosystems and rehabilitating deforested or abandoned lands (Liu et al 2018). Through agroforestry-based reforestation efforts, degraded lands can be rehabilitated, enhancing biodiversity, soil fertility, and watershed functions while providing valuable ecosystem services to surrounding communities.

By adopting agroecological principles, integrating diverse tree species, and incorporating participatory approaches, agroforestry can play a vital role in fostering sustainable landscapes that balance agricultural production with environmental conservation goals.

Agroforestry as a Foe of Forest Conservation

While agroforestry holds promise as a friend to forest conservation, it also presents certain potential challenges and risks that could undermine conservation efforts. Understanding these drawbacks is crucial for implementing agroforestry practices in a manner that maximizes their positive impacts on both agricultural productivity and forest conservation. Several factors contribute to the potential of agroforestry as a foe of forest conservation:

Land Conversion and Habitat Loss: Agroforestry systems, particularly monoculture plantations or intensive agroforestry models, may require clearing of natural forests to establish tree crops or other agricultural components Liu et al., 2018. Environmetal Paper Network, 2022). This process can lead to habitat fragmentation and loss, disrupting ecosystems and threatening biodiversity conservation goals (Perfecto &Vandermeer, 2015).

Biodiversity Impacts: While agroforestry can enhance biodiversity compared to conventional agriculture, certain practices may still result in simplified or homogenized landscapes, reducing habitat diversity and species richness (Schroth et al., 2016). Monoculture plantations within agroforestry systems can also lead to the dominance of a few species, potentially displacing native flora and fauna (Kalischek et al 2023).

Soil and Water Degradation: Intensive agroforestry systems, particularly those involving high-input monocultures, may lead to soil erosion, nutrient depletion, and water pollution due to the heavy use of agro chemicals (Lamb D, 2011). These adverse effects can degrade ecosystem health and compromise the long-term sustainability of agroforestry landscape.

Market Pressures and Deforestation: The commercialization of agroforestry products, such as palm oil, soybeans, or rubber, can promote deforestation and land-use change in regions with valuable forest resources (Rice & Greenberg, 2000). Increased demand for these commodities may drive expansion into forested areas, exacerbating deforestation rates and undermining forest conservation efforts.

Social Conflicts and Land Tenure Issues: Agroforestry initiatives can sometimes exacerbate social conflicts over land tenure, resource access, and property rights, particularly in regions with complex land-use

histories and competing interests (Perfecto & Vandermeer, 2015). Displacement of indigenous communities or smallholder farmers from traditional lands can result in social unrest and undermine local support for conservation efforts.

Addressing these challenges requires a nuanced approach that considers the ecological, economic, and social dimensions of agroforestry. Strategies to mitigate the negative impacts of agroforestry on forest conservation include promoting agroecological practices, encouraging diversified agroforestry systems, implementing landscape-level planning and governance mechanisms, and supporting community-based natural resource management initiatives (Schroth et al., 2016).

By acknowledging the potential of agroforestry as a foe for forest conservation and adopting proactive measures to address these challenges, stakeholders can work towards harnessing the full potential of agroforestry as a sustainable land-use strategy that supports both agricultural productivity and biodiversity conservation goals.

Way Forward towards Achieving Agroforestry to a Friend to Forest Conservation

Certainly, here are strategies that highlight agroforestry's potential as both a friend to forest conservation:

Diversification of Agroforestry Systems: Implementing diverse agroforestry systems with a mix of tree species, crops, and livestock can enhance landscape heterogeneity and provide multiple benefits, including biodiversity conservation, soil fertility improvement, and climate resilience (Nair, 2018). By mimicking natural forest ecosystems, diversified agroforestry systems can support a wide range of plant and animal species while minimizing the risk of habitat simplification and species loss (Schroth et al., 2016).

Promotion of Agroecological Practices: Adopting agroecological principles, such as organic farming methods, integrated pest management, and agroforestry-based soil conservation techniques, can mitigate the negative environmental impacts of agroforestry and enhance its contributions to forest conservation (Perfecto & Vandermeer, 2015). Agroecological approaches prioritize ecological processes and biodiversity conservation while promoting sustainable agricultural production.

Community-Based Natural Resource Management: Engaging local communities in the planning, implementation, and monitoring of agroforestry initiatives can enhance social equity, promote resource stewardship, and build local capacity for sustainable land management (Schroth et al., 2016). Participatory approaches empower stakeholders to collectively address land-use conflicts, ensure equitable distribution of benefits, and promote social cohesion (Nair, 2018).

Integration of Traditional Ecological Knowledge: Incorporating indigenous knowledge systems and traditional land management practices into agroforestry planning and implementation can enrich

biodiversity conservation efforts and enhance the resilience of agroecosystems (Perfecto & Vandermeer, 2015). Indigenous communities possess valuable insights into local ecosystems, adaptive strategies, and culturally appropriate agroforestry techniques that can inform conservation interventions (Schroth et al., 2016).

Policy Support and Institutional Coordination: Establishing supportive policy frameworks, legal incentives, and institutional mechanisms for agroforestry development can create an enabling environment for sustainable land management and forest conservation (Nair, 2018). Policy interventions may include land-use zoning regulations, subsidies for agroforestry practices, extension services, and market incentives for environmentally friendly products (Garrity, et al., 2010)

Land-Use Planning and Regulation: Implementing land-use planning measures, such as zoning regulations and protected area designation, can help safeguard critical forest ecosystems from conversion to agroforestry or other land uses (Liu et al., 2018; Environmental Paper Network 2022). Strategic land-use planning ensures that agroforestry development occurs in areas with lower conservation value, minimizing conflicts between agricultural expansion and forest conservation goals.

Certification and Sustainable Production Standards: Establishing certification schemes and sustainable production standards for agroforestry products can promote environmentally responsible practices while promoting market access for sustainably produced goods (Kalischek et al 2023). Certification programs, such as the Forest Stewardship Council (FSC) for timber products or the Rainforest Alliance for agricultural commodities, set criteria for sustainable land management and biodiversity conservation.

Support for Smallholder Agroforestry: Providing technical assistance, financial support, and market access to smallholder farmers practicing agroforestry can enhance their livelihoods while reducing the pressure on natural forests for agricultural expansion (Perfecto & Vandermeer, 2015). Supportive policies and programs targeting small-scale agroforestry producers can help alleviate poverty, improve food security, and promote sustainable land management practices.

Monitoring and Adaptive Management: Implementing monitoring and evaluation systems to assess the environmental impacts of agroforestry and incorporating adaptive management strategies can enable continuous learning and improvement of agroforestry practices (Garrity et al 2010). Regular monitoring of biodiversity indicators, soil quality parameters, and ecosystem services provision can inform adaptive management decisions and guide interventions to mitigate negative impacts on forest conservation.

By adopting these strategies and approaches, stakeholders can harness the potential of agroforestry as a friend to forest conservation while mitigating its potential negative impacts on biodiversity, ecosystem integrity, and community well-being.

Conclusion

Agroforestry stands as both a friend and a potential foe for forest conservation, depending on its implementation and context. As a friend, agroforestry offers promising solutions by integrating trees with agricultural practices, promoting biodiversity, enhancing soil health, and providing sustainable livelihoods for communities. Its ability to mitigate climate change and restore degraded lands further underscores its positive impact on forest conservation efforts. However, agroforestry can also pose challenges to forest conservation when practiced unsustainable, leading to deforestation, habitat loss, and biodiversity decline. Poor land management practices, such as excessive tree cutting or monoculture planting, can undermine the ecological benefits of agroforestry and exacerbate environmental degradation. Therefore, the key lies in promoting sustainable agroforestry practices that prioritize ecological balance, community involvement, and long-term stewardship of natural resources. By adopting agroforestry systems that integrate diverse tree species, utilize agroecological principles, and empower local communities, we can harness its potential as a powerful ally in forest conservation efforts worldwide. Consequently, agroforestry holds immense promise as a friend to forest conservation when implemented thoughtfully and sustainably. By embracing its multifaceted benefits and addressing its challenges, we can leverage agroforestry to safeguard forests, promote resilience in ecosystems, and support the well-being of both people and the planet.

References

Aaron, W., Ranjitbir, S., Stephane, S., & colleagues. (2024). The ecological and socio-economic sustainability of organic agroforestry: A systematic review. Agroforestry Systems, 98, 2933–2949. https://doi.org/10.1007/s10457-024-01064-w

Environmental Paper Network. (2022, September 21). Statement: Monoculture tree plantations are not forests! Global Forest Coalition. https://globalforestcoalition.org/statement-monoculture-tree-plantations-are-not-forests/

Garrity, D. P., Akinnifesi, F. K., Ajayi, O. C., Weldesemayat, S. G., Mowo, J. G., Kalinganire, A., … Bayala, J. (2010). Evergreen agriculture: a robust approach to sustainable food security in Africa. Food Security, 2(3), 197–214. https://doi.org/10.1007/s12571-010-0070-7

Hasan, M. K., Roshni, N. A., & Akter, R. (2025). Estimating carbon stocks and woody perennials diversity in cropland agroforestry on three different land ecosystems in Bangladesh. Carbon Balance and Management, 20(3), 1–13. https://doi.org/10.1186/s13021-024-00288-8

Kalischek, N., Lang, S., Renier, C., Daudt, C., Addoah, T., Thompson, J., … Blaser-Hart, W. (2023). Cocoa plantations are associated with deforestation in Côte d'Ivoire and Ghana. Nature Food, 4, 507-516. https://doi.org/10.1038/s43016-023-00802-8

Lamb, D. (2011). Regreening the bare hills: Tropical forest restoration in the Asia-Pacific region. Dordrecht, Netherlands: Springer. https://doi.org/10.1007/978-94-007-2232-1

Liu, C. L. C., Kuchma, O., & Krutovsky, K. V. (2018). Mixed-species versus monocultures in plantation forestry: Development, benefits, ecosystem services, and perspectives for the future. Global Ecology and Conservation, 15, e00419. https://doi.org/10.1016/j.gecco.2018.e00419

Nair, P. K. R. (2018). Agroforestry: A blueprint for achieving the Sustainable Development Goals. Advances in Agroforestry,14,1-18.

Perfecto, I., & Vandermeer, J. (2015). Agroecology and the food system. Annual Review of Environment and Resources, 40, 30-52.

San, S. M., Kumar, N., Biber-Freudenberger, L., & Schmitt, C. B. (2023). Agroforestry-based community forestry as a large-scale strategy to reforest agricultural encroachment areas in Myanmar: Ambition vs. local reality. Annals of Forest Science, 80(27), 1–15. https://doi.org/10.1186/s13595-023-01191-x

Schroth, G., Barrios, E., & da Silva, E. V. (2016): Agroforestry and biodiversity conservation in tropical landscapes. Island Press.

Zhang, W., Su, K., Wang, Q., Yang, L., Sun, W., Ranjitkar, S., … El-Kassaby, Y. A. (2023). Agroforestry species selection for forest rehabilitation in the Asia-Pacific region: A meta-analysis on high-level taxonomy. Forests, 14(10), 2045. https://doi.org/10.3390/f14102045

Phytochemistry, Pharmacology, and Toxicological Insights of Underutilized Crops in South-East and South-South Nigeria

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Abstract

Underutilized crops in south-east and south-south Nigeria offer a rich source of phytochemicals with potential pharmacological benefits. This review explores the phytochemistry, pharmacology, and toxicological insights of selected underutilized crops in the region. Phytochemical analysis reveals the presence of bioactive compounds such as alkaloids, saponins, phenolics, flavonoids, and tannins. These compounds exhibit antioxidant, anti-inflammatory, antimicrobial, and antidiabetic properties, supporting their traditional medicinal uses. Toxicological assessments indicate minimal toxicity, with some crops showing no adverse effects. Further research is necessary to fully explore the therapeutic potential and ensure safe consumption of these underutilized crops. This review highlights the importance of integrating traditional knowledge with scientific validation to promote sustainable utilization and potential development of novel therapeutic agents. By exploring these underutilized crops, we can unlock new opportunities for food security, nutrition, and healthcare in Nigeria.

Keywords: Biodiversity, crops, potential, toxicology, underutilized

Introduction

Nigeria is richly endowed with a wide range of plant varieties. More than 5,000 plant species are available in the country. Some of these species are not fully exploited. Underutilized crops are those species which are generally underexploited but which have potential to contribute to food security, health, general income and environmental services. It has been estimated that the highest degree of endemism occurs in low land forests of the south eastern part which has 128 endemic species (Ogunwusi & Ibrahim, 2016). The utilization of some plant species at industrial level is presently constrained by inadequate development.

All over the world, indigenous and underutilized crops promote food security, enhance nutrition and income generation for the rural communities. However, while these crops continue to be valuable in the rural communities, they have not been adequately characterized. This lack of attention has made their potential value to remain unexplored (Agulanna, 2020). For many generations, traditional medicine has been used to prevent and treat many diseases across Nigeria. In many rural areas, it is the only form of

treatment that exists. This review aims to provide a comprehensive overview of the phytochemistry, pharmacology, and toxicological insights of selected underutilized crops in South-East and South-South Nigeria, exploring their potential therapeutic applications, safety considerations and opportunity for further research and development.

Pharmacological Activities of Selected Underutilized Crops in South-East and South-South Nigeria

The pharmacological activities of selected underutilized crops from South-East and South-South Nigeria are discussed below.

Antimicrobial and Antifungal Activities

Guava *(Psidium guajava,* ugwoba in Igbo) leaf exhibits antibacterial activity against food borne pathogens (Hemeg *et al*., 2020). According to Mehta *et al.* (2020), Mentha sp (Mint), Aloe vera and Eucalyptus sp showed high antibacterial and antifungal activities indicating that the extracts can be used to treat microbial infections.

Antioxidant and Anti-inflammatory Properties

Xylopia aethiopica (African pepper in English; uda in Igbo), *Gongronema latifolium* (utazi in Igbo) and *Monodora myristica* (ehuru in Igbo; erhe in Urhobo) used as spices were reported to have free radical scavenging activity. The antioxidant activity of Aidan fruit (Tetrapleura tetraptera; uhio in Igbo; uyayak in Ibibio) is capable of scavenging free radicals and reducing the risk of cancer and chronic diseases (Okechukwu-Ezike & Oly-Alawuba, 2020). The extracts of *Annona muricata* (Sour sop in English; ogbaka nti in Igbo) leaf was reported by Nwaehujor *et al*. (2020), to exhibit great antioxidant and anti-inflammatory activities *in-vitro*.

Antidiabetic and Antihypertensive Potentials

Pharmacological studies have demonstrated that *Psidium guajava* extracts possess antidiabetic and antihypertensive potentials (Ugbogu *et al*., 2022). Several crops were reported by Ayisha *et al*. (2023) to exhibit hypoglycemic and antihypertensive activities. They are; *Persea americana* (ube-beke in Igbo), *Sida acuta* (ogirishi in Igbo), *Azadirachta indica* (ogwu in Igbo), *Carica Papaya* (okworo in Igbo), *Ocimum gratissimum* (nchonwu in Igbo; ntong in Efik), *Parkia biglobosa* (origili in Igbo), *Vernonia amygdalina* (bitter leaf in English; onugbu in Igbo; etidot in Efik), *Moringa oleifera* (okwe oyibo in Igbo), *Momordica charantia* (alo-ose in Igbo), *Picralima nitida* (osi-igwe in Igbo), *Syzygium aromaticum* (osasagbogbo in Igbo), *Ipomoea hederacea* (akili in igbo), *Phragmanthera incana* (awure in Igbo), *Erythrina senegalensis* (echichi in Igbo), *Morinda lucida* (huka in Igbo), and *Calpurnia aurea* (odundu in Igbo), Some of these plants have been proved to be more effective with fewer side effects and cheaper than the conventional synthetic drugs.

Antimalarial Potentials of Underutilized Crops from South-East and South-South Nigeria

The increasing resistance of *Plasmodium falciparum* to antimalarial drugs coupled with the high cost of the available conventional drugs poses a serious risk to malaria control programs thus the need for investigation of traditional herbs as an alternative. Ugwuzor *et al*. (2021), in their research reported a dose dependent antimalarial efficacy of the bark extracts of *Diospyros mespiliformis* (onyekoji in Igbo) and *Ficus sycomorus* (ukwa oyibo in Igbo).

Phytochemical Profile of Underutilized Crops from South-South and South-East Nigeria

Phytochemical analysis of underutilized crops in South-East and South-South Nigeria has revealed the presence of various bioactive compounds. This includes Phenolic compounds such as flavonoids, phenolic acids, and tannins. Some underutilized crops, such as *Gongronema latifolium* (utazi in Igbo), contain alkaloids and saponins. Guava (*Psidium guajava*) leaves contain fatty acids, essential oils, terpenoids, phenolic compounds, carbohydrates, glycosides, alkaloids, saponins and sterols (Kareem & Kadhim, 2024).

Toxicological Insights

Underutilized crops offer several benefits but some may also contain toxic compounds or have potential toxicological effects. Some crops like *Abrus precatorius* seed contain a toxic substance known as abrin (Bhalla *et al*., 2015). *Annona muricata* seed also contain a toxic compound called annonacin. Saponins have health benefits however high concentrations can be toxic to humans and animals. It is necessary to develop processing methods that will eliminate the toxic compounds for effective utilization of the crops.

Challenges Limiting the Use of Underutilized Crops

Underutilized crops face several challenges that hinder their development and adoption. The major constraints include: limited knowledge about the nutritional and economic benefits of underutilized crops; poor storage, processing, and transportation facilities; limited market demand; vulnerability to climate change and variability; lack of standardized dosage; difficulties in integrating traditional knowledge with modern pharmacology; lack of supportive policies; limited research and development on underutilized crops. Addressing these challenges can help unlock the potential of underutilized crops, promoting food security, nutrition, and sustainable agriculture.

Conclusion

Underutilized crops in South-East and South-South Nigeria offer a wealth of phytochemical, pharmacological, and nutritional benefits. However, further research is needed to fully explore their potential and ensure safe consumption. There is need for further phytochemical analysis to identify and characterize bioactive compounds in underutilized crops. Toxicological assessment is needed to ensure safe consumption and minimize potential risks associated with underutilized crops. Exploring the potential

of underutilized crops would promote sustainable agriculture, improve food security, and enhance the livelihoods of local communities in South-East and South-South Nigeria.

References

Agulanna F. T. (2020). The Role of Indigenous and Underutilized Crops in the Enhancement of Health and Food Security in Nigeria. *African Journal of Biomedical Research*, 23, 305-312.

Ayisha, F. J., Sarala, A., Senthil, K. S. K., Bathrinarayanan, M., Dharshansarathy, R., Dhanashree, .M. R. & Dharani, E. (2023). A Comprehensive review on anti-hypertensive activity of some medicinal plants. *International Journal of Pharmaceutical Research and Applications,* 8(5), 605-610. www.ijprajournal.com.

Bhalla, A., Thirumalaikolundusubramanian, P., Fung, J., Cordero-Schmidt, G., Soghoian, S., Sikka, V. K., Dhindsa, H. S. & Singh, S. (2015). Chapter 6 - Native Medicines and Cardiovascular Toxicity. *Heart and Toxins*, Academic Press, 175-202, https://doi.org/10.1016/B978-0-12-416595-3.00006-2.

Hemeg, H. A., Moussa, M. I., Ibrahim, S., Dawoud, T. M., Alhaji, J. H., Mubarak, A. S., Kabli, S. A., Alsubki, R. A., Tawfik, A. M. & Marouf, S. A. (2020). Antimicrobial effect of different herbal plant extracts against different microbial population. *Saudi Journal of Biological Sciences*, 27(12), 3221–3227. doi: 10.1016/j.sjbs.2020.08.015.

Kareem, A. T. & Kadhim, E. J. (2024). *Psidium guajava*: A review on its pharmacological and phytochemical constituents. *Biomedical and Pharmacological Journal*, 17(2). DOI: https://dx.doi.org/10.13005/bpj/2924.

Mehta, R., Dhruv, S., Kaushik, V., Sen, K. K, Khan, N. S., Abhishek, A., Dixit, A. K. & Tripathi, V. N. (2020). A comparative study of antibacterial and antifungal activities of extracts from four indigenous plants. *Bioinformation*, 16(3), 267–273. doi: 10.6026/97320630016267.

Nwaehujor, I., Olatunji, G., Atolani, O. & Akande, S. (2020). Studies on *In-vitro* Anti-inflammatory and Antioxidant Potentials of Annona muricata Leaf Extracts. *Croatian Journal of Food Science and Technology,* 12(2), 177-183. DOI: 10.17508/CJFST.2020.12.2.05.

Ogunwusi, A. A. & Ibrahim, H. D. (2016). Industrial Potential of Underutilized Plants in Nigeria. *Journal of Natural Sciences Research*, 6(6), 20-28.

(Okechukwu-Ezike, N. & Oly-Alawuba, N. (2020). Assessment of the Phytochemical Contents and Antioxidant Activities of Some Herbs and Spices in South-Eastern Nigeria. *Research Journal of Food and Nutrition*, 4(3), 1-5.

Ugbogu, E. A., Emmanuel, O., Uche, M. E., Dike, E. D., Okoro, B. C., Ibe, C., Ude, V. C., Ekweogu, C. N., & Ugbogu, O. C. (2022). The ethnobotanical, phytochemistry and pharmacological activities

of *Psidium guajava* L. *Arabian Journal of Chemistry*, 15(5), 1-26. https://doi.org/10.1016/j.arabjc.2022.10.3759.

Ugwuzor, J. C., Adekunle, A. A., Suleiman, Y. M., Haruna, M., Aina, O. O. and Adewale, B. (2021). In-vivo therapeutic efficacy and phytochemical investigation of three commonly used plants for malaria treatment by the Hausa community in Kano, Nigeria. *Journal of Pharmacognosy and Phytochemistry*, 10(5), 111-117.

Advanced Farming and Postharvest Technologies: Key Challenges and Strategic Approaches for Sustainable Implementation

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Abstract

The global agricultural landscape is experiencing a profound transformation fueled by the emergence of advanced farming technologies designed to boost productivity, promote sustainability, and enhance resilience. Innovations such as precision agriculture, smart irrigation systems, autonomous equipment, and AI-driven crop monitoring are reshaping conventional farming methods. Despite their potential, the adoption of these technologies remains constrained particularly in developing regions due to high upfront costs, limited technical capacity, inadequate infrastructure, and gaps in policy support. This paper examines the evolving domain of advanced agricultural technologies, highlights the primary obstacles to their implementation, and outlines strategic pathways for sustainable integration. Key focus areas include investing in capacity building, tailoring solutions to local contexts, and establishing enabling policy frameworks. By effectively addressing these challenges, stakeholders can unlock the transformative potential of agri-tech to meet rising global food demands while safeguarding environmental sustainability.

Key words: Agriculture, Innovation, sustainability, plans and technical

Introduction

Agriculture plays a vital role in meeting the food requirements of a growing global population. However, its ability to sustain future food production is increasingly threatened by a range of environmental challenges. These include soil crusting and compaction, nutrient imbalances, salinization, alkalization, acidification, toxic buildup, desertification, and the impacts of climate change. As population growth and food demand intensify, they contribute significantly to the degradation of essential land and water resources (Spiertz, 2009). Nigeria's agricultural sector is both diverse and essential, accounting for roughly 23% of the nation's GDP and providing employment for over 70% of the workforce. The country's varied agro-ecological zones support a wide range of crops and livestock, positioning agriculture as a key driver of rural livelihoods and national food security. The majority of Nigerian farmers are smallholders who

primarily grow food for household consumption. Agricultural practices such as mixed cropping, manual cultivation, and the use of organic fertilizers are cost-effective and environmentally sustainable, yet they often yield limited output and face barriers to market integration. Globally, agriculture is under mounting pressure to satisfy the nutritional needs of a rapidly expanding population, expected to approach 10 billion by 2050. Meeting this demand will require a 60–70% increase in food production, achieved in ways that minimize environmental degradation and preserve vital natural resources. Traditional farming methods, though foundational, are often inefficient and unsustainable at scale. They contribute to deforestation, soil degradation, and greenhouse gas emissions. In response, global sustainability goals such as those outlined in the United Nations Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 13 (Climate Action) have emphasized the need for resilient, inclusive, and environmentally sound agricultural systems.

Advanced farming technologies

Advanced farming technologies encompass a range of modern tools, systems, and methodologies that leverage scientific principles, engineering innovations, and digital solutions to enhance agricultural productivity, efficiency, and sustainability. These technologies employ data analytics, automation, biotechnology, intelligent systems to optimize crop and livestock production while minimizing resource consumption and environmental impact. Integrating data-driven approaches, automated processes, and climate-resilient practices. These innovations aim to boost yields, improve resource management, and reduce ecological footprints. However, their implementation must be inclusive and contextually appropriate to ensure that smallholder farmers and marginalized communities are not excluded from the benefits of agricultural modernization.

Tools for Advanced farming technologies

Indoor vertical farming: Indoor vertical farming involves cultivating crops on vertically stacked layers within a fully enclosed and controlled environment. This innovative approach allows for higher food production using significantly less land. It operates independently of climate and weather conditions, lowers labor requirements, and consumes less water compared to conventional farming techniques.

Precision Livestock Farming (PLF): it refers to the continuous, automated, and real-time management of individual animals, focusing on their health, welfare, productivity, reproductive performance, and environmental impact. This technology empowers farmers to enhance output, improve animal well-being, reduce waste, and optimize operational efficiency. The adoption of PLF is driven by rising global demand for animal products, labor shortages in agriculture, limited land resources, and growing concerns about climate change and deforestation.

Precision Agriculture (PA): it, is the scientific approach to maximizing crop yields through the use of sensors and analytical tools. These technologies monitor and respond to spatial and temporal variability in crop conditions, enabling data-driven decisions that improve efficiency and sustainability in crop production.

Farm Management Software (FMS) Farm management encompasses the coordinated activities necessary to ensure efficient operations, optimal production, and profitability. This includes overseeing financial planning, marketing, production processes, human resource management, and risk mitigation. It serves as a centralized digital platform that streamlines and enhances these functions. It enables farmers to monitor crops and livestock, track expenditures, forecast agricultural trends, manage input usage such as fertilizers and pesticides, assess climate-related risks, and perform predictive maintenance.

Water Management Technology: it facilitates real-time monitoring of soil conditions to ensure precise and efficient water delivery across farm landscapes. These smart systems enhance irrigation accuracy, reduce water waste, contribute to increased crop yields and cost savings. Importantly, they offer a viable solution to the pressing issue of water scarcity, as agriculture currently consumes approximately 70% of global freshwater resources. However, widespread adoption faces challenges, particularly due to farmers' hesitancy to replace existing infrastructure.

Artificial Intelligence (AI), Machine Learning (ML), and Data Science: they are increasingly integral to modern agriculture, offering tools that enhance productivity, enable data-informed decision-making, reduce operational costs, and support sustainable farming practices. For instance, systems that analyze soil conditions can assess crop health, detect nutrient deficiencies, identify pests and diseases, and forecast yields. Despite their potential, the adoption of AI and ML in agriculture faces challenges such as high initial investment costs, prolonged integration timelines, and skepticism within the industry. Nevertheless, global spending on agricultural AI is expected to rise from $1.7 billion in 2023 to $4.7 billion by 2028.

Regenerative Agriculture: it is rooted in Indigenous farming traditions; regenerative agriculture adopts a holistic approach to food production that emphasizes conservation and ecological restoration. Its primary goals include revitalizing soil health, addressing food system inequities, and ensuring environmental sustainability for future generations. Industrial-scale farming has significantly impacted the environment, with soil erosion occurring at rates 10 to 100 times faster than natural soil formation.

Challenges to implementation of advanced farming technologies

The integration of advanced agricultural technologies is essential for transforming farming practices, particularly in developing regions. However, addressing these constraints is critical to unlocking the full potential of agri-tech:

Financial Constraints: Smallholder farmers, particularly in developing nations, often face significant financial barriers when considering the adoption of advanced agricultural technologies. Despite gradual reductions in cost, the initial investment remains substantial and frequently restricts access to wealthier farming operations. This economic hurdle continues to limit widespread implementation.

Limited Education and Training: Successful integration of modern technologies into farming practices requires adequate knowledge and technical skills. However, many farmers especially those in rural communities lack access to educational resources and training programs that would enable them to effectively utilize these innovations.

Infrastructure and Accessibility: The absence of reliable infrastructure, including internet connectivity and electricity, poses a major obstacle to deploying technologies such as precision agriculture and smart farming systems. This challenge is particularly acute in remote regions where such resources are scarce or inconsistent.

Technological Complexity: Advanced agricultural systems often involve intricate technologies that demand specialized expertise for operation and maintenance. This complexity can discourage adoption, especially among farmers who feel overwhelmed or unsupported in navigating these tools.

Resistance to Change: Some farmers remain skeptical about the effectiveness of new technologies, preferring traditional methods that are familiar and trusted. This resistance may stem from limited awareness of the benefits or doubts about the relevance of these innovations in specific local contexts.

Strategic approach for sustainable implementation

Policy and Institutional Support: Policymakers can promote sustainable agricultural practices by offering financial incentives, subsidies, and tax relief, thereby encouraging farmers to adopt methods that improve soil health, enhance biodiversity, and strengthen ecosystem resilience (De Schutter, 2010) Complementary to these incentives, robust regulatory frameworks are essential to ensure compliance with standards governing pesticide application, water use, and soil conservation, helping to mitigate environmental degradation (Torhonen et al., 2019)

Agricultural research and extension services: it empowers farmers with the knowledge and tools needed to adapt to evolving environmental conditions and improve productivity in a sustainable manner. Education and capacity-building initiatives further equip farmers with the skills required to implement

sustainable practices effectively, fostering a broad transition toward resilient and environmentally sound farming systems (Lipper et al., 2014).

Innovation and technology development: This is critical to overcoming existing challenges and unlocking the full potential of sustainable agriculture (Tilman et al., 2011). Climate-smart approaches such as drought-resistant crop varieties, predictive weather models, and agroforestry systems to enhance resilience and adaptability to climate change (Lipper et al., 2014). Emerging techniques like vertical farming and controlled environment agriculture (CEA) utilize hydroponics, aeroponics, and LED lighting to grow crops indoors, conserving land, water, and energy while supplying fresh produce to urban populations (Graamans et al., 2018).

Digital agriculture: It is characterized by the integration of AI, data analytics, and smart technologies, is transforming farm management by providing real-time insights into crop health and soil conditions, enabling data-driven decisions for optimized resource use.

Biotechnological advancements: Genetic engineering and genome editing, contribute to the development of crop varieties with enhanced pest resistance and drought tolerance, thereby boosting yields and reducing dependence on chemical inputs (Kumar et al., 2018).

Capacity building and trainings: It remains a cornerstone of sustainable agriculture, by educating farmers, extension agents, and stakeholders through training and outreach programs, it ensures the long-term viability of sustainable practices. This knowledge base supports the adoption of techniques that improve soil health, biodiversity, and ecosystem resilience (Jose, 2009).

Conclusion

Sustainable implementation of advanced farming technologies requires more than innovations; it demands inclusive planning, education, and collaboration. By aligning technological advancement with local needs and long-term goals, agriculture can become more productive, resilient, and equitable.

References

Graamans L, Kromdijk J, Van Den Boogaard R, De Visser PH, Van Kooten O. and Van Den Dobbelsteen A. (2018): Opportunities for Improving Urban Food Supply: The Role of Controlled Environment Agriculture. Environmental Research Letters. 13 (6):063001.

Jose S. (2009): Agroforestry for Ecosystem Services and Environmental Benefits: An Overview. Agroforestry Systems.;76 (1):1-10.

Kumar A, Verma JP, Singh SK. Review: Application of omics technologies in sustainable agriculture. International Journal of Life Sciences. 2018; 6(2):251-260.

Lipper L, Thornton P, Campbell BM, Baedeker T, Braimoh A. and Bwalya M, (2014). Climate-smart agriculture for food security. Nature Climate Change;4 (12):1068-1072.

Spiertz J.H.J. (2009): Nitrogen, sustainable agriculture and food security: a review. Sustainable Agriculture. ; 635-651

Tilman D, Balzer C, Hill J. and Befort BL. (2011) Global Food Demand and the Sustainable Intensification of Agriculture. Proceedings of the National Academy of Sciences.; 108(50):20260-20264.

Torhonen MP, Prettitore PS, Scheierling SM, Hilhorst T, Roquet V and Zakout W. (2019): Enabling the business of agriculture 2019. World Bank Group.

Green Synthesis of Zinc Oxide Nanoparticles from Sweet Potato Peel (*Ipomea Batata*) Extract and Antifungal Application

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Abstract

The aim of this research is to develop a sustainable and environmentally friendly approach for the green synthesis of ZnO NPs, overcoming the limitations of non-biological methods using sweet potato peel extract as the capping agent. The sweet potato peel extract (SPP) proved to be an effective reducing and stabilizing agent for the synthesis of ZnO NP, also promoting waste valorization. This research is novel because this is the first time SPP-synthesized ZnO NPs is used as an antifungal against sweet potato pathogens. In this study, fungal isolates were isolated from spoilt sweet potatoes using serial dilution techniques. Green synthesis of ZnO NPs was carried out and evaluated for antifungal activity towards sweet potato pathogens. The synthesized ZnO NPs were characterized using UV-vis spectrophotometer. Plate assay method was used to compare the antifungal activity of ZnO NPs against Ag NPs and a conventional antibiotic.A total of four pathogens were isolated: Aspergillus, Mucor, Penicillium, and Rhizopus genera. UV-visible spectrum of the ZnO NPs synthesized displayed clear peak at 360.0 nm in tandem with results from previous research. ZnO NPs exhibited higher inhibitory effects against isolated fungal pathogen (Aspergillus sp.) compared to Ag NPs and standard antibiotic when compared at two different concentrations of 0.1 and 0.4 mls. These findings indicate that the biosynthesized nanoparticles could serve as an eco-friendly alternative for controlling fungal infections. This study recommends that further research exploring the utilization of other waste biomass sources for the biosynthesis of nanoparticles contributing to sustainable nanomaterial synthesis.

Keywords: Antifungal, Green Synthesis, Nanoparticles, Sweet Potato Peel and Bioeconomy

Introduction

The synthesis of nanoparticles using environmentally friendly methods has gained considerable attention in recent years due to growing concerns about the ecological impact of conventional synthesis techniques. Green synthesis of nanoparticles using plant-based materials has gained attention due to environmental concerns. It offers cost-effective and non-toxic alternatives to conventional methods (Srivastava et al.,

2022). Natural extracts contain bioactive compounds that can facilitate nanoparticle growth and reduce metal ions (Deng et al., 2018).

Sweet potato peel extract, rich in bioactive components, shows promise for green synthesis. Genetic algorithms enhance control over synthesis parameters, allowing customization of nanoparticle properties (Gupta *et al*., 2019). In recent years, the utilization of natural extracts derived from plants as reducing and stabilizing agents for nanoparticle synthesis has gained significant attention. Sweet potato peel extract has been found to possess abundant bioactive components with strong reducing potential, making it a suitable candidate for green synthesis. (Gupta et al., 2019). Conventional methods of synthesizing zinc oxide nanoparticles (ZnONPs) using hazardous chemicals are environmentally harmful and unsustainable. This study aims to develop an alternative, environmentally friendly, cost-effective, and scalable method for ZnONP synthesis. By promoting waste valorization and precise control over nanoparticle properties, the study addresses the need for greener and more efficient approaches. The goal is to minimize the negative impact on human health and the environment while offering a sustainable solution for ZnO NP production.

Methodology

Preparation of Sweet Potato Peel Extract

Sweet potatoes peel extract was prepared according to (Ramesh et al., 2022). The supernatant was then decanted and filtered using filter paper and then stored in a refrigerator at 4^{o}c for further studies and analysis.

Proximate Analysis

Determination of moisture content and dry matter, total ash, fat, reducing sugars and, total carbohydrate and starch, was determined according to Ojewummi et al. (2018).

Phytochemical Analysis

The phytochemical composition and biological activities of the extract was determined according to Hodoșan *et al*., 2025

Synthesis of Zinc Oxide Nanoparticles (ZnONPs)

About 7.4g of the salt was dissolved in 100ml distilled water. Then a total of 5ml aqueous extract of the potato peels extract was mixed with 50ml of 0.1M Zn $(NO_3)_2$, according to Karu et al. (2020).

Characterization of Zinc Oxide Nanoparticles

The synthesized ZnO NPs was characterized using analytical techniques to assess their physicochemical properties, UV-vis spectroscopy (Prakash et al., 2021).

Antifungal Activities of Zinc oxide using Sweet Potato Extracts

Fungal pathogens were isolated and cultured in Potatoes dextrose Agar (PDA) media. The synthesized ZnO NPs and Ag NPs were prepared in different concentrations. Agar well diffusion method was employed to assess the antifungal activity. Four wells was bored andeach wells was loaded with 20µl of control, 0.5g ZnO nanoparticles, 1.0g ZnO nanoparticles and an antibiotic. The plates were incubated at 37ºC for 24 hours. After incubation, the zone of inhibition was measured (Dhayalan and Denison, 2020).

Determination of Proximate Composition and Phytochemical properties of Sweet Potato (Ipomea batata) Peel Extract

Proximate analysis of the sweet potato samples (Table 4.1a&b) revealed a characteristic nutritional profile. The dry matter content of 90.22% indicates minimal water presence, which is favorable for extract preparation and storage stability. These values align with previous reports on sweet potato varieties, though compositional variations exist across cultivars and geographical origins as documented in ethnobotanical studies of diverse plant species (Zulkifli et al. 2021). We establish the nutritional context of our study and emphasize the importance of understanding the composition of the sweet potato samples used in the biosynthesis process. The study by Awol (2018) examined sweet potato leaves and reported a tannin concentration of 4.9 mg/100 g. These findings suggest that sweet potato leaves may contain higher tannin levels compared to sweet potato powder.

Table 4.1a: Proximate Analysis of Sweet Potato (*Ipomea Batata*) Peel Extract

Sample	Moisture Content (%)	Ash Content (%)	Fibre Content (%)	Lipids Content (%)	Protein Content (%)	CHO%	Dry matter
Sweet potato powder	9.78166	5.03388	7.4162	0.88	5.61392	71.27434	90.21834

Table 4.1b: Phytochemical Analysis

Samples	Phenol Mg/l	Tannin Mg/l	Flavonoids Mg/l	Saponin Mg/l	Alkaloids Mg/l	Terpenoids Mg/l	Steroid Mg/l
Sweet potato powder	0.64269	3.682735	10.19391	0.120482	3.009141	3.156627	6.707317

Biosynthesis and Characterization of ZnONPs

The Spectroscopy result which was represented in (Figure 3.1), provide valuable insights into the absorption characteristics of nanoparticles. The measurement mode employed was absorption, and the range measured spanned from 250.00 nm to 700.00 nm.

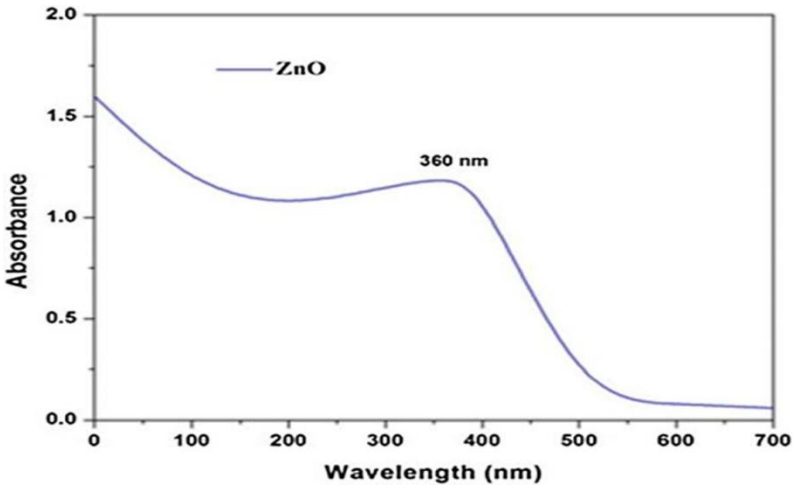


Figure 3.1: Spectroscopy Measurement of Zinc oxide Nanoparticles

Antifungal Activity of Zinc Oxide Nanoparticles (Zno Nps)

Both zinc oxide (ZnO) and silver (Ag) nanoparticles demonstrated concentration-dependent antifungal activity against the test fungus (Table 3.4). At 0.1 ml, ZnO NPs showed high inhibition (++) while Ag NPs exhibited moderate activity (+). At 0.4 ml, both nanoparticles achieved high inhibition (++), with AgNPs reaching maximum effectiveness at this concentration. ZnO NPs displayed stronger antifungal potential overall, showing comparable activity to the standard antibiotic cefuroxime at both concentrations. Ag NPs demonstrated lower activity than cefuroxime at 0.1 ml but surpassed it at 0.4 ml, indicating dose-dependent enhancement. These findings align with previous studies reporting significant antifungal properties of green-synthesized silver nanoparticles and metal oxide nanoparticles including ZnO. Significant to these findings, are previous work by Mallmann et al. (2018) and Khafri et al. (2018)

Conclusion

This study successfully demonstrated the biosynthesis of zinc oxide nanoparticles (ZnO NPs) using sweet potato peel extract as an effective reducing and stabilizing agent. Phytochemical analysis revealed bioactive compounds that facilitated nanoparticle synthesis and stabilization. The synthesized ZnO NPs

exhibited promising physicochemical properties and demonstrated significant antifungal activity against isolated fungal pathogens, with superior inhibitory effects compared to silver nanoparticles. These findings indicate potential applications in medicine, agriculture, and environmental remediation.

Table 4.4: Antifungal activities of ZnNPS, AgNPs and CEFUROXIME

Zone of inhibition measurements (mm)

Concentration (ml)	Zinc Nanoparticle (ZnNps)	Silver Nanoparticles (Ag NPs)	Cefuroxime
0.1	++	+	+
0.4	++	++	+

Keys: + (high zone observed), ++ (Highest zone observed)

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The authors gratefully acknowledge the support of Summit University, Department of Biological Science for providing laboratory facilities and technical assistance throughout the course of this research.

References

Awol, A. (2018). Phytochemical Screening, Proximate and Mineral Composition of Sweet Potato Leaves Grown in Tepi Provision, South-west of Ethiopia. Science, Technology and Arts Research Journal, 3(3), 112–112. https://doi.org/10.4314/star.v3i3.19

Deng,G.-F., Xu, X.-R., Zhang, Y.; Li, D., Gan, R.-Y., and Li, H.-B (2018). Phenolic Compounds and Bioactivities of Pigmented Rice. Crit. Rev. Food Science. Nutrition . 53, 296–306.

Gupta, A., Mumtaz, S., Li, C.-H., Hussain, I., and Rotello, V.M., (2019). Combatting antibiotic-resistant bacteria using nanomaterials. Chem. Soc. Rev., 48, 415–427.

Hodoșan, C., Gîrd, C. E., Marin, Ș.-C., Mihalache, A., Luță, E.-A., Ioniță, E.-I., Biță, A., Gheorghe, Ș., Feodorov, L., Popovici, V., Pogurschi, E., Nistor, L., Bărbuică, I. S., and Popa, L. (2025). Phytochemical Composition and Antioxidant Activity of Traditional Plant Extracts with Biocidal Effects and Soil-Enhancing Potential. Antioxidants, 14(10), 1198. https://doi.org/10.3390/antiox14101198

Khafri Hossein, Z., Mehrorang, G., Arash, A., Hamedreza, J., and Mohammad, S. (2018). Synthesis of CuS and ZnO/$Zn(OH)_2$ nanoparticles and their evaluation for in vitro antibacterial and antifungal activities. Applied Organometallic Chemistry, 32(7). https://doi.org/10.1002/aoc.4398

Mallmann, E. J. J., Cunha, F. A., Castro, B. N. M. F., Maciel, A. M., Menezes, E. A., and Fechine, P. B. A. (2018). Antifungal activity of silver nanoparticles obtained by green synthesis. Revista Do Instituto de Medicina Tropical de Sao Paulo, 57(2), 165–167. https://doi.org/10.1590/s0036-46652015000200011

Srivastava, S.; Bhargava, A. Tools and Techniques Used in Nanobiotechnology (2022). In Green Nanoparticles: The Future of Nanobiotechnology; Springer: Singapore, pp. 29–55.

Zulkifli, N. A., Nor, M. Z. M., Omar, F. N., Sulaiman, A., and Mokhtar, M. N. (2021). Proximate composition of Malaysian local sweet potatoes. Food Research, 5, 73–79. https://doi.org/10.26656/fr.2017.5(s1).045

Bioprospecting Soil Microbiome for Potential Xylanase Producing Fungi and Biotechnology Application

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Abstract

The increasing industrial demand for eco-friendly and efficient biocatalysts has prompted the exploration of xylanase enzymes, which hydrolyze xylan into fermentable sugars. Xylanases have broad applications in industries. Despite global research advances, Nigeria's indigenous microbial resources remain underexplored. This study addresses this gap by investigating xylanase-producing fungi from soil within and around Summit University, Offa, Nigeria. The study aimed to isolate, screen, and characterize fungi capable of producing xylanase enzymes using agrowaste as a substrate. Soil samples were aseptically collected from diverse sites including farms, riverbanks, oil-polluted, and dumpsite areas within and around Summit University. The samples underwent serial dilution and were cultured on Potato Dextrose Agar (PDA) plates. Morphological and microscopic analyses were employed for fungal identification. The isolates were screened qualitatively for xylanase activity using xylan agar stained with Congo red, with the formation of hydrolysis zones serving as indicators of enzyme production.Six distinct fungal isolates were obtained, with one isolate, *Aspergillus niger*, demonstrating superior xylanolytic activity. This isolate produced prominent clear zones on xylan agar plates, signifying potent enzymatic activity. Moreover, the use of local agro- industrial residues such as rice bran, palm kernel shell, and shea butter shell successfully induced xylanase production, highlighting the cost-effectiveness and sustainability of substrate selection. The findings suggest that indigenous microbial strains can serve as viable alternatives to commercial enzyme sources. This research contributes to the growing body of knowledge on microbial biodiversity in Nigeria and advocates for the development of localized, sustainable enzyme production systems using native fungal resources.

Keywords: Agro-Waste, Enzymes, Fungi, Xylanase, Sustainability

Introduction

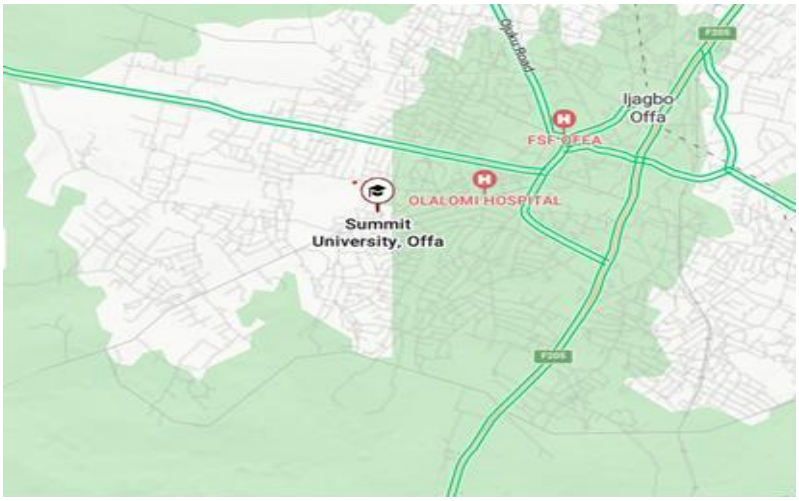
Xylanases are hydrolytic enzymes that degrade xylan (a major component of plant hemicellulose) into fermentable sugars. These enzymes play a crucial role in converting lignocellulosic biomass "abundant in agricultural waste" into value-added products like biofuels, paper, and food additives (Kumar *et al*., 2023). The versatility of xylanases in industrial applications, including pulp bleaching, animal feed processing, and

textile manufacturing, food and feed additives has sparked research to discover novel microorganisms that produce xylanase with enhanced activity and stability (Bhardwaj *et al*., 2023). Xylanase-producing microorganisms from natural (often harsh) environments are especially valued for yielding enzymes that are thermostable and alkali-tolerant, which meet industrial requirements (Singhania *et al*., 2021; Liu *et al*., 2022). Microbes like bacteria, fungi, and actinomycetes are prolific xylanase producers. The study addresses the need for greener and more efficient approaches. The goal is to minimize the use of synthetic xylan, reducing overhead production cost, while offering a sustainable solution.

Materials and Methods

Sampling Site Description and Collection of Samples

Soil samples were collected from diverse locations on the campus of Summit University Offa, Kwara state,



Nigeria located at latitude 8.14911 and longitude 4.72074. Farm area (sample A), oil polluted area (sample B), river side (sample C), dump site (sample D). Samples were taken 10-20 cm below the soil surface using sterile hand shovels and stored in a sterile, universal container. Afterwards, they were taken to the laboratory for further analysis.

Isolation and Identification of Organisms

Serial dilution method was used for the cultivation of soil samples according to (Adebayo, 2012). Potato Dextrose Agar (PDA) was prepared according to manufacturer's instructions. Dilutions factors 10^4 and 10^7 were plated out in triplicate at room temperature for 5 days. Subculturing was carried out to obtain pure isolates, which were identified morphologically, and macroscopically.

Qualitative/Plate Xylanase Assay

The ability of the fungus to metabolize agrowaste to produce xylanase was studied by culturing on a minimal salt agar composed of (g/l); corncob; rice bran, palm kernel shell, and shea butter shell; 20, $NaNO_3$;1.4; KH_2PO_4;1.8,$MgSO_4$;2,NH_4Cl; 2,$CaCO_3$;1.2 and agar;20 (Elegbede and Lateef, 2018). Three wells with 6 mm diameter size were bored on the prepared agar medium and 0.1 of the 24 hours old inoculum was aseptically inoculated into two of the wells while the un-inoculated third was kept as control. The plate was incubated at room temperature for 72 hrs, then stained with aqueous Congo red (0.1%) for 1 h, and destained with 1M NaCl for 15 min (Sridevi and Charya, 2011). A clear zone of hydrolysis taken as a degree of qualitative xylanolytic activity of the fungus was observed.

Results

Quantitative analysis of fungi isolate from different locations

Six pure isolates of different strains of fungal were obtained on PDA plates after inoculating at a room temperature for 5-7 days. Table 3.1: presents the fungi isolates that were isolated from different sites.

Table 3.1 Fungi isolates from Different Sites

S/N	Selected sites	Site symbol	Number of isolates
1.	Farm area 1	F1	5
2.	Oil polluted area 1	O1	10
3.	oil polluted area 2	O2	TMTC
4.	Dumpsite	D1	20
5.	River area 2	R2	7

Isolation and Identification of Organisms

Table 3.2 Morphological Characterization of Fungal Isolates

Samples code	Colon morphology	Reverse colour
$F/10^{-4}/B$	Compact, irregular shape, light ash in color Texture-flat cotton	Deep green
$O/10^{-5}B$	Spread colony, circular in shape. Texture-flat cotton	Brown middle and lighter brown edge
$O/10/^{-4}/A$	Irregular colony shape, black color. Texture-woolly growth	Lighter brown, multiple colony
$R/10^{-5}$	Half circle growth, Texture-cotton	
$R/10^{-3}$	Black color edge, milk color rhizoid shape	yellow

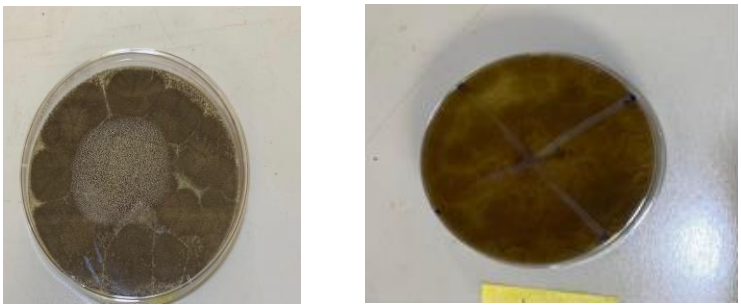


Plate 3.1: oil polluted area fungi growth observed from top and reverse view identified as Aspergillus spp

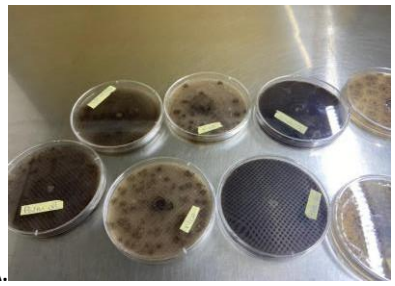
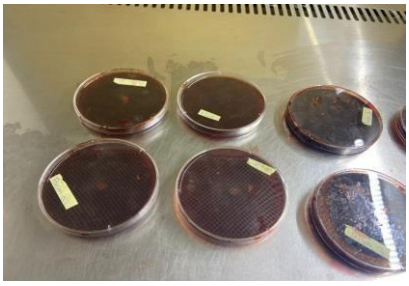
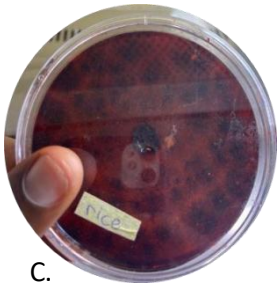
A.  B.  C. 

Plate 3.2: Selected Isolate Growth on Different Agricultural Waste. B-Congo Red Staining For Observing Xylanase Activity. C-Blue Black Staining Indicative of Xylan Production

Discussion

A total of six distinct fungal isolates (Table 3.1) were obtained from the analyzed soil samples, among which one filamentous isolate was morphologically characterized based on colony and spore morphology as *Aspergillus niger* (Table 3.1). This identification was supported by the presence of dense black conidial heads and pale-yellow reverse pigmentation on potato dextrose agar, which are consistent diagnostic traits for *A. niger* (Raj *et al.*, 2021). Notably, this isolate exhibited pronounced xylanolytic activity, as evidenced by clear hydrolysis zones on xylan agar plates following Congo red staining (Plate 3.1a-c). This qualitative assessment strongly indicates the secretion of extracellular xylanases, aligning with earlier reports that Aspergillus species are prolific producers of lignocellulolytic enzymes with broad biotechnological relevance (Raj *et al*., 2021; Gupta *et al*., 2023).

The detection of xylanase activity underscores the enzymatic capacity of *A. niger* to hydrolyze hemicellulosic polysaccharides particularly xylan present in agricultural residues. Such activity is of significant industrial interest, as xylanases contribute to biomass conversion, pulp bleaching, and bioethanol production. The isolation of a locally adapted *A. niger* strain exhibiting robust enzyme secretion is especially noteworthy, given that indigenous isolates frequently possess adaptive advantages such as thermostability, solvent tolerance, and pH resilience suited to their native ecological niches (Liu *et al*., 2022; Kim *et al*., 2024). These characteristics enhance process efficiency and operational stability, rendering local strains valuable for sustainable enzyme-based industries. Furthermore, the potential utilization of locally available agro-industrial residues such as corncob, rice bran, palm kernel shell, and shea butter shell as carbon sources for xylanase production presents a dual environmental and economic benefit. This approach not only valorizes agricultural waste but also significantly reduces production costs, aligning with current trends toward circular bioeconomy and resource-efficient bioprocessing (Singh *et al*., 2023; Zhao *et al*., 2024).

Conclusion

The isolation of a potent xylanase-producing *A. niger* strain from local soil underscores the promise of indigenous fungi as viable biocatalyst sources for industrial applications. Future work should focus on optimizing fermentation parameters, scaling up production using low-cost substrates, and characterizing enzyme kinetics and stability under industrial conditions. Industries engaged in biofuel generation, paper and pulp processing, and agro-residue valorization are strongly encouraged to explore and integrate such locally derived microbial resources to foster sustainable, regionally adapted biotechnological solutions.

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References

Bhardwaj, N., Kumar, B., and Verma, P. (2023). Xylanases in industrial applications: Recent advances and future perspectives. *Biotechnology Advances*, *57*, 102–115.

Kumar, V., Dangi, A. K., and Shukla, P. (2022). Engineering microbial xylanases for industrial applications. *Enzyme and Microbial Technology*, *159*, 110–125.

Liu, J., Tan, H., and Zhang, X. (2022). Engineering xylanase enzymes for improved thermostability and industrial application. *Biotechnology Advances*, *54*, 107-874.

Raj, A., Kumar, S., and Patel, R. (2021). Advances in microbial xylanase production and its industrial applications. *Bioresource Technology Reports*, *15*, 100712.

Singhania, R. R., Patel, A. K., and Pandey, A. (2021). Recent advances in microbial xylanases: Diversity, production, and application. *Critical Reviews in Biotechnology*, *41*(p. 4), 490– 50

Digital and Data-Driven Innovations for Smallholder Fruit & Vegetable Value Chains in Nigeria

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Abstract

Smallholder fruit and vegetable producers in Nigeria face multiple constraints including fragmented value chains, poor market access, high post-harvest losses, and limited digital literacy. Despite the agricultural sector's significant contribution to Nigeria's GDP which is approximately 24% and its employment of about 60% of the workforce, smallholder farmers face persistent challenges including low productivity, post-harvest losses, limited market access, and climate vulnerabilities. Through systematic analysis of current technologies, implementation case studies, and impact assessments, this review synthesizes evidence on how digital tools are reshaping agricultural practices from pre-production to consumption. The findings revealed that precision agriculture, IoT-enabled devices, digital market platforms, and blockchain-based traceability systems collectively address critical value chain constraints. However, meaningful adoption hinges on overcoming substantial barriers including digital literacy gaps, infrastructure limitations, and financing constraints. This review proposes a multi-stakeholder framework for scaling digital solutions, emphasizing the need for context-specific innovations, supportive policies, and strategic investments to build a more resilient, productive, and market-oriented smallholder F&V sector in Nigeria.

Introduction

Agriculture remains the backbone of Nigeria's economy, contributing an average of 24% to the country's Gross Domestic Product (GDP) over the past decade and employing approximately 60% of the national workforce (NBS, 2019). Within this sector, fruit and vegetable (F&V) production represents a crucial subsector for both nutrition security and economic development, providing essential vitamins and minerals while offering smallholder farmers higher profit margins compared to staple crops. Despite its significance, Nigeria's F&V sector grapples with substantial inefficiencies across the value chain, from production to consumption. Smallholder farmers, who dominate the landscape with an estimated 80% share of agricultural production, face persistent challenges including low productivity, significant post-

harvest losses (estimated at 35-50% for highly perishable fruits and vegetables), limited access to markets, and inadequate technical and financial resources (Asfaw et al. 2018). .

The digital transformation of agriculture presents unprecedented opportunities to address these long-standing constraints. With mobile penetration in Nigeria exceeding 80% and increasing internet accessibility, even in rural areas, the foundation for deploying digital solutions across F&V value chains is increasingly favorable. Recent advancements in artificial intelligence (AI), Internet of Things (IoT), big data analytics, and mobile platforms are creating new possibilities for optimizing agricultural production, enhancing supply chain efficiency, improving market access, and strengthening farmer resilience to climate shocks (Anokam, 2025). As noted by the Nigerian National Petroleum Company Limited in a different context, "digitisation, automation, Artificial Intelligence (AI) and advanced analytics are redefining the entire value chain". a transformation equally applicable to the agricultural domain.

This review article provides a comprehensive analysis of current digital and data-driven innovations tailored to smallholder F&V value chains in Nigeria. It synthesizes evidence from academic research, implementation case studies, and technology pilot projects to present a holistic view of the digital agriculture landscape. By examining successes, identifying persistent gaps, and proposing strategic recommendations, this review aims to contribute to the growing body of knowledge on how digital technologies can drive sustainable transformation in Nigeria's horticultural sector, ultimately enhancing productivity, profitability, and sustainability for smallholder farmers.

Methodology

This review employed a systematic approach to identify, evaluate, and synthesize relevant literature and evidence on digital and data-driven innovations in Nigeria's smallholder fruit and vegetable value chains. A comprehensive electronic database search was conducted across academic repositories including Google Scholar, ScienceDirect, JSTOR, and AGRIS, focusing on publications from 2015 to 2024 to ensure relevance. Search terms included combinations of "digital agriculture," "precision farming," "e-commerce," "smallholder farmers," "fruit and vegetable value chains," "Nigeria," "data-driven innovations," and related terminology.

The review prioritized peer-reviewed journal articles, technical reports from recognized institutions (World Bank, FAO, USDA), and verified case studies from implementation organizations. Particular attention was given to the Nigeria General Household Survey (GHS) Panel data from the Living Standards Measurement Study Integrated Survey on Agriculture (LSMS-ISA) project, which provides nationally

representative, geo-referenced plot-level data. This dataset offers valuable insights into adoption patterns and productivity impacts at the household and plot levels.

Inclusion criteria focused on documents specifically addressing digital applications in Nigerian F&V systems, with emphasis on smallholder contexts. The analytical framework organized findings along the value chain continuum: pre-production (planning, input acquisition), production (on-farm management), and post-production (harvesting, processing, marketing, consumption). For each segment, technologies were assessed for their functionality, maturity level, access requirements, impact evidence, and scaling potential. It is important to note the limitations of this methodology, including potential language bias (English-only publications) and urban bias in digital studies, which may underrepresent the most remote smallholder contexts. Additionally, the rapidly evolving nature of digital innovation means that some commercial applications may not yet be documented in academic literature (Salifu, 2025).

Digital Innovations across the Value Chain

Pre-Production Innovations

The pre-production phase sets the foundation for successful F&V cultivation, encompassing activities such as land preparation, input selection, and resource planning. Digital tools are increasingly transforming these critical initial stages for Nigerian smallholders.

Digital Land Preparation Services have emerged as a significant innovation, directly addressing the challenge of limited access to mechanization. Hello Tractor, often described as an "Uber for tractors," exemplifies this approach by connecting farmers with tractor owners through mobile and web applications. Farmers can request tractor services via text messages, which are then matched with available machines through a tech-savvy platform that enables real-time tracking. This model has demonstrated substantial impact, with one initiative in collaboration with the Nigerian Federal Ministry of Agriculture and Rural Development (FMARD) and John Deere aiming to deliver 10,000 tractors equipped with advanced telematics devices Such services are particularly valuable for F&V production, where timely land preparation significantly influences planting windows and subsequent crop performance.

AI-Powered Crop Selection Tools leverage local soil data, historical climate patterns, and market demand information to guide farmers in selecting appropriate F&V varieties. As noted in research on technology adoption, "agricultural production can be increased by either expanding the area under cultivation, changing cropping systems, and or use of sustainable productivity enhancing practices. These digital

decision support systems integrate data from multiple sources including satellite imagery, soil sensors, and market intelligence platforms to recommend optimal crop choices based on local growing conditions and forecasted market prices. For instance, the IBM Watson Decision Platform for Agriculture uses AI to analyze data from weather, satellite imagery, IoT sensors, and other sources to provide actionable insights to farmers.

Digital Input Acquisition Platforms are streamlining smallholders' access to quality seeds, fertilizers, and other essential inputs. These platforms connect farmers directly with certified input suppliers, reducing the layers of intermediaries that often increase costs and compromise input quality. By providing information on input quality, appropriate usage, and localized application recommendations, these systems help address the problem of substandard or counterfeit inputs that frequently plague smallholder F&V producers. The platforms often incorporate digital payment options and sometimes integrate with financing services, making quality inputs more accessible to resource-constrained farmers.

Production Innovations

The production phase encompasses all on-farm activities from planting to harvest, representing where digital technologies are making perhaps their most visible impact on F&V systems through precision agriculture applications.

Precision Agriculture Technologies are revolutionizing crop management practices for Nigerian smallholders. As described by Ogunmola (2024), "precision farming leverages AI technologies to provide farmers with actionable insights and data-driven recommendations". These technologies include drones equipped with AI-powered cameras and sensors that capture high-resolution images and data as they fly over fields. The drones provide several benefits: "they identify pest infestations, monitor crop health, and assess soil conditions". Such detailed, real-time information enables targeted interventions, reducing input waste and minimizing environmental impacts particularly important for F&V crops that often require careful management of water and nutrients.

IoT-Enabled Irrigation Systems represent another transformative innovation, especially critical for F&V production where water management significantly influences both yield quantity and quality. Soil sensors placed in fields monitor various soil parameters, such as moisture levels, temperature, and nutrient content. These sensors offer the advantage of enabling "farmers to optimize irrigation schedules, thus conserving water and energy" while ensuring "efficient nutrient management". For smallholder F&V

producers facing increasingly erratic rainfall patterns due to climate change, these precision irrigation technologies can dramatically improve water productivity and crop reliability.

AI-Driven Pest and Disease Management tools are emerging to address one of the most significant challenges in F&V production. These systems use image recognition algorithms trained on extensive databases of crop symptoms to enable early detection of pests and diseases through smartphone applications. Farmers can simply photograph affected plants and receive immediate diagnostic information along with treatment recommendations. This capability is particularly valuable for high-value F&V crops where pest damage can quickly destroy entire harvests. Research has shown that "climate risks in terms of high variability in temperature and rainfall affect SAPs adoption, highlighting the importance of climate-resilient production technologies (Ogunmola, 2024).

Mobile-Based Extension Services are democratizing access to agricultural knowledge, delivering timely, context-specific advice directly to farmers' phones. These platforms overcome the limitations of traditional extension systems, which often suffer from inadequate farmer-to-extension agent ratios. As reported by Salifu (2025), "providing technical and financial resources to extension agents is crucial so they could better reach rural smallholder households with the knowledge and benefits of these SAPs". Digital extension platforms complement these efforts by providing scalable, cost-effective information dissemination, often incorporating multimedia content (videos, interactive graphics) that enhances comprehension and adoption of improved practices.

Post-Production Innovations

The post-production phase encompassing harvesting, storage, processing, and marketing is where F&V value chains traditionally experience their greatest losses and inefficiencies. Digital innovations are now targeting these critical gaps.

E-Commerce Platforms and Digital Marketplaces are directly connecting smallholder F&V producers with buyers, reducing transaction costs and improving price realization. As highlighted in research on e-commerce in Nigeria, small business owners need to consider having an online presence that enables them to sell and showcase their products to a much broader audience. Platforms like Jumia Nigeria, Konga, and PayPorte have created digital marketplaces where farmers can access wider consumer bases without multiple layers of intermediaries. These platforms are particularly valuable for F&V producers seeking to reach urban consumers who increasingly prefer the convenience of online grocery shopping. The

expansion of digital payment systems, including mobile money and card services, has further facilitated the growth of F&V e-commerce by enabling secure, instantaneous transactions.

Digital Logistics and Cold Chain Management systems are addressing the critical challenge of post-harvest losses in F&V value chains. By leveraging GPS tracking, IoT sensors, and route optimization algorithms, these technologies enable more efficient transportation and distribution of highly perishable produce. Temperature and humidity monitors integrated with mobile alert systems help maintain cold chain integrity, while dynamic routing software identifies the most efficient delivery paths based on real-time traffic conditions. For smallholder F&V farmers who typically lack dedicated refrigeration facilities, access to such coordinated cold chain services can dramatically reduce post-harvest deterioration, extending shelf life and maintaining product quality.

Blockchain-Enabled Traceability Systems are emerging to enhance transparency and value addition in F&V supply chains. These digital solutions create immutable records of produce movement from farm to consumer, capturing essential information about production methods, harvest dates, quality parameters, and handling conditions. Such traceability is increasingly valued by quality-conscious consumers, particularly for fresh produce where safety and authenticity concerns are paramount. By providing verified information about production practices (organic, pesticide-free, etc.), these systems enable differentiation and premium pricing for smallholders employing sustainable or specialized growing methods.

Cross-Cutting Digital Technologies

Beyond value-chain-stage-specific applications, several transformative digital technologies are delivering impacts across multiple segments of F&V systems in Nigeria.

Big Data and Advanced Analytics are enabling unprecedented optimization of agricultural decision-making. As emphasized in the context of Nigeria's energy sector but equally applicable to agriculture, "digitisation, automation, Artificial Intelligence (AI) and advanced analytics are redefining the entire value chain. These technologies integrate diverse datasets including satellite imagery, weather stations, soil maps, market information, and farmer behavior data to generate predictive insights and personalized recommendations. For F&V value chains, analytics can forecast yield volumes and quality days or weeks before harvest, allowing for better market planning and reduced waste. Research has demonstrated that "using data from local markets, seasonal trends, and demand-supply dynamics, analytics tools can

forecast price fluctuations" , empowering farmers to make smarter decisions on what to plant and when to sell.

Internet of Things (IoT) and Sensor Technologies are creating dense networks of real-time monitoring capabilities across F&V systems. From soil moisture sensors in fields to temperature monitors in storage facilities and tracking devices on transportation vehicles, these connected devices generate continuous streams of data that enable precision management throughout the value chain. The resulting information flows help optimize resource use, maintain product quality, and provide early warning of potential problems. For smallholder F&V farmers, IoT systems increasingly offer affordable, solar-powered options suitable for Nigeria's diverse agro-ecological contexts, though connectivity challenges remain in some rural areas.

Artificial Intelligence and Machine Learning algorithms are powering increasingly sophisticated decision support tools for F&V value chains. These systems can recognize complex patterns in large datasets that would be imperceptible to human analysts, enabling more accurate predictions of crop development, pest outbreaks, market trends, and optimal harvest timing. As described in case studies of AI-driven agriculture, technologies like drone imagery, soil sensors, and AI platforms provide farmers with real-time data and actionable insights, enabling them to optimize their practices and improve productivity". For Nigerian smallholders, these AI capabilities are increasingly being packaged in user-friendly mobile applications that deliver personalized advice in local languages through intuitive interfaces (Ogunmola, 2024).

Digital Financial Services are revolutionizing how financial resources flow through F&V value chains, addressing one of the most persistent constraints for smallholders. Mobile money platforms, digital credit scoring systems, and pay-as-you-go financing models are making financial services more accessible to previously excluded rural actors. Hello Tractor's approach exemplifies this innovation: "The platform's ability to track tractor usage proved instrumental in securing low-cost loans from financial institutions, fostering tractor ownership among small-scale contractors". For F&V producers facing significant working capital requirements for inputs and labor, these digital financial tools provide more flexible, timely, and appropriate options than traditional banking services.

Impact Assessment of Digital Innovations

Rigorous assessment of digital innovations' impacts is essential for understanding their true value and guiding further investments in Nigeria's F&V sector. Evidence is emerging across multiple dimensions of impact.

Productivity and Yield Improvements have been demonstrated through various digital intervention studies. Research using nationally representative, geo-referenced plot-level data from Nigeria has shown that technology adoption generally correlates with enhanced productivity, noting specifically that "inorganic fertilizer is positively correlated with plot-level productivity". When combined with digital tools that optimize the timing and placement of these inputs, the productivity benefits can be further amplified. For F&V crops, where yield responses to management precision are particularly pronounced, the integration of digital monitoring with appropriate input use has demonstrated potential for significant gains.

Income Enhancement and Market Access represent perhaps the most compelling impact of digital innovations for smallholder F&V producers. By enabling more direct market connections and reducing intermediary margins, digital platforms can improve farmers' terms of trade. As noted in analysis of e-commerce platforms, these digital marketplaces "have redefined how Nigerians shop and interact with products and services, creating new channels for F&V producers to reach consumers. Additionally, by providing "timely weather alerts to farmers" and insights that "help them decide when to plant, irrigate, or harvest, digital systems help stabilize production and income streams despite increasing climate variability.

Food Loss Reduction impacts are particularly significant for highly perishable F&V crops. Digital platforms that improve coordination between producers, distributors, and retailers help synchronize supply with demand, reducing the time that produce spends in the value chain. One study emphasizing the importance of post-production innovations noted that better "market access" is crucial for smallholder households . Digital logistics systems that optimize transportation routes and provide real-time tracking further contribute to minimizing the delays that exacerbate deterioration in F&V quality and value.

Environmental Sustainability benefits are increasingly documented from precision agriculture technologies deployed in Nigerian F&V systems. By enabling more targeted application of water, fertilizers, and pesticides, these digital tools reduce input waste and environmental contamination. As

observed in the context of climate resilience, agricultural technology adoption is vital for spurring agricultural productivity in a changing climate environment. The optimization capabilities of digital systems are particularly valuable in F&V production, where over application of inputs has been common due to the high value of these crops and farmers' risk aversion.

Barriers to Adoption and Scaling

Despite their demonstrated potential, digital innovations for F&V value chains in Nigeria face significant adoption barriers that must be addressed to achieve impact at scale.

Infrastructure Limitations remain a fundamental constraint in many rural areas where F&V production is concentrated. Irregular electricity supply compromises the charging of digital devices and operation of more advanced technologies like IoT sensors and automated processing equipment. Limited internet connectivity, particularly broadband services with sufficient bandwidth for data-intensive applications, restricts the functionality of cloud-based digital platforms in remote farming communities. As noted in research, poor infrastructure (road networks to allow easy market access as well as access to credit) represents a systemic challenge that affects digital adoption alongside other aspects of agricultural development.

Digital Literacy and Skills Gaps affect both farmers and other value chain actors, limiting their ability to effectively utilize available technologies. Many digital agriculture tools assume certain levels of technical proficiency, educational background, or language capabilities that may not align with smallholders' realities. Abdulquadri et al., (2024) has emphasized that providing technical and financial resources to extension agents is crucial so they could better reach rural smallholder households with the knowledge and benefits of agricultural innovations a finding equally applicable to digital technologies. Without targeted digital skills development and user-friendly design, even the most sophisticated solutions may fail to achieve adoption.

Economic and Financial Constraints pose significant challenges, particularly for resource-constrained smallholder F&V producers. The direct costs of smartphones, data plans, and subscription fees for digital services can be prohibitive for farmers operating with thin profit margins. Additionally, as noted in research on technology adoption, "smallholder households should diversify their livelihood portfolios to include non-farm income generating activities", suggesting that financial limitations affect multiple

aspects of agricultural investment. While digital financial services are emerging to address these constraints, their penetration in rural agricultural communities remains limited.

Technical and Support Challenges affect the functionality and reliability of digital solutions in Nigeria's diverse F&V contexts. Many platforms are not adequately adapted to local languages, cropping systems, or value chain structures, reducing their relevance and utility for intended users. Limited technical support networks in rural areas mean that hardware malfunctions or software issues can render technologies unusable for extended periods. Maintenance requirements for sophisticated equipment like sensors or drones often exceed local capacity, creating dependency on external service providers with associated costs and delays.

Conclusion and Recommendations

This comprehensive review demonstrates the significant potential of digital and data-driven innovations to transform smallholder fruit and vegetable value chains in Nigeria. From pre-production through to marketing and consumption, digital tools are enabling more precise, efficient, and connected agricultural systems that can enhance productivity, improve market access, reduce losses, and strengthen resilience to climate and market shocks. However, realizing this potential at scale requires coordinated action across multiple dimensions

Based on the evidence synthesized in this review, the following recommendations are proposed for various stakeholders in Nigeria's F&V sector:

For Policymakers and Government Agencies:

Develop and implement a national digital agriculture strategy specifically addressing the unique needs of horticulture value chains, with dedicated attention to smallholder inclusion.

- Invest in rural digital infrastructure, particularly broadband connectivity and electricity access, to create an enabling environment for digital innovation in F&V production zones.
- Reform regulatory frameworks to support digital financial inclusion, data privacy and security, and fair competition in digital agriculture markets.
- Strengthen public-private partnerships for digital extension services, building on existing platforms to reach more smallholder F&V producers with context-specific advice.

For Technology Developers and Providers:

- Prioritize user-centered design approaches that engage smallholders throughout development processes, ensuring technologies address real pain points and are accessible to users with varying digital literacy levels.
- Develop affordable business models appropriate for resource-constrained smallholders, including pay-as-you-go options, group subscription plans, and bundled service packages.
- Create offline-functionality and low-bandwidth versions of digital platforms to ensure usability in areas with limited connectivity.
- Build local technical support capacity through training of community-based digital champions who can provide troubleshooting and basic maintenance services.

For Development Partners and Research Institutions:

- Support rigorous impact evaluation of digital innovations in F&V value chains, generating evidence on what works, for whom, and at what cost to inform future investments.
- Facilitate knowledge sharing platforms where practitioners can exchange lessons learned, successful models, and implementation challenges across different Nigerian contexts.
- Invest in digital literacy programs specifically tailored to smallholder F&V producers, with content relevant to their cropping systems and value chain roles.
- Promote interoperability standards that enable different digital platforms to exchange data and functionality, creating more integrated solutions for farmers.

For Farmer Organizations and Cooperatives:

- Develop collective digital procurement models that enable members to access technologies and services at bulk purchase discounts.
- Establish peer learning networks where digitally experienced farmers can mentor others in adopting and benefiting from new tools.
- Negotiate group subscription plans with digital service providers to reduce costs and improve bargaining power for smallholders.
- Create digital champion programs that identify and support tech-savvy youth within farming communities to provide local support services.

Conclusion

In conclusion, digital and data-driven innovations offer transformative potential for Nigeria's smallholder fruit and vegetable value chains, but this transformation will not occur automatically or equally. It

requires intentional, coordinated efforts to ensure that digital tools are appropriate, accessible, and beneficial for those at the core of F&V production—smallholder farmers. With the right ecosystem of support, Nigeria can harness digital technologies to build more productive, profitable, and sustainable F&V systems that contribute significantly to rural development, food security, and economic growth.

References

National Bureau of Statistics (NBS) (2019). General Household Survey—Panel 2018/2019. Abuja, Nigeria.

Asfaw, S., McCarthy, N., Paolanti, M., & Cavatassi, R. (2023). Climate variability, agricultural technologies adoption, and productivity in rural Nigeria: a plot-level analysis. Agriculture & Food Security, 12(7), 1-24.

Ogunmola, S. (2024). AI-Driven Agriculture: Precision Farming in Africa (Nigeria as a Case Study). LinkedIn Pulse.

Harvard Ministerial Leadership Program. (2023). Hello Tractor Case Study: Empowering Farmers: Hello Tractor's Digital Revolution in Nigeria.

Food and Agriculture Organization of the United Nations (FAO). (2018). Country factsheet on smallholder family farms: Nigeria.

Anokam, E. (2025). AI, Digitisation, Advanced Analytics Redefining Entire Energy Value Chain. NAN News.

Salifu, S. (2025). How Data Analytics Can Help the Nigerian Government Improve Agriculture. LinkedIn Pulse.

Abdulquadri, A. O., Aliyu, A. O., & Yahaya, B. O. (2024). Transforming Nigeria's Agricultural Value Chains: The Role of Digital Platforms in Market Access and Price Transparency. UNIZIK Journal of Marketing, 1(2), 37–57.

Megaphrynium Macrostachyum: A Promising Green Alternative with Antifungal Properties

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Abstract

Megaphrynium macrostachyum, a plant species native to West and Central Africa, has been found to possess significant antioxidant, phytochemical and antimicrobial properties. The leaf and seed of the plant contains many phytochemicals responsible for its bioactivity. The bioactive secondary metabolites identified in the plant have many pharmacological properties which can be exploited as pharmaceuticals. *M. macrostachyum* extracts exhibit moderate antimicrobial activity against various bacteria species. The results of the antifungal assays of the plant indicate significant activity as an antifungal agent. The plant shows promise in post-harvest management since its extracts have been found to inhibit microbial growth, reducing spoilage and extending shelf life. The presence of flavonoids, saponins and phenolics compounds contribute to its preservative properties. Studies demonstrate the efficacy of *M. macrostachyum* extracts in the control of post-harvest pathogens, making it a potential natural alternative to synthetic agents. Its use could minimize food waste and enhance food security. *M. macrostachyum* extracts presents an opportunity for developing eco-friendly and cost-effective post-harvest management solutions.

Keywords: Antioxidant, *Megaphrynium macrostachyum*, post-harvest management,

Introduction

Natural products have for ages played crucial roles in drug discovery as medicinal plants are the most exclusive drugs for the majority of the world's population (Sagwan *et al*., 2010). The use of different plant parts for therapeutic and medicinal purposes especially in Africa has been on the increase due to their availability, accessibility and affordability (Caccia-Bava *et al*., 2017). The WHO has estimated that 85 percent of traditional medicine involves the use of such plant extracts, especially in Africa and Asia (Oyebode *et al*., 2016; Obonga *et al*., 2019), and one of such plant is *Megaphrynium macrostachyum* belonging to the family Marantaceae. This plant is found distributed in the African region, from Guinea and Sierra Leone to DR Congo, Cabinda (Angola), Sudan and Uganda. In Central Africa, the vegetative parts

of *Megaphrynium macrostachyum* are an important food of gorillas, chimpanzees and bonobos (Pischtschan *et al*., 2010). *Megaphrynium macrostachyum* is also found in the rainforest of West and Central Africa. Nigeria, it is commonly called 'Yoruba Soft Cane' with local names such as 'Ebieba' (Bini), 'Ekparanga' (Ijaw) and 'Akwukwo – mma' (Delta – Ibo) (Okungbowa *et al*., 2017). The plant exhibits rapid vegetative reproduction by rhizome and seed. Originally, it grows in the wild but is sometimes also cultivated (Jiofack, 2011). Traditionally, the leaves find use in food wrapping (before or after cooking), packing of agricultural produce (fruits, vegetables, seeds, kolanuts, tomato, pepper, garden egg, okra etc.) (Termote *et al*., 2010). Elsewhere, as well as in Nigeria, the leaves and petioles are also used for thatching, and for weaving several household materials like mats and baskets (Ajayi and Ojelere, 2013).

The *in-vitro* evaluation of the plant extracts by Adeogun *et al* (2017) and Ajayi and Ojelere (2013) reveals the antimicrobial properties of the plant as it shows good inhibition on isolates studied. This indicates potentials of the plants as a preservative agent. The plant as well has good antioxidants potential as reported by Cedric *et al*. (2016); Oboh *et al*. (2016) and Adeogun *et al*. (2017). Cholesta-3,5-diene, a phytoconstituent of the plant extract has been reported as having *in-silico* activity against the fungal enzyme, lanosterol-14α-demethylase and therefore is a promising antifungal agent in postharvest management of stored grains (Ajayi *et al*., 2024).



Figure 1: *Megaphrynium macrostachyum* plant
Source: Jiofack (2011)

Extraction of *Megaphrynium macrostachyum*

Several authors have reported the extraction of different parts of *M. Macrostachyum* plant together with their yields. One of such is as reported by Odeogun *et al*. (2017). According to Odeogun *et al*. (2017), the *M. Macrostachyum* leaf extracts from acetone, aqueous, ethanol and hexane were assayed for preservative activity. The percentage yield of the aqueous extract was the highest among the four solvents analyzed. This result corroborated with what Do *et al*. (2014) obtained on the extraction yield of the same plant that identified aqueous extracts with higher yield compared with other test solvents. Francois *et al*. (2015) also showed that aqueous extracts had higher yield compared to those obtained from ethanol,

benzene and chloroform extracts and this suggests a higher proportion of water-soluble plant components. The yield of the hexane extracts showed the presence of some non-polar compounds as reported by Khanum *et al*. (2014) and Ganatra and Gurubaxani (2016).

Phytochemistry/Chemical Composition of *Megaphrynium macrostachyum*

There is need to know which constituents in the medicinal herb are responsible for therapeutic uses. Therefore, the need arises to extract, isolate and identify the phytoconstituents (bioactive components) responsible for its therapeutic use. Screening of various natural organic compounds and identifying active agents is the need of the hour, because successful prediction of drug like properties at the onset of drug discovery will pay off subsequently in drug development (Ajayi and Ojelere, 2013).

According to Cédric *et al*. (2016), *M. Macrostachyum* seed (Figure 2) contained tannins, terpenoids, flavonoids and polyphenols. The seed of *M. Macrostachyum* showed a strong presence of saponins (Figure 3) in the water and water-ethanol extracts. They are also known to possess antibacterial, antiviral, antimutagenic and anticarcinogenic properties (Feuya *et al*., 2015). Adeogun *et al*., (2017) reported on the qualitative phytochemical constituents of *M. Macrostachyum*. The report shows the presence of alkaloids and saponins in all the test extracts of *M. Macrostachyum* leaves. Steroids were present in acetone and aqueous extracts and flavonoids were present in ethanol and aqueous extracts. The result of quantitative phytochemical constituents of ethanol extract of *M. Macrostachyum* leaves which was the most active, revealed also considerate amount of alkaloids, saponins, and flavonoids. The essential oils analysis of fresh and dried leaves of *M. Macrostachyum* showed the percentage composition of essential oils of extracts from the dried and fresh leaf of *M. Macrostachyum*. The essential oils of fresh and dried leaves of *M. Macrostachyum* revealed Isodecane with highest percentage composition, followed by 3',4'-dihydro-2'-(morpholin-4-yl)-5',7'-dinitrospiro[cyclopentane-1,3'-quinazoline] and 2-(4-chlorophenyl)-1-cyclohexyl-2-piperidinoethanone in dried leaves and Hendecane and (1,3,3-Trimethylnonyl) benzene in fresh leaves (Adeogun *et al*., 2017).



Figure 2: Seed of *Megaphrynium macrostachyum*
Source: Ajayi *et al*. (2013)

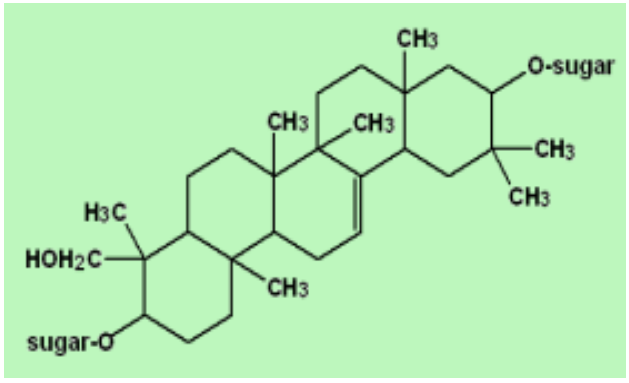


Figure 3: Chemical Structure of Saponin
Source: Lorent *et al*. (2014)

Antimicrobial Activity

The antimicrobial activity of *M. Macrostachyum* using agar well diffusion method revealed that aqueous extract of the plant seeds showed little significant effect against both the gram positive and gram negative organisms tested (Ajayi and Ojelere, 2013). The antimicrobial activity of aqueous extracts of the seeds of *M. Macrostachyum* has been tested against four pathogenic bacteria. Antimicrobial activity of the extracts of the seeds of *M. Macrostachyum* was investigated against *Escherichia coli*, *Pseudomonas aeruginosa*, *Bacillus subtilis* and *Staphyllococcus aureus*. For all the tested microorganisms, aqueous extracts of *M. macroctachyum* was not active against *P. aeruginosa* and maximum inhibition was observed in *B. subtilis* followed by *S. aureus*. This implies that the higher concentrations of the extracts were observed to be more active against the tested bacterials (Ajayi and Ojelere, 2017). However, the low effect of the aqueous extracts on the microorganisms agrees with the assumption that bioactive substances that are less soluble in water could dissolve in organic solvent (Oyagade *et al*., 1999). In similar study, the efficacy of the plant

extracts of *M. Macrostachyum* in controlling the growth of spoilage fungi was demonstrated by Adebayo and Kolawole (2010). With positive effects on the microorganisms, the authors highlighted their potentials as sources of alternative natural preservatives in the food industry. The antioxidant and antimicrobial activities of the ethanolic leaf extract of the plant have also been reported. (Ajayi et al., 2024).

Conclusion

Megaphrynium macrostachyum emerges as a valuable plant species with significant antioxidant, phytochemical and antimicrobial properties making it a potential resource for industrial applications. Its bioactive compounds contribute to its preservative effects highlighting its potential as a natural alternative for post-harvest management and food preservation.

References

Adebayo, G.J. & Kolawole, L.A. (2010). *In vitro* activity of *Thaumatococcus daniellii* and *Megaphrynium macrostachyum* against spoilage fungi of white bread and 'Eba', an indigenous staple food in Southern Nigeria. *African Journal of Microbiology Research* 4(11):1076-1081.

Adeogun, O., Adekunle, A.A., Adongbede, E.M. & Ashafa, T.A. (2017). Chemical Composition, Toxicity and Antifungal Activities of *Megaphrynium macrostachyum* (K. Schum) Leaf Extract against Foodborne Fungi. *Not Sci Biol.* 9(3):361-370.

Ajayi, A.I. & Ojelere, O.O. (2013). Phytochemical Screening, Proximate analysis and Antimicrobial Activity of aqueous extract of *Megaphrynium macrostachyum* seeds. *International Journal of Engineering Research & Technology (IJERT)* 2(9):2123-2130.

Ajayi, O.A., Ayanda, S.I., Ige, M.I., Okunlade, F.A., Adegbola, Q.R., Jimoh, O.M., Ihum, T.A., Olatunji, J.T. & Oyeyipo O.S (2024). A Comparative Study of the Phytochemical Screening, DPPH Radical Scavenging Activity and Antimicrobial Activity of the Ethanolic Extract of *Thaumatoccoccus daniellii* and *Megaphrynium macrostachyum* presented at the 10th Regional Food Science and Technology Summit on Attaining Sufficient, Safe and Healthy Food for Nigerians through Food Science and Technology.

Ajayi, O.A., Babatunde, O.T., Atanda, S.A., Jibrin, A.F., Salako, M.O., Odutola, S.B., Okparavero, F.N. & Otenaike, O.E (2024). Molecular docking of cholesta-3,5-diene from M*egaphrynium macrostachyum* as potent inhibitory agent against fungal enzyme, lanosterol-14α-demethylase

presented at the 48th Nigerian Institute of Food and Science Technology Conference on Food Science and Technology for Sustainable Food and Nutrition Security.

Lorent, J.H., Quetin-Leclercq, J. & Mingeot-Leclercq, M. (2014). "The amphiphilic nature of saponins and their effects on artificial and biological membranes and potential consequences for red blood and cancer cells". *Organic and Biomolecular Chemistry. Royal Society of Chemistry.* 12 (44): 8803–8822.

Obonga, W.O., Nnadi, C.O. & Chima, C.C. (2019). *In vitro* Antioxidant and *In-vivo* Anti-inflammatory Potentials of *Marantochloa leucantha* (Marantaceae) Extracts and Fractions. *J. Pharm. Sci.* 18(2):233-240.

Postharvest Management of Nigeria Staple Crops: Spoilage and Preservation of Millet and Sorghum

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Abstract

The Nigerian government plays a pivotal role in strengthening the agricultural sector, enhancing the food and nutritional landscape, fostering income growth, creating employment opportunities, and improving Nigeria's position in global food markets. The vision of a hunger-free Nigeria is attainable, supported by effective post-harvest technologies that minimize losses in staple crops and contribute to the nation's Gross Domestic Product (GDP). Millet and sorghum have become popular crops in Nigeria, valued for their affordability and availability for human consumption and food industry use. The postharvest processes for these grains include drying, threshing, cleaning, dehulling, milling, packaging, transportation, and storage. Local farmers in Nigeria have used some traditional storage facilities, and there are some advanced storage techniques like the use of the hermetic system, which ensures good quality products and minimal postharvest losses. To a large extent, postharvest losses are attributed to poor handling practices; inadequate storage facilities and mycotoxin contamination all of which can significantly reduce the quality of harvested sorghum and millets and increase overall losses. Major mitigating strategies have been implemented to prevent post-harvest loss, like using an integrated pest management (IPM) system, breeding for resistance, extension training for farmers, and maintaining good storage practices and advanced storage structures. Closing the knowledge gap in postharvest technology and management among farmers and stakeholders can greatly transform the agricultural sector.

Keywords: Millet, Sorghum, Postharvest technology, Farmers, Best Practices

Factors Influencing Access to and the Intensity of Utilization of Agricultural Credit by Vegetable Marketers in Enugu State, Nigeria

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Abstract

Vegetable marketing plays a crucial role in the Nigerian economy; however, marketers face significant challenges in accessing credit to expand their operations and improve profitability. This study examines the financial behaviors of vegetable marketers in Enugu State, focusing on the factors that influence their participation in agricultural finance. A multi-stage random sampling technique was used to select 120 vegetable marketers. Data were collected with a well-structured questionnaire and analyzed using descriptive statistics and the Double Hurdle Regression Model. Findings reveal that 85% of respondents were female, with 65.9% aged between 31 and 50 years. Educationally, 40.8% had completed secondary school, and 69.2% had less than three years of experience in marketing. Informal financial sources were predominant, utilized by 83.4% of marketers, while only 16.7% accessed bank loans. Key factors affecting access to agricultural credit included age, saving habits, loan repayment terms, and availability of formal loans. Determinants influencing the extent of financial resource utilization encompassed gender (-4.61), education (2.18), saving habits (-2.68), interest rates (-2.15), repayment terms (-1.28), lending source (-2.34), and household size (6.23). The study concluded that formal financial institutions exist, but marketers usually access credit informally because of the difficulty in satisfying loan requirements. Therefore, vegetable marketers must receive improved agricultural finance policies and financial inclusion strategies to enable them to meet the requirements of formal financial sources of credit.

Keywords: Vegetable Marketing, Agricultural Finance, Access, Barriers, Double-Hurdle model.

Proximate Composition and Bioethanol Production from Cassava Bagasse

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Abstract

Cassava bagasse is a waste material generated from the processing of fermented and non-fermented cassava. It is considered to be of little or no significance and is often discarded as waste after the fufu or garri has been processed thereby constituting environmental nuisance. This study therefore determined the proximate composition and feasibility of cassava bagasse as a raw material for the production of ethanol as a biofuel. The determinations were made using standard methods of analyses of Association of Official Analytical Chemists (AOAC) using different concentrations of HCl for acid hydrolysis. Results of the proximate analysis showed the following; moisture (3.60%), crude ash (1.52%), crude fibre (19.60%), crude fat (1.63%), protein (0.93%), carbohydrate (72.72%). Acid hydrolysis revealed that different concentrations of acid gave different amounts of reducing sugar in this order; 15.0%, 17.9%, 26.0%, 48.5% and 19.1% for 0.8M, 1.0M, 1.5M, 2.0 M and 2.5M respectively. The ethanol yield also followed this trend as follows, 8.30% v/v, 9.57%v/v, 12.55%v/v, 21.68%v/v and 10.44%v/v for 0.8M, 1.0M, 1.5M, 2.0M and 2.5M respectively. This means that cassava bagasse is a good substrate for the production of biofuel. With Nigeria ranking very high in terms of production of energy crops such as cassava, corn, sorghum, soybean, yam etc, it has immense potential for the production and utilization of bioethanol, thereby easing the financial strain relating to the heavy burden of fossil fuel subsidy and maintaining a healthy environment since discarding this waste in the open cause's environmental degradation.

Keywords: Proximate composition, Bioethanol, Cassava bagasse, Waste management, Environmental sustainability.

Serum and Haematological Indices of Broiler Chickens fed Raw Undecorticated and Decorticated *Adansonia Digitata* Seed Meal with or without Vitamin E and C Supplementation in Nutrition of Broiler

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Abstract

Leguminous grains are good sources of plant protein feed source for poultry. However, presence of anti-nutritional factors (ANF) in feedstuffs is a factor negatively affecting feed quality. *Adansonia digitata* seed has been identified as a potential feed ingredient due to its high protein content. This study investigates the effects of raw undecorticated and decorticated *Adansonia digitata* seed meal (ADSM) supplemented with vitamins E and C on serum and haematological indices of broiler chickens. A total of 175-day-old broiler chicks were randomly assigned to seven dietary treatments over a six-week feeding trial, including control and 10% of ADSM (undecorticated and decorticated) with or without vitamin E or C supplementation. Blood samples were collected to assess biochemical and haematological parameters post-experiment. The results indicated no significant differences ($p<0.05$) across treatments for most serum parameters, although numerically higher values of alkaline phosphatase 62.25 (T5), total protein 14.04 (T5), and globulin 8.99 (T6) were observed in vitamin supplemented groups. Furthermore, haematological indices showed significant differences in parameters such as mean corpuscular volume (MCV) ranging from 79.63 (T2) to 127.53 (T3), mean corpuscular haemoglobin (MCH) ranging from 45.88 (T5) to 140.55 (T2) and white blood count types MID ranging from 6.47 (T1) to 17.53 (T2) and GRAN ranging from 6.43 (T7) to 28.90 (T2) among treatments. The findings suggest that the inclusion of ADSM in broiler diets, particularly with vitamin supplementation, may enhance certain biochemical and haematological profiles, thereby contributing to improved poultry health and growth. Further research can adopt processing methods to mitigate the effects of antinutritional factors present in *Adansonia digitata* seed meal to improve its utilization in broiler diets.

Keywords: *Adansonia digitata*, Serum, Haematology, Vitamin, Decorticated, Undecorticated



SUB-THEMES

1. Innovative farming practices
2. Agricultural Technology and Digitalization
3. Enhancing food security through value chain development
4. Climate-smart agriculture and environmental sustainability
5. Women and youth empowerment in agriculture
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8. Sustainable Wildlife Management, Livestock, Fisheries and Aquiculture development
9. Gender issues in Agricultural research for development
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