DIGITALISATION OF AGRICULTURE AND BIO-CONSERVATION FOR FOOD SECURITY

PROCEEDINGS OF THE 2ND FACULTY OF AGRICULTURE INTERNATIONAL CONFERENCE, NNAMDI AZIKIWE UNIVERSITY, AWKA, NIGERIA

held at the Nnamdi Azikiwe University, Awka Campus, Anambra State, Nigeria from 12th to 14th of March, 2024

2ND FAIC UNIZIK 2024

Edited by:
Onyekachi CHUKWU,
Chika F. IKEOGU,
Eucharia A. OBIDIEBUBE,
Cordelia I. EBENEBE.

DIGITALISATION OF AGRICULTURE AND BIO-CONSERVATION FOR FOOD SECURITY

Edited by:

Onyekachi CHUKWU, Ph.D
Chika F. IKEOGU, Ph.D
Eucharia A. OBIDIEBUBE, Ph.D
Cordelia I. EBENEBE, Ph.D

2024

Digitalisation of Agriculture and Bio-Conservation for Food Security

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PROGRAMME OF EVENTS

12th March, 2024

DAY ONE: ARRIVAL OF PARTICIPANTS

13th March, 2024

DAY TWO: OPENING CEREMONY & FARMERS SUMMIT

Venue: University Auditorium, Garba Square, Nnamdi Azikiwe University, Awka, Nigeria

	PROGRAME	
8.00am	Registration	Mrs Chisom L. Umeh, Mr. Tochukwu Nwosu, Dr. Adeyemisi T. Victor-Aduloju, Mrs Oti Chinelo
8.30 - 9.00am	Courtesy Visit	Dean, HODs, Professors and Special guest
9.00 – 9.15am	Introduction of Guests	Dr. Onyekachi Chukwu
9.15 – 9.20am	National / UNIZIK Anthems	DJ
9.20 – 9.25am	Opening Prayer	Ven. Dr. Innocent Enwelu
9.25 – 9.30am	Presentation of Kola nut	Prof. C.I. Ebenebe (Dean, FAG)
9.30 – 9.40am	Welcome Address from the Host	Prof. C.I. Ebenebe (FAG Dean)
9.40 – 9.50am	Opening Remarks / Declaration by Chief Host	Prof. Charles O. Esimone (Vice Chancellor, Nnamdi Azikiwe University, Awka)
9.50 – 10.30am	Keynote Address	Dr. Yemi Akinbamijo (Former Director, Forum for Agricultural Research in Africa (FARA), Ghana)
10.30– 10.50am	Lead Paper Presentation I	Rev. Fr. Prof. Godfrey Nzamujo O.P. Director, Songhai Integrated Farm, Port Novo, Republic of Benin
10.50– 1.30am	Agriculture at a Glance in Anambra	Dr Foster Ihejiofor (Hon. Commissioner for Agriculture, Anambra State)
11.30– 11.35am	Conferment of Awards	Awardees
11:40-12:20pm	Response by the Awardee(s)	Awardees
12.25– 2.35pm	Vote of thanks (Conference C'ttee Chair.)	Dr Eucharia A. Obidiebube
12.35– 2.45pm	Announcements	Dr. Onyekachi Chukwu
12.45-12.50pm	UNIZIK / National Anthems	DJ
12.50-12.55pm	Group photograph/ Visit to Exhibition stands/	Tochukwu Nwosu/ Mrs. Nkoli B. Ndulue, Mrs. Ndidi B. Ezenyilimba / Mr. Chukwumaije C. Okechukwu / Dr. Blessing O. Gbughemobi
12.55 –1.00pm	Lunch Break	Dr. Akudo Onunwa
1.00– **2**.0**0**pm	Farmers Summit	Dr. Onyekachi Chukwu/Mr. Ikechukwu Obiamalu
2:00– 2.**3**0pm	Question and Answer	
2.05 – 4.35pm	Exhibition / Visits to some interesting sites within the UNIZIK	Mrs. Nkoli B. Ndulue, Mrs. Ndidi B. Ezenyilimba / Mr. Chukwumaije C. Okechukwu / Dr. Blessing O. Gbughemobi

14th March, 2024

DAY THREE: PLENARY/TECHNICAL SESSION

Venue: Ekwueme Center for multi-disciplinary research, Nnamdi Azikiwe University, Awka, Nigeria

	PROGRAME	
8.00am	Registration continues	Mrs Chisom L. Umeh, Mr. Tochukwu Nwosu, Dr. Adeyemisi T. Victor-Aduloju, Mrs Oti Chinelo
8.30 - 8.35am	Opening Prayer	Dr C. C. Iwuagwu
8.35 – 8.40am	Opening Remarks	Prof. C. I. Ebenebe (FAG Dean)
8.40– 8.45am	Announcements on Plenary/ breakout sessions	Mr. Tochukwu Nwosu
	Lead Paper Presentation II	Prof. Shadrach Olufemi Akindele Vice Chancellor Redeemer's University, Nigeria
8.45am– 12:40pm	Plenary Session (Virtual)	Dr Uko Ibeabuchi, Dr. Onyekachi Chukwu (Media)
		Chairpersons: Dr. C. C. Iwuagwu
8.45am– 12:40pm	Plenary Session (Physical)	Mr. Ude Sabastine Chukwumeluje (Media)
		Chairpersons: Dr. Helen Agu
12.40 – 1:00pm	Lunch Break	Dr. Akudo Onunwa, Mrs. Chisom L. Umeh, Dr. Adeyemisi T. Victor-Aduloju
	Lead Paper Presentation III	Prof Rotimi E. Aluko, University of Manitoba, Canada
1.00 – 3.00pm	Plenary Session (Virtual and Physical)continues	Chairperson: Dr J. U. Ezenwenyi (Virtual)
		Chairperson: Dr. Dr. C. F. Ikeogu & Dr. C. A. Nwigwe (Physical)
3.00 – 3.40pm	Presentation of Communiqué	Dr. Isaac Ugwumba & Dr. Clement C. Ezegbe
3.45 – 3.50pm	Announcements	Dr. Onyekachi Chukwu
3.50 – 3.55	Vote of Thanks	Dr Eucharia A. Obidiebube
3.55 – 4.00pm	Closing Prayer	Dr Chika F. Ikeogu
4.00pm	Departure	

FOREWORD

It is with great pleasure that I introduce the conference proceedings titled "Digitalization of Agriculture and Bio-conservation for Food Security." In an era marked by unprecedented challenges to global food systems, this collection of papers stands as a testament to the innovative approaches emerging at the intersection of technology and agriculture.

As our world grapples with the urgent need to sustainably feed a growing population while preserving our natural resources, the role of digitalization in agriculture has become increasingly paramount. From precision farming and remote sensing to blockchain-enabled supply chains and AI-driven decision support systems, digital technologies offer immense potential to enhance productivity, optimize resource allocation, and foster resilience in the face of climate change.

Furthermore, the imperative to safeguard biodiversity and conserve our ecosystems has never been more pressing. Through bio-conservation efforts, we strive not only to protect the diversity of life on Earth but also to ensure the long-term viability of our food production systems. By harnessing the power of digital tools in tandem with ecological principles, we can forge a path towards sustainable agriculture that harmonizes with nature rather than exploits it.

Within these proceedings, readers will find a wealth of knowledge, insights, and innovative solutions contributed by researchers, practitioners, and policymakers from around the globe. Each paper encapsulates the spirit of collaboration and interdisciplinary thinking essential for addressing the complex challenges facing agriculture and food security in the 21st century.

I extend my sincere gratitude to all the authors for their invaluable contributions and to the organizers for orchestrating this vital platform for knowledge exchange. May the discussions and discoveries contained within these pages inspire continued advancements in the digitalization of agriculture and the pursuit of bio-conservation for a more food-secure and sustainable future.

Warm regards,

Rotimi E. Aluko, PhD.
Professor & Tier 1 Canada Research Chair
Department of Food and Human Nutritional Sciences
University of Manitoba, Winnipeg, MB, Canada

PREFACE

Welcome to the conference proceedings titled "Digitalization of Agriculture and Bio-conservation for Food Security." This proceedings represents a culmination of efforts by experts, scholars, and practitioners dedicated to exploring the transformative potential of digital technologies in agriculture while emphasizing the critical importance of bio-conservation for ensuring food security.

In recent years, the convergence of agriculture and digitalization has spurred a paradigm shift in how we produce, manage, and distribute food. From the adoption of precision farming techniques to the integration of data-driven decision support systems, technology has become an indispensable tool in addressing the complex challenges facing the agricultural sector.

At the same time, we recognize the urgent need to prioritize bio-conservation efforts as we navigate a rapidly changing environmental landscape. Preserving biodiversity, safeguarding natural habitats, and promoting sustainable farming practices are essential components of ensuring the long-term resilience of our food systems. Hence the the theme will be discussed within the following eight sub-themes:

1. Precision crop production strategies for food security
2. Digital strategies for natural resources and environmental management
3. Gender participation in agricultural digitalization: the challenges and prospects
4. Sustainable aquaculture: a lead way to national food security, wealth creation and nature conservation
5. Soil smart agriculture for ecosystem services and food security
6. Precision farming: using digital technologies for animal management
7. Trends, challenges and prospects of digitalizing extension services and agricultural economy
8. Novel technologies in food processing

Within these proceedings, readers will find a diverse array of research findings, case studies, and innovative solutions presented by leading experts in the field. Topics range from the use of satellite imagery for crop monitoring to the implementation of agroecological principles in farming practices, reflecting the interdisciplinary nature of the digitalization-agriculture nexus.

As editors, we are grateful for the contributions of all the authors whose work has enriched this volume and advanced our collective understanding of the challenges and opportunities at the intersection of digitalization, agriculture, and bio-conservation.

We hope that this compilation serves as a valuable resource for researchers, policymakers, and practitioners alike, inspiring continued collaboration and innovation in pursuit of a more sustainable and food-secure future.

Warm regards,

Dr. Chika Florence Ikeogu
Deputy Chairman, Editorial Board FAIC 2024 and Chairman, Technical and Review Committee,
Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria

AN ADDRESS DELIVERED BY THE DEAN, FACULTY OF AGRICULTURE, NNAMDI AZIKIWE UNIVERSITY, AWKA, NIGERIA

PROTOCOL

On behalf of the Faculty of Agriculture, Nnamdi Azikiwe University, Awka and Ifite-Ogwari Annex and the Local Organizing Committee of this auspicious 2nd International Conference, I welcome every one of you. I am deeply honoured to be the Dean of this Faculty and to be at the helm of affairs in organizing this 2nd International Conference with the theme Digitalization of Agriculture and Bioconservation for Food Security. I started my work as the Dean of the Faculty by hosting a banquet tagged Repositioning of Faculty of Agriculture for Greatness and Productivity. The pursuit of that repositioning of the faculty for greatness and productivity is still the underlying aim for every other activity in the faculty including this 2nd (Second) International Conference. It is on this note, I welcome everyone of our guests who has chosen to honour our invitation to be witnesses of the ongoing transition. Thanks for being part of our story of change, you have not only come to witness a change in our faculty, you have also come to gain knowledge required for change in your farm business and in your person.

Faculty of Agriculture Nnamdi Azikiwe University started in 2011 following a successful Resource verification exercise by NUC team with Prof. P.C. Nnabude as the pioneer Dean. The Faculty started with seven departments: Agricultural Economics and Extension, Animal Science, Crop science and Horticulture, Fisheries and Aquaculture Management, Food Science and Technology, Forestry and Wildlife, Soil Science. The Faculty has grown from babyhood to adolescent so it is time to transit to adulthood. The transition to adulthood if not well-planned results into the making of an adult with a baby brain, Thus, the need for Repositioning of the Faculty to prepare her for an adult stage characterized by greatness and productivity. The reason for International Conference is to relate with practitioners in the same trade at the global parlance, to learn from their achievements, challenges, strategies designed to surmount challenges,

It is on this note that the Local Organizing Committee went within and beyond the shores of Nigeria to bring not just erudite personalities in the field of Agriculture but also real farmers with wealth of experiences from the practice of farming:

1. Dr. Yemi Akinbamijo, Former Executive Director, Forum for Agricultural Research in Africa, Ghana.
2. Prof. Akindele Vice Chancellor, Redeemer’s University, Ede, Osun State, Nigeria.
3. Rev. Fr. Prof Godfrey Nzamujo Director/CEO Songhai Integrated Farm, Port Novo.
4. Prof. Rotimi Aliluko from University of Manitoba, Canada

With these veterans in the agricultural business I believe everyone who has come here will have an inward chard, a new propensity to agriculture and farming. The conference opening ceremony will be followed by a section tagged “Farmers Summit” a town and gown interactive section, where academics will become acquainted with the farmers challenges and farmers will go home with solutions to their problems, the LOC therefore sought out for successful farmers who will relate to others the secret of their success especially in the realities of Nigeria today.

I must commend our visionary Vice Chancellor, Prof. Charles Esimone for his interest in development of Faculty of Agriculture, I thank him especially for PROJECT 200 that has brought our University among the best in the World. To me he has set the pace that summarizes the fact that leadership is all that is required to move from one position to better one. I have also made up my mind to make Faculty of Agriculture Nnamdi Azikiwe University one the best Faculties of Agriculture in Nigeria and in Africa. It is therefore my utmost desire that the big wigs in agricultural industry: the Keynote address speaker, the lead paper presenters will oblige us with the personal requests made on them behind the scene. Collaboration and partnership are the two key ingredients for achieving great feats in life, these are our two major requests to each of them, so we can climb on their shoulders to fly. I believe strongly that if they will honour our requests, the sky will be our starting point.

Once again, I welcome you all to this auspicious conference as I enjoin you to avoid distractions, listen with rapt attention, keep your eyes on the ball, so you will return home a changed man/woman with a new zeal to embark on farming in a new way, using proven methodologies that enhance productivity.

Thank you.

Prof. Cordelia I. Ebenebe, RAS, FCASN, FASAN, MNSAP, MNIAS
Dean, Faculty of Agriculture, Nnamdi Azikiwe University, Awka

KEYNOTE ADDRESS

Big Data Science and the Application of Digital Twins: Imperatives for Africa's Agriculture

Dr. Yemi Akinbamijo, PhD

International Agricultural Research for Development Expert and Former Executive Director, Forum for Agricultural Research in Africa (FARA)

on the Occasion of the 2nd Faculty of Agriculture International Conference (Hybrid), Nnamdi Azikiwe University, Held at the University Auditorium, Awka Campus of the University from 12th to 14th March, 2024, during the Openning Ceremony Being Thursday 13th March, 2024.

INTRODUCTION

The present paper places its emphasis on the emerging but poorly understood concept of 'Big Data and Digital Twins'. The literature describes Digital Twins as digital models of actual physical systems interweaving solutions of complex systems analysis, decision support and technology integration[1]. In the Article ***Computers and Electronics in Agriculture***, *Pylianidis* describes Digital Twins as a digital or virtual representation of physical assets, products or services[2]. Digital Twins applications collect real-world data to create simulations through integrated models that are useful in providing decision support in the life cycle of a product or system or service[3]. The development and use of digital twins have been on the ascendency in the transformation agenda of many sectors of development including industry, service, and more recently the agricultural sectors[4]. Digital twins application provides different levels of control over physical units and helps to manage complex systems through the integration of a range of technologies. Lately, the agricultural sector and the food system have seen several technological improvements including the development and use of digital twins. In this presentation, I shall draw your attention to how digital twin technology has been utilized in different economic sectors including agricultural sector by emphasizing the benefits it brings to these sectors. I will further discuss the practical challenges limiting with the adoption and use of digital twin in the agri-food system. Before I end my presentation, I shall make propositions worth considering in our collective efforts to adopt and use of digital twin to transform the agri-food system.

APPLICATION OF DIGITAL TWIN IN SELECTED SECTORS

Research has shown that over the past few years, the use of digital twin has been increasing across several disciplines. The concept of digital twin was introduced in 2003[5] and since then, it has been applied in various

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[1] Pylianidis, C., Sjoukje Osinga , Ioannis N. Athanasiadis. Introducing digital twins to agriculture Wageningen University and Research, the Netherlands.
[2] O. Elijah, I. Orikumhi, T. A. Rahman, S. A. Babale, and S. I. Orakwue, "Enabling smart agriculture in nigeria: Application of IoT and data analytics," in 2017 IEEE 3rd International Conference on Electro-Technology for National Development (NIGERCON). IEEE, 2017, pp. 762–766.
[3] Q. Qi, F. Tao, T. Hu, N. Anwer, A. Liu, Y. Wei, L. Wang, and A. Nee, "Enabling technologies and tools for digital twin," Journal of Manufacturing Systems, Qi2019.
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5 M. Grieves, "Digital twin: manufacturing excellence through virtual factory replication," White paper, vol. 1, pp. 1–7, 2014.

fields. The manufacturing sector[6], the automotive sector[7], the energy sector[8], the healthcare sector[9], petrochemical[10] and the utility sector[11] have all benefited from the application of digital twin for addressing their respective difficulties. However, the application of digital twins application in agriculture is an emerging area[12]. This provides an opportunity for researchers and scientist to focus their lenses on its application in the agricultural sector. This is particularly so in Africa where efforts are being made to draw attention to the enormous contribution of digital twin can make towards the promotion and transformation of the agri-food system of Africa where millions are still food insecure and malnourished. The concept of digital twin in agriculture is described as consisting of a physical system which is interconnected to the virtual system to monitor and control farming (*crop, livestock, aquaculture*) process.

The emergence and increased use of digital twin application in the different sectors of several economies is attributed to many factors including the enhanced uptake of Internet of technologies th*at al*low for the monitoring of physical twin at high spatial resolutions in real-time, through both miniature devices and remote sensing. Digital twins have been useful for bringing together the physical and virtual spaces guaranteeing information continuity through the system lifecycle, system development and validation through simulation[13]. The integration of internet of things and data analysis has enabled data acquisition, simulations, and interaction between human and physical objects on the field[14]. Promoting technologies such as wireless communication technologies and cloud computing have also triggered the interactions between the physical and virtual space and have led to the increased application of digital twin in various economic sectors[15].

APPLICATION OF DIGITAL TWIN IN THE AGRICULTURAL SECTOR

The use of innovative technologies such as the internet of things (IoT), data analytics (DA), and artificial intelligence (AI) in the agriculture sector is aimed at addressing the issues of food security globally[16]. These technologies pave the way for smart agricultural practices with applications such as real-time monitoring, tracking, and tracing in the food cycle, precision agriculture, agricultural machinery, as well as greenhouse production of food crops.

There are several advantages digital twin provides to the agri-food sector. The use of digital twin helps actors along the agri-food system to better understand the operations and processes required in different agricultural activities. Actors are able to use the virtual systems of various applications of the digital twin to simulate the performance of various farm inputs and growth parameters. Actors in the sector can estimate how the different parameters affect growth processes and production within the sector. Digital twins models can be used to educate agricultural value chain actors on various aspect of the agri-food system. The virtual system can be used to train stakeholders for skills acquisition without embarking on actual farming on the field. One of the potential benefits of the digital twin to the agricultural sector is its ability to interact with the physical

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[12] [12] R. G. Alves, G. Souza, R. F. Maia, A. L. H. Tran, C. Kamienski, J.-P. Soininen, P. T. Aquino, and F. Lima, "A digital twin for smart farming," in 2019 IEEE Global Humanitarian Technology Conference (GHTC). IEEE, 2019, pp. 1–4.

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[14] Abioye, A.E., Sharul, K. A. R., and Olakunle, E. Enabling Smart Agriculture in Nigeria: Application of Digital-Twin Technology Conference Paper · July 2021 DOI: 10.1109/ICMEAS52683.2021.9692351

[15] S. Neethirajan and B. Kemp, "Digital twins in livestock farming," Animals, vol. 11, no. 4, p. 1008, 2021.

[16] O. Elijah, T. A. Rahman, I. Orikumhi, C. Y. Leow, and M. N. Hindia, "An overview of internet of things (IoT) and data analytics in agriculture: Benefits and challenges," IEEE Internet of Things Journal, vol. 5, no. 5, pp. 3758–3773, 2018.

system using a virtual system, and this provides enormous opportunity for experts to provide technical support to farmers and other value chain actors remotely. Digital twins have the potential to transform agricultural practice in the developing world such as Africa, Asia, and South America as well as the Caribbeans. This is particularly true especially for rural dwellers in in these economies who are constantly exposed to a lot of risks such as drought, diseases, and other non-agricultural-related problems such as security[17].

I wish to state here that, despite the tremendous benefits digital twins provide to the agri-food system in Africa and other developing world, its application in the agriculture sector has been at a low level, and traditional practice and small-scale farming still dominate in these regions. Socioeconomic factors responsible for this observation include low literacy rate among farmers, lack of internet, the relatively high cost associated with such technologies, and non-adaptability of some of these technologies to the African terrain[18]. Regardless, governments in Africa are making tremendous efforts to promote the adoption and use of digital twin technologies across the continent as evident in the increased area under smart farming over the last five years[19]. However, there is still tremendous opportunity for the revolutionizing of the agricultural sector using the latest innovative technologies in irrigation, smart farming, livestock, preservation, equipment, and crop growth models, and ***I call upon*** scientists and researchers on the continent to take up this challenge.

Smart farming, irrigation, livestock farming, food preservation, equipment automation and crop growth model are few of the agricultural sub-sectors that can easily adopt digital twin for transformation and growth.

Smart Farming

Smart farming involves the use of modern technologies in various farming activities to reduce the amount of agricultural input while increasing efficiency and productivity[20]. The use of digital twin technology is intended to increase agricultural production with minimal use of farming inputs is a **necessary and sufficient condition** for the transformation of the food system. Several studies including[21] have demonstrated the ability for smart farming to estimate final production/output and resource consumption based on different parameters that govern agricultural activities. The literature has well documented the application of digital twin framework for the detection of crop diseases, monitoring of soil parameters and prescription of fertilizers around the world. In Nigeria for example, digital twins have been applied in tomato cultivation using sensor information from a physical greenhouse[22]. A similar approach has been recorded in the literature where digital twin has been used for future cultivation and production of orchard farms where the digital twin adaptively learnt the production system by querying it to automatically analyze specific outcomes under varying simulated environmental and orchard management parameters[23]. Another practical example is a novel digital twin for hydroponic farming which was achieved using wireless sensor networks to track the environmental condition and growth pattern of plants. The data collected was used to develop a forecasting model integrated into digital twin to serve as feedback to the farmer to aid decision management[24].

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[24] M. Jans-Singh, K. Leeming, R. Choudhary, and M. Girolami, "Digital twin of an urban-integrated hydroponic farm," Data-Centric Engineering, vol. 1, 2020.

Irrigation

Digital twin applications have enhanced the proactive management of irrigation systems through online predictions to mitigate the effect of environmental disturbances before there is an adverse effect on the yield and quality of crops produce. Toward building a digital farming environment, a cyber-physical system using digital twin technology can be developed for better management of resources such as water and fertilizer[25]. To further explore the opportunities in digital twin to help improve irrigation, the integration of digital twin with real-time data monitoring has helped to provide the virtual digital representation of soil, plant, and weather behavior to optimize water and fertilizer usage[26].

Livestock Farming

The integration of digital twin technology into livestock farming is still evolving, but it has the tendency to improve on the real-time monitoring and control of the behaviors, physiological, and environmental parameters surrounding the animals using different types of sensors, camera, microphone, and detector27. Using the data collected from the animal's ecosystem and condition such as body temperatures, humidity, it is highly possible to formulate a control strategy for the management of the barn, pen, or housing of the animals. Similarly, the use of digital twin technologies through real-time video capture of images can facilitate early-stage disease detection when there is an anomaly from the usual behavior of farm animals. This has shown to prevent further spread of the diseases among the herd28. In countries in Africa such as Nigeria, Sudan, Ghana, and Burkina Faso, cattle farmers and headers are faced with a lot of challenges ranging from cattle rustling, cattle theft, and uncontrolled grazing. Digital twin offers a promising solution to these issues, as effective sensor-based monitoring and tracking of livestock movement with grazing advice can be achieved to address some of the issues faced by livestock farmers29.

Crop Growth Model

The use of crop growth models is a promising strategy for simulation of crop performance. The increasing use of data-driven predictive modelling of weather and soil moisture predictions can be enhanced through digital twin to simulate crop response to water deficit as well as control of irrigation30. Crop water simulation models such as AQUACROP, regression, artificial intelligence, and other mechanistic models which provide predictions on crop development, weather, and environmental factors such as soil moisture content, can be implemented efficiently on a digital twin framework to guide farmers on the management of their farmers. The feasibility of digital twin to monitor nitrogen cycle between growth models and soil models is also being studies to limit losses and to minimize Nitrogen use by the plant31. There is the need for farmers and researchers, especially in Africa to put into use some of these crop growth models to be able to simulate and validate crop cultivation performance in terms of yield and required agricultural inputs.

Food Processing and Preservation

Food waste and high post-harvest losses continue to be a bane in many African countries, and their contribution to food insecurity, poverty and malnutrition cannot be underestimated. Preservation of agricultural produce helps to reduce waste and spoilage due to bacterial, fungi and other microorganisms or chemical changes. The lack of adequate preservation results in post-harvest food loss and poses as a major factor of high cost of food and food insecurity, especially for seasonal produce which is common in Africa. Traditional methods of food preservation such as smoking, salting, fermentation, roasting, canning or

[25] R. G. Alves, G. Souza, R. F. Maia, A. L. H. Tran, C. Kamienski, J.-P. Soininen, P. T. Aquino, and F. Lima, "A digital twin for smart farming," in 2019 IEEE Global Humanitarian Technology Conference (GHTC). IEEE, 2019, pp. 1–4.
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[31] B. T, Accessed on May 06, 2021. [Online]. Available: https://www.wur.nl/en/project/Digital-Future-Farm.htm.

bottling, and refrigeration are still largely practiced in many countries in Africa and around the developing world32. It is estimated that approximately 50% of perishable farm produce, including fruits, vegetables, roots, and tubers, and approximately 30% of food grains, such as maize, millet, and rice, are lost after harvest or before reaching the market in West African countries due to a lack of modern preservation facilities33. Digital twins can be applied in better preservation methods such as solar drying to predict the appropriate time to halt drying to avoid under-drying or over-drying. In digital twin, a virtual system can be integrated with the physical system of a solar dryer to capture relevant kinetics of heat and mass transfer processes inside and around the product34.

Agricultural Robotics and Equipment Automation

In the area of industrial automation and agricultural robotics, full digitization of production equipment can leverage on the internet of things technologies to achieve the interconnection of equipment's in digital twin configuration. The data of production process are transferred to the cloud server where an artificial intelligence processing can be equipment or farming controllers, the production activities will not be on hold as it was in many cases.

Agricultural Business

Digital twin can be applied in agricultural businesses to simulate, plan and analyze farming process towards sustainability. Risk analysis can be carried out by forecasting models to minimize external risks from uncontrollable factors such as weather or drought. Farmers can simulate profitability by minimizing cost and decreasing time to market their agricultural products. In addition, methods to determine the per-land area yield and soil management can be simulated to maximize profitability.

MAIN CHALLENGES TO THE APPLICATION OF DIGITAL TWINS

Notwithstanding the obvious benefits of digital twin in transforming the agri-food system, its development and adoption are challenged, especially in Africa, and I seek to discuss some of these challenges in the African context.

Inadequate Human Capacity and Expertise

The development and deployment of digital twin begins with the design which involves the collaboration of researchers from different fields. Skills and expertise such as data scientist, engineering, agricultural scientist, animal scientist, developers and programmers, business analyst are required for a successful implementation of digital twin. Though available on the continent, the number of scientists and researchers with these skills and expertise are limited in Africa. With low number of scientists in Africa (*250 researchers per million people)*[35] on the continent, it is imperative that more scientists are trained in these areas of expertise by various governments to take advantage of the benefits digital twin provides to the agricultural sector. The ability to coordinate between different departments, research organizations and ministries where this expertise reside can pose a challenge for the development and operationalization of the technology in Africa.

Inadequate Infrastructure

The operation of digital twins' technology especially in the agricultural sector requires basic infrastructure such as constant electricity, access to reliable internet, water availability and equipped laboratories for research purposes. The lack of these facilities in many parts of Africa pose a challenge to the deployment of the technology. Several models of digital twin have been developed for agricultural production in other parts of the world[36]. While these models can be adopted for digital twin in Africa there is the need for enhancement

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[33] S. Agbota, Accessed on May 10, 2021. [Online]. Available: https://www.sunnewsonline.com/how-food-preservation-technologyll-boost-nigerian-markets-competitiveness.
[34] K. Prawiranto, J. Carmeliet, and T. Defraeye, "Physics-based digital twin identifies trade-offs between drying time, fruit quality, and energy use for solar drying," Frontiers in Sustainable Food Systems, vol. 4, p. 286, 2021.
[35] World Economic Forum (2019). There are not enough scientists in Africa. How can we turn this around?
[36] E. A. Abioye, M. S. Z. Abidin, M. S. A. Mahmud, S. Buyamin, M. H. I. Ishak, M. K. I. Abd Rahman, A. O. Otuoze, P. Onotu, and M. S. A. Ramli, "A review on monitoring and advanced control strategies for precision irrigation," Computers and Electronics in Agriculture, vol. 173, p. 105441, 2020.

or modification of such models to suit the natural, climatic, environmental, soil, pest, and diseases as well as the socioeconomic conditions of the continent.

Difficulty in Accessing Big Data

With the large amount of data generated and analyzed in digital twins' systems, big data algorithms and the internet of things technology are powerful allies that can provide support to a great extent to successful digital twins implementations[37], but these are generally unavailable in Africa. Also, the development and deployment of digital twins rely on the availability of accurate and quality data especially geospatial data. Data acquisition problems especially in sub-Saharan Africa has been detected. One of the major data acquisition problems in Sub-Saharan Africa includes instrumental errors due to lack of modern equipment for data capture and observer errors which arise from the limitation of human expertise. especially error in the reading data.

High Cost of Implementation

High costs of implementation due to the increased cost of sensors and computational resources needed pose another challenge to the implementation of the technology in Africa[38]. Due to the expensiveness of digital twin implementations, their accessibility is limited by the accessibility of such resources, which is often poor in developing countries[39]. The increase in the cost of sensors needed comes with an added complexity regarding data connectivity and processing poses a challenge. This challenge also poses a limitation for practitioners to pilot the technology for full-scale deployment.

Low Predictive Power of Digital Twin

Digital Twins are also expected to offer predictions of the future world for better planning and preparations towards eventualities against the agri-food system. However, digital twin that extrapolate knowledge based on data from the past into the future may fail to take into consideration relevant modifications that may come about in environmental conditions, social and economic behaviour, market structures, laws and institutions or governments[40]. Such changes may undermine the relevance of the future that is presented by the digital twin technology. For example, data of the past may fail to predict disruptive events like the Russia-Ukraine conflict, or environmental disasters such as excessive rain that causes floods, or extreme drought conditions. While the digital twin is said to represent reality, reality may change faster than it is able to anticipate, given that it is based on data from the past.

RECOMMENDATIONS

The application and tremendous benefits of digital twin technology to the transformation of the agri-food system especially in Africa has been discussed. The challenges that militate against the application of the technology to take advantage of its benefits have also been discussed in this presentation. *May I take* this opportunity to make the following suggestions as my recommendations to enhance the development and application of digital technology in the agri-food system in Africa.

Pilot Digital Twin

Piloting the technology is needed to develop models such as fertilizer models, crop growth models, irrigation models, preservation models, etc. for various agricultural practices. This will ensure generating interest in the application of the technology through the showcasing of the enormous benefits digital twin to the agri-food sector[41]. Governments on the African continent are urged to develop fertilizers to suit different soil types in the various countries. Digital Twin models can be developed and piloted for the application of fertilizers that are suitable for the different soil and crops such as rice, maize and sorghum. The soil test meter has been

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used to determine the values of soil parameters such as pH, organic carbon, and sodium levels in Africa[42]. The production of various crops in Africa can be digitized to analyze growth and farm input parameters, and the data generated from these analyses can be converted into models for simulation purposes[43]. Research in preservation models can be piloted to digitize the traditional methods and adopt modernized methods used in developed countries. Several preservation models for perishable crops can be developed using DT to address the current challenges of farmers in many parts of Africa[44]. Several livestock farming systems such as fish, poultry, snail, pig, snail, cattle, goat, and rabbit farming require models that consider food formulation, weather condition, diseases, and market. Automated physical systems can be deployed for monitoring fishponds and interconnected to the digital twin platform, and the data such as feeds, medication, rate of growth and production acquired can be used for modelling of fish production in various parts of the continent[45].

Create Digital Twins Agriculture Platform

One of the most important constraints concerns the limited interoperability and lack of openness of different technical systems, thus limiting the choices farmers can make between suppliers of new technologies[46]. There is the need for increased research into the development and deployment of a digital twin platform for the agricultural sector and the entire food system. An enhanced interoperability would allow for increased data sharing and the resulting knowledge generation[47]. Improved and inclusive information flows and management within and among the targeted agricultural sectors based on transparent and fair data governance practices. Another main constraint is the lack of information on the effectiveness of new technologies which slows down their up-take[48]. Digital Twin could be deployed as an online platform to address this challenge faced by farmers and other value chain actors. Models which are developed from pilot projects be integrated into a digital twin platform for use by food system value chain actors in Africa[49].

Facilitate Research Collaborations

Applying participatory design methodologies in digital development projects can help develop more user-centered innovation[50]. There is enormous opportunity in the agriculture sector for collaboration among local researchers from the academia, research institutes and industry inn Africa. There are several research funds for developing countries that can be targeted towards international research collaboration for the deployment of digital twin in agriculture[51]. Examples of research funds are the Canada Fund for Local Initiatives (CFLI)[52] which is targeted for high-impact projects in developing countries, and Kirkhouse Trust targeted at legume research. I entreat scientists and researchers on the continent to take advantage of these opportunities to learn from their counterparts through collaborative drive to broaden their knowledge, skills, and expertise in the field of digital twin.

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Create Enabling Policy Environment

Realizing the vision of digital transformation for Africa requires appropriate policies and an enabling environment with critical policy reforms to the foundation pillars and critical sectors to drive digital transformation. Collaborative regulatory measures and tools are the new frontier for regulators and policy makers as they work towards maximizing the opportunities afforded by digital transformation across industries[53]. Recognizing the potential of emerging technologies and the impact that policy and regulatory frameworks can have on their success, countries and their regulators should encourage a regulatory paradigm that pushes frontiers and enables digital transformation[54]. Policy support for the application of digital twins is needed to improve efficiency, equity, and environmental sustainability of the African food system. Public policy and regulatory frameworks need to be up-to-date, flexible, incentive-based and market-driven to support digital transformation across sectors and across the continent regions[55]. Policies to support general agricultural financing including public financing digital twins is relevant for this course. The private sector could be leveraged as a good sources of financing technological advancement and application in the agri-food system. Sources of private finance for digitalizing the food system are growing on the continent and includes farmers' own-savings, local and international banks, microfinance institutions, and private sector foundations as well as agricultural investment funds. Actions such as harmonization of policy frameworks, integration of e-services *at al*l levels of economic sectors, strengthening collaboration between African institutions and building digital infrastructure have been identified to promote the application of digital twins in the food system of the continent[56].

CONCLUSION

The concept of digital twins and its application in different sectors of development as well as the agricultural and food system sectors have been presented in this paper. Several applications of digital twins including smart farming, livestock, food preservation, agricultural robotics and equipment automation, crop growth models, agriculture, and food processing, and have been identified and discussed in this presentation. The benefits and challenges of digital twins in the Africa context have also been presented. The steps towards the adoption of digital twins in Africa have also been presented. It is my strongest view that digital twins' applications offer an opportunity to transform the agriculture sector and food systems of Africa. To take full advantage of these opportunities, adequate infrastructure needs to be made available for the successful deployment of digital twin in Africa. Governments need to show commitment by creating the enabling environment in terms of policies and investment to enhance the involvement of the private sector in promoting the use and adoption of digital twins. There is an urgent need to train scientists to develop their expertise in digital twins and their application to take advantage of the benefits the technology brings towards the transformation of the agri-food sector.

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LEAD PAPER

Exploring Trends of Digitalization in Natural Resources and Bio-Conservation Management

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ABSTRACT

In this era of rapid technological advancements, the application of digitalization in natural resources and bio-conservation management has become crucial for sustainable development and biodiversity preservation. This review paper systematically examines the evolving trends, applications, and implications of digital technologies in the context of natural resources and bio-conservation management. Drawing upon a wide range of sources, including scholarly articles, case studies, and technological assessments, the paper outlines the transformative potential of digital tools such as Geographic Information Systems (GIS), remote sensing, artificial intelligence (AI), blockchain, and the Internet of Things (IoT) in enhancing the effectiveness of conservation efforts.

The analysis reveals that digitalization facilitates unprecedented levels of data collection, processing, and dissemination, enabling more informed decision-making and fostering greater transparency and collaboration among stakeholders. Specifically, the paper highlights how digital technologies are being employed to monitor ecosystem changes, track wildlife populations, optimize resource use, and engage communities in conservation practices. Furthermore, the review identifies key challenges associated with the digital transition, including technological accessibility, data security, privacy concerns, and the need for capacity building among conservation practitioners.

INTRODUCTION

Nigeria is endowed with abundant natural resources and a rich biodiversity that includes a wide range of ecosystems from mangroves and rainforests in the south to various types of savanna landscapes in the north. However, the country faces significant environmental challenges that threaten its natural heritage and the livelihoods of its people. These pressures stem from a combination of socio-economic, environmental, and political factors that interplay to exacerbate the strain on its natural resources and biodiversity. Of the socio-economic factors, rapid population growth is key. Nigeria's population is estimated at slightly over 223.8 million and ranked as the 6th most populous country in the world and largest in Africa at an annual growth rate of 3.2 per cent (NPC, 2023). This increase in population has continued to place immense pressure on our natural resources. The demand for housing, arable land, freshwater, and other resources has led to extensive habitat loss and degradation, significantly impacting biodiversity. The quest for agricultural land has resulted in the conversion of natural habitats into farmland, while the need for housing and urban development has led to deforestation and the loss of wildlife habitats. To address these multifaceted challenges facing natural resources and biodiversity conservation, digitalisation holds great potentials.

Digitalization in natural resources and bio-conservation management is the use of digital technologies in managing natural resources and conserving biodiversity. In recent years, digitalization has revolutionized various sectors, including natural resources management and bio-conservation. According to Mondejar *et al.* (2021), the world is transitioning through the digitalization era in which most of our daily activities are highly dependent on innovative digital and computer technologies. This transitioning has been driven by advancements in digital technology. Digitalization covers a wide range of digital technology trends, including virtualisation, sensor-based technologies including the Internet of Things (IoT), additive manufacturing, wireless communication technologies (e.g., 5G), robotization, digital platforms, digital twins, blockchain technologies, machine learning and artificial intelligence (Eerola *et al.*, 2021). Existing digital tools enable researchers, conservationists, and policymakers to monitor, analyze, and manage natural resources and biodiversity more effectively than ever before, thereby leading to improvement in efficiency of many operations, and reduction in human errors and operational costs.

In natural resources and biodiversity conservation, digitalization is gaining prominence. Many organizations have replaced analog processes with digital alternatives. Indeed, digital technology increasingly influences the ways members of the public perceive, think about and engage with nature (Kahn 2011; Verma *et al.* 2015). Digital technologies are often greeted with optimism by conservationists because they promise more data, faster processing, better information access and connectivity, new communication routes, exciting visual representations and empowering decision-making support systems (Arts *et al.*, 2015). Such optimism may be deceptive in light of the many practical challenges (Joppa 2015; Newey *et al.* 2015), and the unintended consequences that technology use may bring (Humle *et al.* 2014; Maffey *et al.* 2015). The objectives of this review paper are to identify and discuss emerging digital technologies and trends in the field of natural resources and bio-conservation management, outline the challenges and barriers to the adoption of digital technologies in natural resources management, and propose a strategic framework for the effective integration and implementation of digital technologies in biodiversity conservation and natural resources management.

EMERGING DIGITAL TECHNOLOGIES IN NATURAL RESOURCES AND BIODIVERSITY MANAGEMENT

The advancement in information and communications technologies has been a very important enabler of innovation and development (Akindele, *et al.*, 2022). Emerging digital technologies are increasingly playing a pivotal role in natural resources and biodiversity management, offering innovative solutions to some of the most pressing environmental challenges. These technologies include the following:

Artificial Intelligence (AI) and Machine Learning (ML)

Artificial Intelligence (AI) and Machine Learning (ML) stand out for their ability to process and analyze vast amounts of environmental data with unprecedented speed and accuracy. AI applications in wildlife conservation, for instance, are revolutionizing species monitoring and protection efforts. Algorithms trained to recognize individual animals via camera trap images are facilitating more efficient population assessments and behavioral studies. Ko *et al.* (2021) detail how AI-enabled acoustic monitoring systems can detect and identify the calls of specific species in real-time, allowing for non-invasive monitoring of biodiversity in remote or challenging terrains. Similarly, ML models are being employed to predict the impacts of climate change on species distributions, offering valuable insights for conservation planning and habitat management (Fegraus *et al.*, 2020). Another area of application of AI and ML is in the development of a mobile application, named *PlantSnap*, for plant and tree identification. PlantSnap has a searchable database of over 650,000 plants and can be used to identify over 90% of all known species of plants and trees (Akindele, 2022).

Blockchain Technology

Blockchain technology is another emerging tool with significant potential in natural resources and biodiversity management. By providing a secure, decentralized platform for recording transactions, blockchain can enhance transparency and traceability in supply chains, crucial for combating illegal logging and wildlife trafficking. Transparency ensured by blockchain systems helps in verifying the legality and sustainability of natural resource extraction and trade practices, thereby promoting environmental stewardship and ethical business practices. Roe *et al.* (2019) explore the application of blockchain in certifying the provenance of sustainably sourced timber, demonstrating its potential to reduce illegal logging by ensuring that only legally harvested timber enters the global market.

The Internet of Things (IoT)

The Internet of Things (IoT) continues to make significant strides in environmental monitoring and resource management. Networks of sensors deployed across various ecosystems can collect real-time data on a range of environmental parameters, from soil moisture and temperature to forest canopy density and water quality. This real-time data collection facilitates dynamic management practices, enabling immediate responses to environmental changes or threats. For instance, IoT-enabled smart water management systems can significantly improve irrigation efficiency in agriculture, reducing water waste and enhancing crop yields (Jayaraman *et al.*, 2019). Additionally, IoT technologies are integral in urban environments, where they contribute to creating 'smart cities' that can monitor and manage energy consumption, waste production, and air quality, contributing to more sustainable urban development.

Virtual and Augmented Reality

Emerging digital technologies also encompass virtual and augmented reality (VR and AR), which offer novel ways to engage the public in conservation efforts and environmental education. By simulating real-world environments and ecological processes, VR and AR can enhance public understanding of complex environmental issues and foster a deeper connection to natural worlds. This immersive technology can be particularly effective in environmental education, providing interactive experiences that highlight the importance of biodiversity and the impacts of human activities on natural ecosystems. As these digital technologies continue to evolve, their integration into natural resources and biodiversity management promises not only to enhance operational efficiencies but also to foster greater public engagement and support for conservation efforts, paving the way for a more sustainable and informed interaction with the natural world.

Remote Sensing and GIS

Remote Sensing and Geographic Information Systems (GIS) have become indispensable tools in environmental science, offering detailed insights into earth's surfaces and facilitating the management of natural resources and conservation efforts. By collecting data from satellite imagery and aerial photography, remote sensing provides critical information on land use changes, vegetation cover, and water bodies, among other features. When combined with GIS, these data can be analyzed and visualized to support decision-making processes in urban planning, forestry, agriculture, and disaster management. Turner *et al.* (2015) underscore the importance of these technologies in biodiversity conservation, enabling the monitoring of ecosystem changes and habitat fragmentation on a global scale. The integration of remote sensing and GIS technologies thus represents a powerful approach to understanding and managing the Earth’s natural resources more effectively.

Big Data Analytics

Big Data Analytics in environmental science transforms large and complex datasets into actionable insights for natural resource management and conservation. By harnessing the power of advanced analytics, machine learning, and AI, researchers and practitioners can predict environmental trends, optimize resource use, and enhance biodiversity conservation strategies. Li *et al.* (2016) highlight the application of big data in understanding species distribution, genetic diversity, and ecosystem dynamics, thereby facilitating targeted conservation actions. Big data analytics not only aids in the efficient processing and analysis of data from satellite images, sensor networks, and citizen science initiatives but also supports the formulation of policies for sustainable environmental management. With the development of big data technologies, the speed of smart forestry construction and the level of forestry information management has significantly improved (Jing, *et al.*, 2023). A comprehensive survey of big data analytics in forestry has been provided by Zou *et al.* (2019).

IoT and Sensor Networks

The Internet of Things (IoT) and sensor networks are revolutionizing environmental monitoring and natural resource management by providing real-time data and enhancing connectivity across various devices. Martínez-Pérez *et al.* (2019) discuss how IoT technologies enable the precise monitoring of environmental conditions, such as air and water quality, forest health, and wildlife activity, through networks of interconnected sensors. This continuous stream of data supports more responsive and adaptive management strategies, allowing for immediate actions to mitigate environmental risks and conserve resources. IoT applications extend beyond monitoring, offering innovative solutions for smart agriculture, sustainable water management, and energy efficiency, thus playing a crucial role in advancing sustainable development goals.

DNA Barcoding and Molecular Ecology

DNA barcoding and molecular ecology are transforming biodiversity conservation and species identification by enabling the precise genetic analysis of organisms. This technology aids in the identification of species, even from minute samples, facilitating the monitoring of biodiversity and the detection of illegal wildlife trade. Hebert *et al.* (2003) introduced DNA barcoding as a method for rapid species identification, which has since been applied in various fields including conservation biology, ecosystem monitoring, and the study of species interactions. Molecular ecology, through the use of DNA barcoding and other genetic techniques, provides insights into the genetic diversity and evolutionary processes of species, offering a powerful tool for the conservation of biodiversity and the management of natural resources.

Citizen Science and Crowdsourcing

Citizen science and crowdsourcing are democratizing scientific research and conservation efforts, engaging the public in data collection and environmental monitoring. Through platforms and mobile applications, volunteers contribute valuable data on species observations, pollution levels, and habitat conditions. Bonney *et al.* (2014) discuss how these participatory science projects not only expand the scale and scope of research but also increase public awareness and engagement in conservation issues. Citizen science bridges the gap between the scientific community and the general public, fostering a collaborative approach to tackling environmental challenges and promoting a more inclusive model of scientific inquiry and environmental stewardship.

TRENDS IN DIGITALIZATION FOR NATURAL RESOURCE MANAGEMENT

The landscape of natural resource management is rapidly transforming through the integration of digital technologies, marking a significant shift towards more sustainable and efficient practices. Among these, Geographic Information Systems (GIS) and remote sensing technologies have become indispensable tools for mapping, analyzing, and monitoring natural resources. These technologies offer comprehensive spatial and temporal insights into land use patterns, vegetation cover, water resources, and wildlife habitats, facilitating informed decision-making and policy formulation. Turner *et al.* (2015) highlight the pivotal role of remote sensing in biodiversity conservation, providing a means to assess changes in ecosystem extent and health across large and often inaccessible areas. Similarly, GIS applications in natural resource management, as explored by Brown (2018), enable the integration of various data types and sources, supporting the planning and management of resources by predicting future trends and potential conflicts.

Advancements in big data analytics represent another significant trend, offering profound insights into natural resource management by processing vast amounts of data from diverse sources, including satellite imagery, sensor networks, and social media. These analytics can uncover patterns, trends, and relationships, facilitating predictive modeling and risk assessment in resource management. For example, Li *et al.* (2016) discuss how big data applications in biodiversity research can lead to more effective conservation strategies by enabling the analysis of species distribution, genetic information, and environmental changes on a global scale. This capacity for predictive analytics is crucial for anticipating environmental impacts, managing natural resources sustainably, and mitigating potential threats to biodiversity.

The Internet of Things (IoT) is also revolutionizing natural resource management by enabling the real-time monitoring and control of environmental parameters through networks of interconnected sensors and devices. Martínez-Pérez *et al.* (2019) describe how IoT applications in environmental monitoring can significantly improve the management of water resources, air quality, and forest health by providing continuous, real-time data. This granular level of monitoring allows for the immediate detection of anomalies, supporting rapid response to environmental incidents and enhancing the precision of conservation efforts. Moreover, IoT technologies facilitate the efficient use of natural resources, for example, through smart irrigation systems that optimize water usage based on soil moisture levels and weather forecasts, thereby contributing to more sustainable agricultural practices.

These trends in digitalization are paving the way for a new era in natural resource management, characterized by enhanced efficiency, accuracy, and sustainability. As these technologies continue to evolve and become more accessible, their integration into natural resource management practices is expected to deepen, offering promising avenues for addressing the complex challenges of conserving and managing the planet's invaluable natural resources.

CHALLENGES AND BARRIERS TO THE ADOPTION OF DIGITAL TECHNOLOGIES IN NATURAL RESOURCES MANAGEMENT

The adoption of digital technologies in natural resource management presents numerous benefits, including enhanced monitoring capabilities, improved decision-making, and increased efficiency. However, several challenges and barriers hinder the widespread implementation of these technologies. Understanding and addressing these obstacles is crucial for leveraging digital innovations to safeguard natural resources effectively.

Digital Divide

One significant challenge is the digital divide, which refers to the gap between individuals and communities that have access to digital technologies and those that do not. This divide is particularly pronounced in developing countries, where limited access to the internet and lack of digital literacy among local populations can impede the adoption of technologies like GIS, remote sensing, and IoT. The digital divide not only limits the ability of communities to engage in digital natural resource management but also exacerbates inequalities in access to information and resources (Sullivan, 2017). Overcoming this barrier requires targeted investments in digital infrastructure and educational programs to build local capacities and ensure equitable access to technology.

High Cost

Another barrier is the high cost associated with implementing and maintaining advanced digital technologies. The deployment of sensor networks, satellite imagery analysis, and sophisticated data analytics platforms often requires substantial financial investment, which can be prohibitive for many organizations and governments, especially in resource-constrained settings. The ongoing costs of data storage, processing, and analysis, along with the need for technical expertise, further compound this challenge (Kitchin, 2014). Securing funding and resources for these technologies necessitates innovative financial models and partnerships between the public and private sectors.

Data Privacy and Security concerns

Data privacy and security concerns also pose significant challenges to the adoption of digital technologies in natural resource management. The collection and analysis of environmental data, particularly through IoT devices and sensor networks, raise issues related to the privacy of individuals and communities and the security of sensitive information. Addressing these concerns requires robust data governance frameworks that ensure data are collected, stored, and used in a manner that respects privacy rights and protects against unauthorized access and cyber threats (Weber, 2010).

Interoperability and standardization issues

Interoperability and standardization issues further complicate the integration of digital technologies into natural resource management practices. The diversity of data formats, platforms, and protocols can hinder the seamless exchange and integration of data from different sources, limiting the effectiveness of digital solutions. Developing and adopting universal standards and protocols is essential for facilitating data sharing and integration across technologies and sectors (Janssen *et al.*, 2015).

Technological obsolescence

Technological obsolescence represents another challenge, as the rapid pace of innovation in digital technologies means that devices and systems can quickly become outdated. This necessitates continuous investment in technology upgrades and training for staff, which can be difficult for organizations to sustain over time. Planning for obsolescence and ensuring systems are adaptable and scalable can help mitigate these issues (Li, 2018).

Lack of awareness

Finally, there is often a lack of awareness and understanding of the potential benefits and applications of digital technologies among stakeholders involved in natural resource management. Overcoming skepticism and building trust in new technologies requires effective communication, demonstration projects that showcase tangible benefits, and the involvement of stakeholders in the design and implementation of digital solutions (Wilson *et al.*, 2017).

Addressing these challenges and barriers is essential for harnessing the full potential of digital technologies in natural resource management. It requires concerted efforts from governments, the private sector, academic institutions, and communities to invest in digital infrastructure, foster innovation, and build the capacities needed to implement and sustain these technologies.

STRATEGIES FOR THE EFFECTIVE INTEGRATION AND IMPLEMENTATION OF DIGITAL TECHNOLOGIES

Effective integration and implementation of digital technologies in natural resource management require strategic planning, stakeholder engagement, and robust institutional frameworks. Several key strategies can enhance the adoption and utilization of these technologies, ensuring that they contribute to sustainable resource management and biodiversity conservation.

Firstly, fostering collaboration and partnerships among stakeholders is essential for the successful integration of digital technologies. Collaboration between government agencies, research institutions, non-governmental organizations (NGOs), and local communities facilitates the sharing of resources, expertise, and best practices. By working together, stakeholders can leverage complementary strengths and resources, address common challenges, and develop innovative solutions to complex environmental issues (Rudd, 2018).

Secondly, building technical capacity and digital literacy among relevant stakeholders is critical for maximizing the benefits of digital technologies. Training programs, workshops, and capacity-building initiatives can equip individuals and organizations with the necessary skills to use digital tools effectively. Investing in education and skill development helps to overcome barriers related to the digital divide and empowers communities to take ownership of natural resource management initiatives (Duncan *et al.*, 2016).

Thirdly, establishing supportive policy and regulatory frameworks is essential for creating an enabling environment for the integration of digital technologies. Clear policies and regulations governing data management, privacy, and security provide certainty and guidance to stakeholders involved in natural resource management. Furthermore, policies that incentivize the adoption of digital technologies, such as tax incentives or grants for technology investments, can help overcome financial barriers and encourage innovation (McGinnis *et al.*, 2018).

Fourthly, promoting open data initiatives and data sharing platforms facilitates collaboration and transparency in natural resource management. Open data policies encourage the sharing of environmental data and information among stakeholders, fostering collaboration, innovation, and evidence-based decision-making. Open data platforms provide access to a wealth of information, enabling researchers, policymakers, and the public to analyze trends, identify patterns, and develop solutions to environmental challenges (Dufour-Kowalski *et al.*, 2019).

Fifthly, ensuring interoperability and compatibility among digital technologies is essential for seamless data exchange and integration. Standardizing data formats, protocols, and interfaces enables different systems to communicate and share information effectively. Interoperable technologies facilitate the integration of data from various sources, enhancing the accuracy and reliability of environmental monitoring and decision support systems (Mulders *et al.*, 2018).

Finally, fostering a culture of innovation and learning is crucial for adapting to evolving technological trends and maximizing the potential of digital tools. Encouraging experimentation, piloting new technologies, and learning from both successes and failures enables organizations to stay abreast of emerging trends and technologies. By embracing a culture of innovation, stakeholders can continuously improve their approaches to natural resource management and conservation (Sareen *et al.*, 2020).

The effective integration and implementation of digital technologies in natural resource management require a multifaceted approach that encompasses collaboration, capacity-building, supportive policies, data sharing, interoperability, and innovation. By adopting these strategies, stakeholders can harness the transformative potential of digital technologies to address pressing environmental challenges and achieve sustainable development goals.

PROPOSED FRAMEWORK FOR INTEGRATING DIGITAL TECHNOLOGIES INTO NATURAL RESOURCE AND BIO-CONSERVATION MANAGEMENT

Proposing a comprehensive framework for integrating digital technologies into natural resource and bio-conservation management involves several key components that together ensure the effective, sustainable, and equitable use of digital tools. The framework outlined in Table 1 is designed to guide policymakers, practitioners, and researchers in adopting and implementing digital solutions to enhance conservation efforts.

Table 1: Proposed framework for integrating digital technologies into natural resource and bio-conservation management

Major Components	Activities
1. Assessment and Planning	***a. Needs Assessment*** • Identify specific challenges and opportunities in natural resource and bio-conservation where digital technologies can provide solutions. • Assess the technological readiness of the region or sector, including infrastructure and local capacity for adopting digital technologies. ***b. Goal Setting*** • Define clear, measurable objectives for integrating digital technologies into conservation practices, aligning with broader conservation goals and sustainable development targets.
2. Technology Selection and Customization	***a. Evaluation of Digital Technologies*** • Review and evaluate available digital technologies (e.g., remote sensing, AI, GIS, blockchain, IoT) for their applicability, effectiveness, scalability, and sustainability in conservation contexts. • Consider the environmental impact of deploying these technologies, aiming for solutions that are not only effective but also environmentally sustainable. ***b. Customization and Localization*** • Customize digital solutions to address specific conservation needs, ecological characteristics, and socio-economic contexts. • Ensure technologies are accessible and usable by local communities, practitioners, and decision-makers.
3. Capacity Building and Stakeholders Engagement	***a. Training and Education*** • Develop and implement training programs for local communities, conservation practitioners, and policymakers on using and managing digital technologies. • Promote digital literacy and technical skills development to ensure broad-based participation and ownership. ***b. Stakeholders Engagement*** • Foster inclusive engagement processes that involve local communities, indigenous peoples, private sector, academia, and government agencies in the planning and implementation phases. • Encourage participatory approaches to technology deployment, ensuring th*at al*l voices are heard and considered.

4. Implementation and Integration	***a. Deployment of Technologies*** • Implement digital technologies according to the planned framework, ensuring that deployment is ethical, respects privacy, and adheres to relevant laws and guidelines. • Integrate digital tools with existing conservation practices and management strategies to enhance their efficiency and impact. ***b. Data Management and Sharing*** • Establish robust data management protocols to ensure the accuracy, security, and ethical use of data collected through digital technologies. • Promote open data policies and platforms that encourage data sharing and collaboration across stakeholders, enhancing transparency and innovation.
5. Monitoring, Evaluation, and Adaptation	***a. Monitoring and Evaluation (MandE)*** • Develop and implement MandE frameworks to assess the impact of digital technologies on conservation outcomes, identifying lessons learned and areas for improvement. • Use MandE findings to refine and adjust digital strategies, ensuring they remain aligned with conservation goals and responsive to changing conditions. ***b. Adaptive Management*** • Employ an adaptive management approach, allowing for the iterative refinement of digital integration strategies based on feedback and evolving environmental, technological, and socio-economic contexts. • Remain open to emerging technologies and innovative practices that can enhance conservation efforts.
6. Policy Support and Legal Frameworks	***a. Policy Development*** • Advocate for and assist in the development of supportive policies and regulations that facilitate the ethical and effective use of digital technologies in conservation. • Ensure policies promote equity, protect against misuse of technology and data, and support sustainable development goals. ***b. Cross-Sectoral Collaboration*** • Encourage cross-sectoral collaboration and partnerships to leverage resources, expertise, and networks for the successful integration of digital technologies into conservation practices. • Foster international cooperation to address global conservation challenges and share knowledge and innovations.

This framework presents a holistic approach to integrating digital technologies into natural resource and bio-conservation management. By following these guidelines, stakeholders can leverage digital solutions to enhance conservation efforts, promoting biodiversity protection and sustainable use of natural resources in an equitable and effective manner.

CONCLUSION

This review has provided a comprehensive overview of the emerging trends and advancements in digitalization within the realm of natural resources and bio-conservation management. From remote sensing and GIS applications to the integration of big data analytics, IoT, DNA barcoding, and citizen science initiatives, the landscape of conservation and resource management is undergoing a profound transformation. Digital technologies offer unprecedented opportunities to monitor, analyze, and protect ecosystems, biodiversity, and natural resources more effectively than ever before.

Through the synthesis of current knowledge and examination of case studies and best practices, this review underscores the potential of digitalization to address complex environmental challenges. The integration of digital technologies facilitates more informed decision-making, enhances stakeholder engagement, and fosters interdisciplinary collaboration across sectors. Moreover, these technologies empower local communities, researchers, policymakers, and conservation practitioners to work together towards common conservation goals.

However, it is essential to acknowledge the challenges and barriers to the widespread adoption and implementation of digital technologies in natural resource management. Issues such as the digital divide, data privacy and security concerns, interoperability issues, and the need for capacity building must be addressed to ensure equitable access to digital tools and maximize their effectiveness.

Moving forward, concerted efforts are needed to overcome these challenges and leverage the full potential of digitalization in conservation and resource management. This requires strategic investments in digital infrastructure, capacity building, and supportive policy frameworks. Moreover, fostering a culture of innovation and collaboration is crucial for adapting to evolving technological trends and continuously improving conservation practices.

In conclusion, while digitalization offers promising avenues for enhancing the sustainability and resilience of natural ecosystems, its successful integration depends on the collective efforts of stakeholders *at al*l levels. By embracing digital technologies and fostering partnerships, we can pave the way for more effective and inclusive approaches to conserving biodiversity and managing natural resources for future generations.

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SUB-THEME ONE

PRECISION CROP PRODUCTION STRATEGIES FOR FOOD SECURITY

Characterization of Mung Bean (*Vigna radiata* L. Wilczek) Accessions using Quantitative Traits

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ABSTRACT

An experiment was conducted at the Crop Science and Horticulture Agricultural farm, Nnamdi Azikiwe University Awka, to study the characterization of 5 mung bean accessions using quantitative traits.The five mung bean genotypes were :Tvr 72,Tvr73,Tvr98,Tvr77 and Tvr 8.The randomized complete block design experiment that was replicated 3 times showed a reasonable level of variations in the mung bean accessions. Tvr8 had the highest plant height (52.7cm) while Tvr73 had highest number of leaves (43). Tvr77(26) and Tvr8(25.9) had highest number of pods, highest number of seeds per pod(12.8) and (13.6) and also the longest pods(9.23) and (9.7) respectively. Traits like pod colour, seed colour, pigmentations are qualitative and were not affected by the environment. Tvr77 and Tvr8 accessions are therefore, recommended for use in mung bean seed production while Tvr73 is recommended for forage production. The findings from this Research can be used for the selection of genotypes for breeding purposes in mung bean.

INTRODUCTION

Mung bean (*Vigna radiata* L.) commonly known as green gram is an ancient and well-known pulse crop that belongs to family Papilionoideae and originated from South East Asia (Agugo, 2017). Mung beans are mainly grown for human food, in the form of boiled dry beans, stew, flour, sprouts and immature pods as a vegetable (Chadha,2010). The dry beans are sometimes used for poultry feed. , Roasted or boiled mungbean is used as fodder (Agugo,*et al.*, 2010). Thus, it has great value as food and fodder. Mungbean is a cheap source of protein for human consumption. According to Olumike (2014), the nutrient composition of the seed of mung bean contains 20–24% protein, 9.4% moisture, 2.1% oil, 2.05% fats, 6.4% fiber, 343.5 kcal per 100 gram energy, carbohydrates and a fair amount of vitamin A and B. In addition, the protein and carbohydrate contents of mung bean are more easily digestible than proteins derived from other legumes (Ebert *et al*.,2014). On the other hand, mung bean fixes atmospheric N_2 and enriches the soil with N nutrient for the growth of succeeding crops (Idoko and Ajayi, 2013). Moreover, the crop can be successfully grown on marginal lands where other crops perform poorly and most suitable for green manure use (Das,*et al*.,2014).Mung bean has special features such as its earliness in maturity, supply of good yield, drought-resilient property that makes it highly responsive in scanty rainfall and its ability to stimulate striga without being parasitized (Agugo, 2017). The crop also has good nutritive value and reasonable cost for the consumers (Asrate *et al.,* 2012). Also, mung bean can be used for diabetic patients and it reduces cancer growth in lung and stomach cells. It reduces heart disease risk by reducing low density lipoprotein cholesterol and protects the low density lipoprotein particles from interacting with unstable free radicals. Quantitative traits are measurable phenotypes that show continuous variation over a wide phenotypic range and are influenced by the environment(Fery,2002).They include;plant height, mumber of pods per plant, days to flowers, days to first pods, number of seeds per pod. The main objective of the study was to characterize the 5 mung bean accessions using their quantitative traits.

MATERIALS AND METHODS

Experimental Site:

This research was carried out at the Crop Science and Horticulture Research Farm of Nnamdi Azikiwe University Awka, South East Nigeria, The vegetative cover was dominated by both grasses particularly the spear grass (*Imperata cylindrical*), Elephant grass (*Pennisetumn purpureum*) and broad leaf weed like Wild sunflower (*Aspilia africana*) and the Siam weed (*Chromolaena odorata*) and the land was previously used for inter cropping of cassava with maize.

Source of Materials:

The genotypes of mung bean used for this research were gotten from International Institute of Tropical Agriculture (IITA) Ibadan. The treatments used for this research include:

(1). Tvr8 (2).Tvr72 (3).Tvr73 (4).Tvr77 (5).Tvr98 **Agronomic Practices:** Normal agronomic activities were observed and data collected included :Percentage Emergence(%):,Plant height(cm):Days to Flowering, Number of leaves per plant, Number of branches per plant, Number of Pods Per Plant, Pod length(cm),Pod weight(g),Number of seeds per pod.

Statistical Analysis:

The data obtained from the various observations were subjected to statistical analysis by using analysis of variance while differences of the treatment of means were tested using least significant difference at 5% level of probability. Agronomic traits were tested using Genstat 12thedition.

RESULTS:

Table1. showed that there was variability in plant heights at 2, 4, 6, and 8 weeks after planting. At 2 weeks after planting,Tvr72(19.3cm)had the highest plant height while the other genotypes did not vary significantly for example TVr8 (17.7cm). At 4 weeks, the five genotypes did not vary significantly. At 6 weeks, Tvr72 (29cm),Tvr73 (28cm) and Tvr8 had the highest plant heights followed by Tvr98 and Tvr77 which did not vary. At 8 weeks, Tvr8 had the highest plant height (52.7cm), followed by other 4 accessions which did not significantly vary.

Table 1. Effect of mung bean genotypes on plant height (cm)

TREATMENTS	Weeks after planting			
	2	4	6	8
Tvr72	19.3b	24.7b	29.0b	50.0ab
Tvr73	16.3ab	27.7b	28.3b	50.3ab
Tvr98	17.3ab	24.7b	26.3ab	51.3ab
Tvr77	16.3ab	25.7b	23.3ab	51.8ab
Tvr8	17.7ab	25.7b	27.3b	52.7a

Means with the same letter(s) under the same column are not significantly different (P ≤ 0.05) using Duncan Multiple Range test (DMRT).

Table 2. At two and four weeks after planting, number of leaves of the accessions did not significantly vary. At 6 weeks after planting,Tvr8(21.33) was the least. At 8 weeks after planting, Tvr73(43.05cm) had the highest number of leaves but not significantly different from Tvr98(42.67cm),Tvr77(42.08cm) and Tvr8(38.40). while Tvr72(28.07cm) had the least number of leaves. Table 2.

Table 2. Effect of mung bean genotypes on the number of leaves.

TREATMENTS	Weeks after planting			
	2	4	6	8
Tvr72	6.83a	20.08a	28.33b	28.07ab
Tvr73	6.67a	22.83a	27.33b	43.05b
Tvr98	8.00a	20.33a	28.00b	42.67b
Tvr77	6.33a	22.50a	31.00b	42.08b
Tvr8	6.67a	21.17a	21.33ab	38.40b

Means with the same letter(s) under the same column are not significantly different ($P \leq 0.05$) using Duncan Multiple Range test (DMRT).

At two weeks, Tvr98 (2.33) had the highest number of branches,other genotypes were not significantly different.At weeks 4 and 6, the genotypes number of branches were not significantly different.Table.3. All the genotypes had emergence that is 50% and above at four days after planting.

Table 3. Effect of mung bean genotypes on number of branches and Days to 50% Emergence

TREATMENTS	NO OF BRANCHES			Days To 50%
	2 WEEKS 2	4 WEEKS 4	6WEEKS 6	Emergence(4days)
Tvr72	2.00ab	4.03a	5.57a	50
Tvr73	2.00ab	4.17a	5.90a	50
Tvr98	2.33b	4.47a	5.87a	56
Tvr77	2.00ab	4.37a	6.17a	50
Tvr8	2.00ab	4.17a	5.97a	50

Means with the same letter(s) under the same column are not significantly different ($P \leq 0.05$) using Duncan Multiple Range test (DMRT).

There was no significant difference ($P \leq 0.05$) in the number of flowers among the varieties. Table 4.

Table 4. Effect of mung bean genotypes on flower number.

TREATMENTS	Weeks after planting		
	4	6	8
Tvr72	4.83a	8.08a	7.73a
Tvr73	7.40a	10.58a	8.07a
Tvr98	7.33a	9.58a	6.75a
Tvr77	6.50a	10.17a	8.97a
Tvr8	5.67a	8.92a	7.13a

Means with the same letter(s) under the same column are not significantly different ($P \leq 0.05$) using Duncan Multiple Range test (DMRT).

Table.5 showed that there was slight variability in the pod characteristics. There was significant difference ($P \leq 0.05$) in the pod lengths Tvr77(9.23cm) and Tvr8(9.7cm) had the longest but similar pod lengths. Tvr73(7.87cm) and Tvr98 (7.9cm) accessions were the least. At 8 weeks, highest number of pods came from Tvr77(26) and Tvr8(25.9) which were significantly the same.The least values also came from Tvr73(16.83cm) and Tvr98(13.07cm)accessions. On number of seeds/pod, Tvr77(12.8) and Tvr8(13.6) had the highest number of pods but not significantly different from the other genotypes.

Table.5 Effect of mung bean genotypes on pod characteristics

Accessions	**Pod length(cm)**	**Pod weight(g)**	**Number of Pods/plant**		**Seed/pod**
			6WEEKS	8WEEKS	
Tvr72	8.57a	14.00a	15.33bc	21.08a	11.13b
Tvr73	7.87ab	9.67a	15.10abc	16.83a	11.47b
Tvr98	7.90ab	14.00a	15.08bc	13.07a	11.60b
Tvr77	9.23a	12.33a	17.67ab	26.00b	12.87b
Tvr8	9.70a	14.67a	15.28ab	25.90b	13.67b

Means with the same letter(s) under the same column are not significantly different ($P \leq 0.05$) using Duncan Multiple Range test (DMRT).

DISCUSSION

The experiment was conducted to study the characterization of 5 mung bean accessions using qualitative and quantitative traits. The experiment showed a reasonable level of variations in the mung bean accessions and this is in line with the findings of Paven *et al.,* (2019). Tvr8 had the highest plant height (52.7cm), Tvr73 had the highest number of leaves (43).On yield parameters, Tvr77(26) and Tvr8(25.9) had the highest number of pods, the highest number of seeds per pod,(12,8) and (13.6) and also the longest pods(9.23) and (9.7) respectively. This is in harmony to the findings Rasul *et al*.,(2009); Ebert,(2014); and Sajjan *et al*., (2002), who reported that genetic constitution of crop varieties influence their growth characters. Mehmet *et al* .,(2014) and Imran *et al* (2015) also attributed the growth characters of crop species not only to genetic constitution of the crop but also to the suitable agro-ecological zone where they can express their full genetic resources for growth and yield enhancement. Higher number of branches, plant height,flowers, pod size pod number observed in Tvr77 and Tvr8 could possibly be attributed to the utilization of its good genetic make-up to exploit the favourable agro-ecological conditions of the study area for rapid growth and branching. This is also in harmony with the reports of Ebert,(2014) and Ray and Sofie *et al*., (2011) who attributed the growth characters of crop species not only to genetic constitution of the crop but also to the suitable agro-ecological zone where they can express their full genetic resources for growth and yield enhancement Traits like petiole and pod colour, seed colour, pigmentations are qualitative and not effected by the environment. colour in their study involving accessions from Andhra Pradesh.Traits like pod colour, seed colour, pigmentations are qualitative and not effected by the environmentPaven *et al.,* (2019). We therefore recommend Tvr77 and Tvr8 accessions for use in mung bean seed production and Tvr73 for forage production, as a cover crop and for poor soils remediation. The findings from this Research can be used for the selection of genotypes for breeding purposes in mung bean.

CONCLUSION

In conclusion, The experiment revealed significant variations among the mung bean accessions, particularly in quantitative traits related to plant height, number of leaves, pods, seeds per pod, and pod length. These findings align with previous studies emphasizing the influence of genetic constitution and agro-ecological conditions on crop growth and yield. Additionally, qualitative traits such as pod and seed color were observed, providing further insights into the genetic diversity of the accessions. Based on these results, Tvr77 and Tvr8 are recommended for mung bean seed production, while Tvr73 is suitable for forage production. Overall, these findings provide valuable information for genotype selection and breeding efforts in mung bean cultivation.

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Amino Acids Profile of Selected Five Genotypes of Cowpea and Mung Beans Grown in Awka, Rain Forest Zone

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KEYWORDS

Amino-Acids
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Genotypes,
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ABSTRACT

A comprehensive analysis was done at the Food Profiling Biotechnology Laboratory, National Root Crops Research Institute (NRCRI) Umudike, Umuahia to explore, as well as to compare the amino acid components of five cowpea (Vigna aunguiculata) (ITA 1,2,3,4,5) and five mung bean (Vigna radiata) (TVR 72,73,77,8,98) genotypes that were grown at the Research Farm of Crop Science and Horticulture, Nnamdi Azikiwe University. The results showed that the mung bean genotypes were high in alanine, glycine and valine while the cowpea genotypes were high in tryptophan, methionine and other sulfur-containing essential amino-acids. Both crops have relatively similar arginine, isoleucine, lysine, serine and tyrosine contents. While they reduce flatulence, the tested mung beans genotypes values for threonine, tryptophan and total sulphur-containing amino acids (methionine and cysteine) were nutritionally inadequate but this can be compensated by consuming mung bean in combination with cereals. Based on individual genotypes contents of essential amino-acids, we recommend cowpea genotypes:ITA 1,2, 5 and mung bean genotypes:TVR 72,73 and 98.

INTRODUCTION

Legumes belongs to the family Fabaceae,while edible legumes are called pulses. Legumes are grown primarily for human consumption, for livestockforage and silage, and as soil-enhancing green manure (Elbert, 2014).Mungbean (Vigna radiata L. Wilczek) is an important annual leguminous crop mainly cultivated in the tropical, subtropical and temperate zones of Asia.It is a short duration legume, hence grown solely as well as in inter and multiple cropping system under rain fed and irrigated conditions. It is an excellent source of easily digestible high quality protein for the predominant vegetarian population of India (Tomooka *et al*., 2003). It contains 3.5-4.5% fiber, 22-28% total protein, 21-25% of total amino acid and 1.53-2.63% lipids, 1.0-1.5% fat, ash content ranges from 4-5% and 59-65% carbohydrate on dry weight basis and provide 334-344 kcal energy (Aguogu and Aguogu, 2010). Mungbean is known to be high source of manganese, potassium, magnesium, copper, zinc, and phosphorus. It is also rich in various B vitamins and also serves as a food filter high in protein, resistant starch and dietary fibre (DOA., 2013).

Mungbean is widely used as human food, green manure and forage for livestock.it also serves for medicinal purpose (Hujjie *et al*., 2003). Due to good taste easy digestibility, better palatability and acceptable market price may be the first choice of farmers (Aguogu,2017). It increases farmers income and improves soil fertility through symbiotic nitrogen fixation (Malik *et al*., 2000).It is a vital crop in developing countries where it is consumed as dry seeds, fresh green pods or leaves due to its high protein, vitamin and mineral content. It is also consumed as green pods and seeds as vegetables (Tang *et al*., 2014).Cowpea, (*Vigna aunguiculata* [L.] Walp.) is an important pulse found in the tropical as well as subtropical countries..Cowpea belongs to the family Fabaceae, sub-family Papilionoideae, tribe Phaseoleae and genus,vigna.Cowpea performs well in agro ecological zones where the rainfall range is between 500 and 1200 mm/year.However, with the development of extra-early maturing cowpea varieties, the crop can thrive in the Sahel where the rainfall is less than 500mm/year.The chemical composition of the cowpea seeds corresponds with those of most edible legumes(Boukar *et al.*,2018).Nutritionally, cowpea grain is more or less same as other pulses, with a relatively low fat content and high total protein. Cowpea is considered as nutrient dense food with low energy density. An average cowpea grain contains 23-32% ofprotein, 50-60% carbohydrate and about 1% fat in dry basis. The total protein content of cowpea is approximately two to four times greater than cereal and tuber crops(Khalid and Elharadallou,2013).

Moreover the protein in cowpea is rich in amino acids like lysine and tryptophan,.Kirse and Karklina,(2015) suggested that mature seeds contain per 100 gram edible portion as follows : carbohydrate 56-66g, protein 22-24 g, water 11g, crude fibre 5.9-7.3 g, ash 3.4-3.9 g, fat 1.3-1.5 g, phosphorus 0.146 g, calcium 0.104-0.076 g and iron 0.005 g.Amino acids are the monomers of proteins as well as the end-products of protein digestion in the alimentary canal. Usually they are classified into essential and nonessential amino acids. Both groups are absolutely essential for life. Amino acids contain carbon, hydrogen,oxygen and nitrogen, and some contain sulphur(Ukpene and Imade,2015). The body needs to use about twenty common forms of amino acids to function. They are all important but eight of them cannot be synthesized by the body. They are essential(indispensable) and therefore must be obtained from food. The other ten amino acids are considered to be nonessential (also called dispensable), are not necessarily consumed because the body synthesizes them from other amino acids consumed(Ukpene and Imade,2015).Cowpea and Mung bean are among the pulse's species of greatest economic and social importance,and strategic for the food security and health of millions especially in Africa owing to the high and ever increasing cost of animal-based protein foods. This Research is imperative as it was geared towards the proper identification and evaluation of the proteins and their amino acids components in some selected genotypes of these pulses. This will enhance the selection of superior genotypes for food production and breeding. The objectives of this study was to evaluate and compare the selected amino acid of mung bean and cowpea"

MATERIALS AND METHOD

Study Area.The seeds of cowpea and mung bean were planted at the Teaching and Research Farm,Faculty of Agriculture, Nnamdi Azikiwe University Awka, Anambra state, Nigeria. Anambra state consists of twenty-one local government areas within the latitude 6.2209ºN and longitude 6.9370ºE. It covers an estimated land area of 4,844 km^2. The state has two main climatic seasons, the dry and wet season, with peak of raining season between June and July. Annual rainfall ranges between 2062mm while the average temperature lies between 26.1ºC.The cowpea and mung bean seeds were planted separately on 1m x1m ridges and at 50cmx50cm spacing.Manure application and weedings were done as need be nd the pods were harvested at physiological maturity.

The samples preparation: The cowpea genotypes were :i. ITA-813 ii. ITA-814 iii. ITA-816 iv. ITA-888 v.ITA-817 (All from IITA Ibadan,Nigeria)while the mung bean were :i. IVC-112 ii. IVC-137 iii. IVC-32 iv. IVC-71 v. IVC-162(All from International Vegetable Centre,Taiwan).LABORATORY ANALYSIS: The dried mung bean and cowpea seeds were cleaned, sorted to remove defective and foreign matters. The cleaned seeds were soaked in potable water for just 20 min to soften the seed coat for easy dehulling. The dehulled seeds were dried in hot air oven at 65ºC for 24h and milled into flour. The flour were stored in air-tight polythene until needed. The known samples were dried to constant weight, defatted, hydrolyzed, evaporated in a rotary evaporator and loaded into the Applied Biosystems PTH Amino Acid Analyzer.

Data Analysis: All the data collected were analyzed using Genstat 12 edition and means were separated using Least significance difference (L.S.D) at 0.05 level of significance.

RESULTS

Table 1 showed that**:** Alanine **co**ntents varied significantly among the tested genotypes. Mung bean genotype TVR98 (5.24g/mg) was the highest followed by cowpea genotypes ITA1 (4.58g/100g) and ITA5 (4.39g/100g).The genotype ITA2 (1.55g/100g) had the least Alanine content.Argnine contents varied significantly among the tested genotypes. Mung bean genotype TVR98 (6.67g/mg) was the highest followed by cowpea genotypes ITA1 (6.03g/100g) and ITA5 (5.45g/100g).Other genotypes were not significantly different. The genotype ITA2 (4.28g/100g) had the least Argnine content.

Glycine contents slightly varied among the tested genotypes. Mung bean genotype TVR98 (5.53g/mg) was the highest although not significantly different from other mung bean and cowpea genotypes.Isoleucine contents varied significantly among the tested genotypes. Cowpea genotype ITA1 (4.50g/mg) was the highest followed by cowpea genotypes ITA2 (4.25g/100g) and higher than ITA4 (2.57g/100g) and TVR8 (2.84g/mg).Other genotypes were not significantly different.

Lysine contents varied significantly among the tested genotypes. Cowpea genotype ITA1 (7.78g/100g) and Mung bean genotype TVR72 (7.69g/mg) were the highest followed by cowpea genotype ITA2 (7.23g/100g).and ITA5 (5.45g/100g).The genotype ITA5 (3.99g/100g) had the least Lysine content.

Table 1 Alanine, Argnine, Glycine, Isoleucine and Lysine (g/100g) content of the tested pulses

Cowpea genotypes	**Alanine**	**Argnine**	**Glycine**	**Isoleucine**	**Lysine**
ITA 1	4.58	6.03	4.98	4.50	7.78
ITA 2	1.55	4.28	4.35	4.25	7.23
ITA 3	4.11	5.37	4.64	3.33	6.85
ITA 4	3.24	5.74	4.28	2.57	4.95
ITA 5	4.39	5.45	4.54	3.43	3.99
Mung bean genotypes					
TVR72	3.10	4.96	4.56	3.78	7.69
TVR 73	4.08	4.73	4.04	3.83	4.85
TVR 77	3.28	5.13	4.48	3.81	5.17
TVR 8	2.18	5.37	4.20	2.84	5.98
TVR 98	5.24	6.67	5.35	3.82	7.11
LSD	1.401	1.47	1.72	1.62	0.30

Table 2 showed that:Lysine contents varied significantly among the tested genotypes. Cowpea genotype ITA1 (7.78g/100g) and Mung bean genotype TVR72 (7.69g/mg) were the highest followed by cowpea genotype ITA2 (7.23g/100g) and ITA5 (5.45g/100g). The genotype ITA5 (3.99g/100g) had the least Lysine content.Methionine contents varied significantly among the tested genotypes. Cowpea genotype ITA2 (3.85g/100g) was the highest followed by Mung bean genotype TVR72 (2.79g/mg) and cowpea genotype ITA1 (2.64g/100g). The genotypes that had the least Methionine contents were ITA5 (0.94g/mg) and ITA4. (0.89g/mg).

Serine contents did not vary significantly among the tested genotypes. A typical value for Mung bean genotype TVR98 was (3.72g/mg) and that for cowpea genotype ITA1 was (4.67g/100g).

Tryptophan contents varied significantly among the tested genotypes. Cowpea genotype ITA2 (3.22g/100g) was the highest followed by Mung bean genotype TVR98 (1.74g/mg). Both pulses were generally low in Tryptophan. The genotype ITA4 (0.18g/100g) had the least Tryptophan content.

Tyrosine contents were significantly the same among three tested Mung bean genotypes TVR72 (3.30g/mg), TVR73 (3.44g/mg) and TVR8 (3.11g/mg) and also in three cowpea genotypes ITA1 (3.68g/100g), ITA3 (3.26g/mg) and ITA4 (3.02g/mg), the genotype ITA2 (2.04g/100g) had the least Tyrosine content followed by TVR98 (2.10g/100g).

Valine contents varied significantly among the tested genotypes. Mung bean genotype TVR98 (5.46g/mg) had the highest value and significantly the same with other genotypes other than ITA2 (2.30g/100g) which had the least Valine content.

Table 2: Methionine, Serine, Trytophane, Tyrosine and Valine (g/100g) content of the tested pulses

Cowpea genotypes	Methionine	Serine	Tryotophane	Tyrosine	Valine
ITA 1	2.64	4.67	0.74	3.68	4.76
ITA 2	3.85	3.69	3.22	2.04	2.30
ITA 3	1.79	3.03	0.64	3.26	4.66
ITA 4	0.89	2.87	0.18	3.02	5.01
ITA 5	0.94	3.27	0.74	2.41	4.85
Mung bean genotypes					
TVR72	2.79	3.29	1.03	3.30	3.90
TVR 73	1.36	3.82	1.04	3.44	3.91
TVR 77	2.09	3.53	1.16	2.44	3.99
TVR 8	2.14	3.13	0.54	3.11	4.31
TVR 98	1.71	3.72	1.74	2.10	5.46
LSD	1.18	1.92	0.73	0.74	1.74

DISCUSSIONS

A comprehensive analysis was done at the Food Profiling Biotechnology Laboratory, National Root Crops Research Institute (NRCRI) Umudike, Umuahia to investigate the amino acids components of five cowpea (*Vigna aunguiculata*) and five mung bean (*Vigna radiata*) genotypes that were grown at the the Research Farm of Crop Science and Horticulture, Nnamdi Azikiwe University, Awka. The present project was designed to explore, as well as to compare the amino acids components.

Alanine contents of the tested pulses 4.58-1.55g/100g for cowpea genotypes and 5.24-2.18g/100g for mung bean genotypes signifying that mung bean has higher alanine content than the tested cowpea genotypes. This result is in line with that of Ukpene and Imade, (2015) that recorded Alanine range of 3.10-3.61g/100g on nine cowpea genotypes. The values agreed also with Aremu *et al*(2006). Alanine is important in the inter tissue transfer of amino groups generated from amino acid catabolism. Arginine contents of the tested pulses 4.28-6.05g/100g for cowpea genotypes and 4.73-6.67g/100g for mung bean genotypes showed that the two pulses have similar Arginine contents. This result is in line with that of Ukpene and Imade, (2015) that recorded Arginine range of 4.18-6.11g/100g.06) on two cowpea varieties. The values of this amino acid also exceeded the recommended FAO/WHO daily provisional pattern of 2.0.Arginine is catabolized in the liver and generates urea as part of the urea cycle, and ornithine. In the kidney arginine is used with glycine in the first reaction of creatine synthesis (Elhardallou *et al*., 2015).Glycine contents of the tested pulses was 4.28-4.98g/100g for cowpea genotypes and 4.04-5.53g/100g for mung bean genotypes signifying that mung bean has higher Glycine content than the tested cowpea genotypes. This result is in line with that of Ukpene and Imade, (2015) that recorded Glycine range of 2.71-3.14g/100g for cowpea genotypes.

The values agreed also with Aremu *et al.*,(2006).Glycine acts as aninhibitory neurotransmitter in the brain. It is also converted to serine which is used in foliate reactions. Isoleucine contents of the tested pulses was 2.57-4.25g/100g for cowpea genotypes and 2.84-3.52g/100g for mung bean genotypes signifying equal ranges for the tested genotypes. The values of this amino acid agreed with Ukpene and Imade,(2015) that recorded Isoleucine range of 2.81 3.14g/100g for cowpea genotypes, the reports of Amata (2012), and Aremu *et al*.(2006) but were slightly below the recommended FAO/WHO provisional pattern of 4.2.for mung bean genotypes but the same for the cowpea genotypes .Jayathilake*et al*.,(2018) noted that this amino acid is used for different purpose including providing cells with energy. Lysine contents of the tested pulses was 4.95-7.78g/100g for cowpea genotypes and 4.85-7.69g/100g for mung bean genotypes signifying equal ranges for the tested genotypes. Agreed with the reports of Aremu *et al*. (2006) on two cowpea varieties. These two genotypes also corresponded with the recommended FAO/WHO daily provisional pattern of 4.2g/100g. Furthermore, the catabolism of lysine generates acetyl COA, a useful element in the citric acid cycle.

Methionine contents of the tested pulses was 0.89-3.85g/100g for cowpea genotypes and 1.36-2.79g/100g for mung bean genotypes which showed that the cowpea genotypes contained more Methionine than mung bean genotypes .The 1.30mg/100g mung bean genotypes average agreed with the findings of ZhuYi shen *et. al.,* (2018).Also the tested cowpea genotypes range agreed with Ukpene and Imade, (2015) finding that ranged from 2.24 to 2.61 g/100g-1.These values were in agreement with the FAO/WHO provisional pattern of 2.2. This amino acid is very essential for humans. It is always the first amino acid to be incorporated into a protein, sometimes removed after translation. Like cysteine, it contains sulfur, but with a methyl group instead of hydrogen. Indeed, the total essential amino acid content of MBPI exceeds the FAO/WHO recommendations (FAO/WHO.,1991,2018). Conversely, values for threonine, tryptophan and total sulphur-containing amino acids (methionine and cysteine) were nutritionally inadequate which can be compensated by consuming mung bean in combination with cereals.(ZhuYi shen *et. al.,* 2018).

Serine contents of the tested pulses 2.87-4.67g/100g for cowpea genotypes and 3.13-3.83g/100g for mung bean genotypes showed that the two pulses have similar Serine contents. This result is in line with that of Ukpene and Imade,(2015) that recorded Serine range of 4.18-6.11g/100g.06) on two cowpea varieties and ZhuYi shen *et. al.,* (2018) 3.8g/100g average of for mung bean genotypes. The value of this amino acid across the cowpea genotypes agreed with the reports of Kalidass and Mohan (2012). Serine is synthesized from glycine and it is a major source of one-carbon unit for use in foliate reactions. Tryptophan contents of the tested pulses 0.18-3.22g/100g for cowpea genotypes and 0.54-1.74g/100g for mung bean genotypes showed that the two pulses have low Tryptophan contents. These values of tryptophan in various cowpea genotypes were higher than those reported by Aremu *et al*. (2006). They were also exceedingly higher than the recommended FAO/WHO daily provisional pattern of 1.4. Tryptophan is used in the synthesis of the hormone melatonin and the neurotransmitter serotonin. Melatonin is made in the pineal gland, which lies in the centre of the brain. Melatonin synthesis and release corresponds with darkness and is thought to be involved with the regulation of circadian rhythms and sleep. Serotonin functions as an excitatory neurotransmitter and as a potent vasoconstrictor and stimulator of smooth muscle contraction. Tyrosine contents of the tested pulses were 2.04-3.68g/100g for cowpea genotypes and 2.40-3.44g/100g for mung bean genotypes showed that the two pulses have similar Tyrosine contents. These values of tyrosine in various cowpea and mung bean genotypes were higher than those reported by Aremu *et al*. (2006)(4.81-6.22g/100g). Tyrosine is used in the body to synthesize epinephrine and norepinephrine which have major effects on nutrient metabolism. It can also be degraded to form fumarate which can be used to synthesize glucose. Valine contents of the tested pulses 2.30-5.01g/100g for cowpea genotypes and 3.90-5.46g/100g for mung bean genotypes showed that the two pulses have moderately high valine contents. The value of this amino acid across the cowpea genotypes agreed with the reports of Ukpene and Imade, (2015) that ranged from 2.87 to 3.61 g/100g-1.The values agreed with the reports of Aremu *et al*. (2006) on cowpeas but were below the recommended FAO/WHO provisional pattern of 4.2g/100g. This is also in line with the average of 4.6g/100g recorded by ZhuYi shen *et. al.,* (2018) on mung bean cultivars. Isoleucine contents of the tested pulses was 2.57-4.25g/100g for cowpea genotypes and 2.84-3.52g/100g for mung bean genotypes signifying equal ranges for the tested genotypes.

CONCLUSION

The present project was designed to explore, as well as to compare the amino acids components. The results showed that the tested mung bean genotypes were high in alanine, arginine, glycine, isoleucine, lysine and valine. While the tested cowpea genotypes were high in methionine, serine tryotophane, and tyrosine.

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Determination of Helminths in Wastewater and Vegetable Irrigated in Kawo Irrigation Farm of Kaduna State

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KEYWORDS

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ABSTRACT

The research is to investigate Helminths for the untreated municipal wastewater and vegetables produced in the Kawo abattoir irrigation farm. The location lies between latitude 100 34' 40.8'' E and longitude 070 26'39.1'' N of Kaduna North Local Government Area of Kaduna State. Abattoir and municipal wastewater confluence at a point where farmers get the wastewater for irrigation, not minding the health implication involve. The wastewater sample was collected from three different points designated as WW01, WW02, WW03, and WW04. The samples were analyzed for Helminths in the wastewater and fresh vegetable produce. The following Helminths were discovered, (i) Ova of Fasciolopsis buski, (ii) Segment of Tapeworm (Tania saginata), (iii) Cyst of Entamoeba histolytica (iv) Ova of Ascaris lumbricoid were found and above the recommended guidelines of which specify <1 nematode egg per liter of wastewater. This study observed that untreated wastewater used for irrigation at the study site contains hazardous Helminths. This practice can be dangerous to consumers and life-threatening to farm workers due to direct constant physical contact with the wastewater. It recommended that farmers should practice the use of stabilization ponds (aerobic, facultative, and maturation) before using the water for irrigation, adoption of safer irrigation methods such as drip or sub-surface irrigation to minimize contact of crops with contaminants present in irrigation water, and farmers around the study site should make use of personal protective equipment such as gloves, boots, trousers, and long sleeve shirts during farm work to reduce the level of exposure.

INTRODUCTION

Urban and peri-urban agriculture in some areas of many developing countries, at least to some extent depends on wastewater as a source of irrigation water (Khaled and Muhammad, 2016). In most parts of Nigeria, farmers prefer untreated wastewater even when freshwater is available because they earn higher profits. This shows that wastewater can be a more reliable source both in terms of availability and volume than rain or freshwater supply for irrigation systems. However, many households in poorer areas lack access to fertilizers and have a limited supply of fresh water; wastewater reuse at the individual level can provide a combined solution to these problems by supplying the water and nutrients needed for household food production, This practice is common amongst millions of farmers worldwide and it is estimated that 10% of the world's population consumes foods irrigated with Wastewater (WHO 2006).

The microbial population of untreated water is very diverse and dangerous microorganisms that can cause illness or disease are usually associated with human or animal faecal matter present in wastewater and surface water sources. Irrigation water contaminated with pathogens has often been blamed for foodborne illness outbreaks ((Blumenthal *et al*., 2000). It is important to carefully manage this risk when promoting the reuse of non-potable water sources to fulfil the water demand of agricultural irrigation activities. The pathogens are transmitted to the public through consumption of irrigated produce, especially crops eaten raw (Blumenthal *et al*., 2000). Several studies throughout the world have demonstrated a very close relationship between the consumption of fruits and vegetables irrigated with raw wastewater and many food-borne diseases like gastroenteritis, cholera, chemical toxicity etc (Sou *et al*., 2011).

Initial improvements in water quality can be achieved in many developing countries by at least the primary treatment of wastewater, particularly where wastewater is used for irrigation. Secondary treatment can be implemented at a reasonable cost in some areas, using methods such as waste-stabilization ponds, constructed wetlands, infiltration-percolation, and up-flow anaerobic sludge blanket reactors (Mara, 2003). Wastewater is increasingly being used in the agricultural sector to cope with the depletion of freshwater resources as well as water stress linked to changing climate conditions. As wastewater irrigation expands, research focusing on the human health risks is critical because exposure to a range of contaminants must be weighed with the benefits to food security, nutrition and livelihoods. (Dickin *et al*., 2016). (Abakpa *et al*., 2013) Conducted a study in Kano State Nigeria, which shows high-level contamination of irrigation water and irrigated vegetables as a result of point sources of effluents to the water bodies used for irrigation contributing significantly to the continuous influx of microorganisms throughout the year. The quality of the water and the irrigated vegetables exceeded standard microbiological limits. Helminthes and protozoan parasites enter the environment in feces from the intestinal tract of a wide range of domestic, wild, and companion animals used as manure for production. These pathogenic organisms can therefore pose a health threat to the farmers, of particular health importance is the transmission of intestinal helminths often referred to as Soil-transmitted Helminths (STHs). Soil-transmitted Helminthes infections are among the most common infections worldwide and affect the poorest and most deprived communities. They are caused by parasitic worms (Helminths) that are transmitted to people through contaminated soil. The main species of soil-transmitted Helminths that infect people are the roundworm (Ascaris lumbricoides), the whipworm (Trichuris trichiura), and the hookworms (Necator americanus and Ancylostoma duodenale) (Toze, 1997) . Soil-transmitted Helminths are transmitted by eggs that are passed in the feces of infected people. Adult worms live in the intestine where they produce thousands of eggs each day. In areas that lack adequate sanitation, these eggs contaminate the soil. People become infected with A. lumbricoides and T. trichiura by ingesting infective parasite eggs. This can happen in several ways.

Eggs attached to vegetables are ingested when the vegetables are not carefully cooked, washed, or peeled.

Eggs are ingested from contaminated water sources.

Eggs are ingested by children who play in soil and then put their hands in their mouths without washing them. Helminthes eggs require moist shady soil for embryonation of the eggs over five to ten days before they can cause infection (Toze, 1997).

Farmers and their households (especially children) engaged in wastewater irrigation are at a higher risk of Helminthes infection due to the duration and intensity of their contact with the wastewater and contaminated soils (Strunz.,*et al*). Consumers of vegetables irrigated with wastewater, especially vegetables that are eaten without proper cooking or no cooking (spinach and lettuce) before consumption are also at risk of infection with pathogenic microorganisms found in the wastewater. Therefore there is the need to determine the risk of infection with those pathogenic microorganisms for the farmers and consumers. It has also been made abundantly clear that the approach of banning the largely informal practice will not work, therefore the main challenge is how to maximize the benefits of wastewater use while safeguarding public health and the environment as well. The research carried out in Kawo Abattoir irrigation farm aimed to assess the Helminths level in wastewater and vegetable produce in the research area which could cause serious health challenges to the consumers and farm workers.

MATERIALS AND METHOD

Study Area

The study site selected for this study is the Kawo Abattoir irrigation farm (Figure 3.2) which lies between latitude 100 34' 40.8'' E and longitude 070 26'39.1'' N of Kaduna North Local Government Area Kaduna State Nigeria. Kaduna North lies completely in the part of Western Africa, well within the northern limit of the movement of the Intertropical Convergence Zone (ITCZ). It is characterized by two distinct seasonal regimes, oscillating between cool to hot dry and humid to wet season. The climate is tropical in Kaduna. When compared with winter, the summers have much more rainfall. The climate here is classified as Aw by the Köppen-Geiger system (Aw = Tropical wet and dry or savanna climate; with the driest month having precipitation less than 60 mm (2.4 in) and less than 4% of the total annual precipitation). The average annual temperature in Kaduna is 25.2 °C, and about 1211 mm of precipitation falls annually. The driest month is January. There is 0 mm of precipitation in January. In August, the precipitation reaches its peak, with an average of 284mm**.**

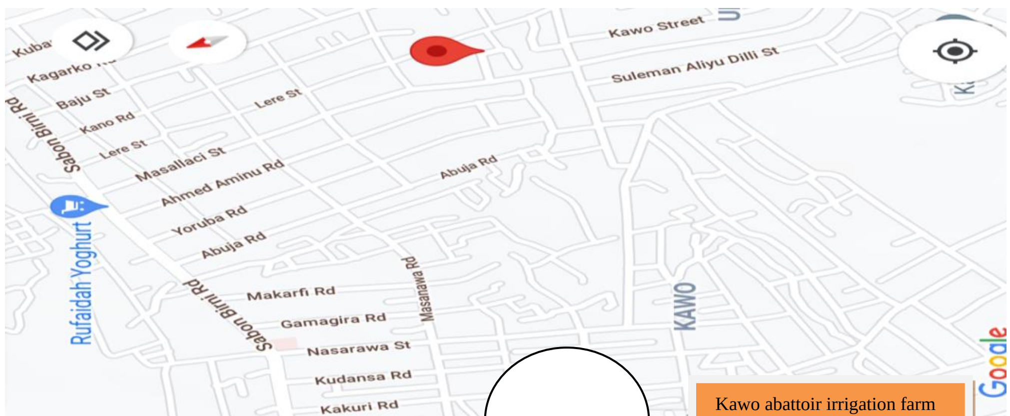


Figure 1: Map of kawo Kaduna showi ... arm ... 24)

Sampling

Sample collection for waste water

Wastewater samples were collected from four different points designated as WW01, WW02, WW03, and WW04. Wastewater from municipal, (which is the wastewater coming directly from municipal), Wastewater from Abattoir, (wastewater flowing from the abattoir), Wastewater from Irrigation (the point of confluence of the two wastewater above is now pumped and used for irrigation), and open well water (control) respectively. Wastewater samples were collected in 50ml clean sterile containers as shown (plate 1). The samples were collected and transported in a cooler box to the laboratory for analysis within twenty-four hours of collection.

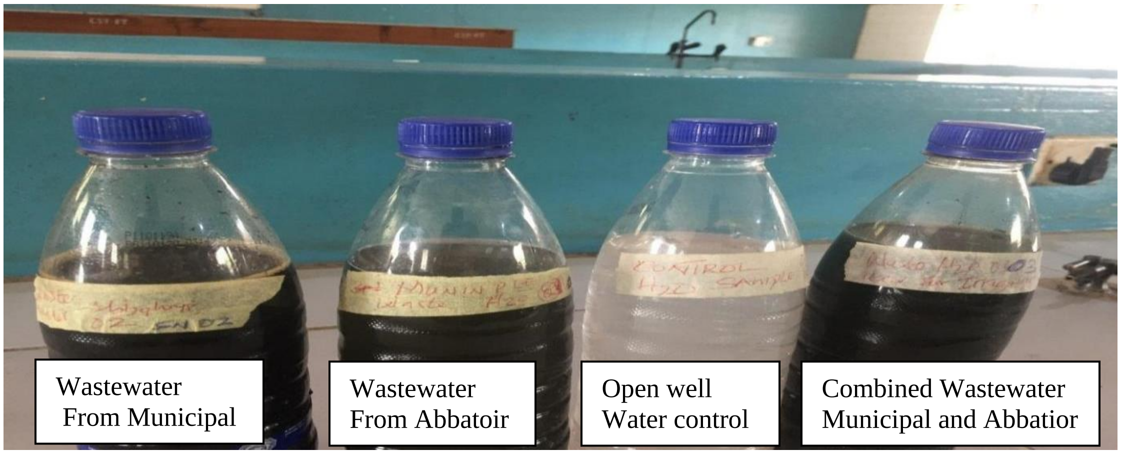


Plate 1: Wastewater sample

Sample collection for vegetables

Vegetable (spinach and lettuce) samples were collected under normal conditions, from three sampling points of the irrigation farm, put in paper bags, and then transported immediately to the laboratory where they were analysed within 24hrs. The same method was also applied to a control group of vegetables (spinach and lettuce) grown using open well water under identical conditions

Determination of Helminthes using Parasite direct microscope iodine method

Procedure for determination of Helminthes Parasite in wastewater

Two loops full of the sample were placed at the center of the clean dried sterilized microscope slide as shown in Plate 2 below. Two drops of 1% solution of grams iodine were mixed with the content and covered with the cover slip. The content was observed with low and high power objectives of the microscope as shown in plate 3 below for the cysts ova or larva of parasites, where the observation was recorded with the aid of a diagram. The experiment was conducted in the laboratory of the department of food and nutrition Kaduna polytechnic Kaduna State.

Procedure for determination of Helminthes Parasite in Vegetable

Ten grams of each vegetable sample was weighed and blended using an RM 206 model blender containing 100 ml of sterile saline solution for 2 min under sterile conditions. The blender was carefully disinfected to prevent any cross-contamination. Then the same method was employed as in this Section.

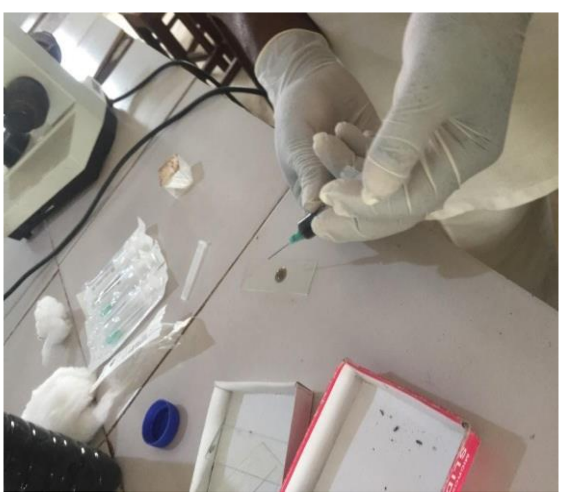


Plate 2: Loops full of the sample preparation

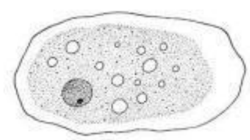
Plate 3: Observation of sample with microscope

RESULTS AND DISCUSSION

Results

A total of 4 samples for wastewater and 4 samples each of vegetable (spinach and lettuce) were collected and analyzed for Helminthes, Table 1 shows the result for Helminthes found in the Wastewater sample which was counted and observed to be above <1 nematode egg per liter of wastewater by (WHO 1989).

Table 1: Results of Parasite/Helminthes determination

S/N	CODE	SAMPLE NAME	IDENTIFIED PARASITE (seen)	PARASITE DIAGRAM
1	WW01	Wastewater from Municipal	i. No ova or cyst of parasites seen	
2.	WW02	Wastewater from Abattoir	i. Ova of *fasciolopsis buski* ii. Segment of Tapeworm (*Tania saginata)*	*Fasciolopsis (Wikipedia.org DPDx.JPG)*
3.	WW03	Wastewater from Irrigation	i. Ova of fasciolopsis buski ii. Segment of Tapeworm *(Tania saginata)* iii. Cyst of *Entameoba histolytica* iv. Ova of *Ascaris lumbricoids*	
4.	WW04	Open wellwater (Control)	i. No ova or cysts of parasites	*Tania sagina (Wikipedia.org DPDx.JPG)*
5.	SP01	Spinach Farm A	i. No ova or cysts of parasites	
6.	SP02	Spinach Farm B	i. Ova of *faciolopsis buski*	
7.	SP03	Spinach Farm C	i. Ova of *faciolopsis buski* ii. Cyst of *Entamoeba histolytica*	
8.	SP04	Spinach Control	i. No ova or cysts of parasites	
9.	LT01	Lettuce Farm A	i. Cyst of *Entamoeba histolytica*	*Entameoba histolytica (Wikipedia.org DPDx.JPG)*
10.	LT 02	Lettuce Farm B	i. Ova of *faciolopsis buski*	
11.	LT 03	Lettuce Farm C	i. Ova of *faciolopsis buski*	
12.	LT 04	Lettuce Control	i. No ova or cysts of parasites	 *Ascaris lumbricoids Wikipedia.org DPDx.JPG)*

CONCLUSION

This study observed that untreated municipal wastewater and vegetable produce at the study site contains Helminthes above the recommended guideline value of <1 ova of Helminths/l (WHO 2006). The study aimed at reducing the risk of infection, which indicates that the water is unfit for irrigation purposes and the vegetables are highly contaminated. From the findings of the research it is recommended that farmers should practice the use of a stabilization pond (aerobic, facultative, and maturation) before using the water for irrigation, Consumers of vegetables should wash them properly using vinegar, and adoption of safer irrigation methods such as drip or surface irrigation to minimize contact of crops with contaminants present in irrigation water especially crops that are eaten raw, and also farmers should be encouraged to use Personal Protective Equipment such as gloves, boots, trousers, and long sleeve shirts during farm work to reduce the level of exposure. Most times major sources of these parasites might be as a result of inadequate modern toilet facilities and, a lack of public health enlightenment where people practice open defecation resulting in pollution of water sources and farmlands.

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Evaluation of Cucumber (*Cucumis sativus* L.) Genotypes for Growth and Yield in Ifite-Ogwari, Southeastern Nigeria

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KEYWORDS

Cucumber,
Evaluation,
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Yield,

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ABSTRACT

The quest for increased cucumber productivity in Nigeria's diverse agro-ecological zones necessitates the continuous evaluation of promising genotypes. This study delves into the yield potential of five cucumber genotypes (Oliveira Bold F1, Amarisa Super F1, Gorald, CU99, and Darina) cultivated in Ifite-Ogwari, Anambra State. Conducted under a Randomized Complete Block Design with three replications, the experiment meticulously tracked various parameters including flower initiation, leaf morphology (number and width), vine length, and most importantly, yield components (fruit circumference, length, weight, and number). The findings unveiled significant variations among the genotypes, painting a nuanced picture of their strengths and weaknesses. Jorad and Darina emerged as potential champions, demonstrating impressive yield attributes. Notably, Jorad produced the highest number of fruits (7.00 per plant) at 7 weeks after planting, significantly outperforming its counterparts. Furthermore, Darina showcased remarkable fruit weight (356.33 g), highlighting its potential for heavier harvests. These findings are particularly encouraging for farmers seeking high-yielding cucumber varieties in the Ifite-Ogwari region. Evaluating these promising genotypes under different agro-ecological conditions and exploring their suitability for large-scale commercial production will provide a more comprehensive understanding of their potential impact on regional cucumber production. Additionally, investigating the underlying factors contributing to the superior performance of Jorad and Darina could pave way for breeding programs focused on developing even more productive cucumber varieties adapted to the specific needs of Nigerian farmers. By unveiling high-yielding genotypes and pinpointing areas for further exploration, this study contributes valuable knowledge to the ongoing pursuit of sustainable and productive cucumber cultivation in Nigeria.

INTRODUCTION

Cucumber (*Cucumis sativus*) originated in South Asia, specifically in the area encompassing present-day India and Pakistan. Its wild ancestor, known as *Cucumis hardwickii*, is native to these regions (Dhillon *et al*., 2012). Cucumbers were introduced to other parts of the world through trade and exploration. They were brought to the Mediterranean region by the Romans and later spread to other parts of Europe (Grumet *et al.*, 2019).

Over time, cucumber cultivation and selection led to the development of various cucumber varieties with different characteristics, such as size, shape, color, and taste. Today, cucumbers are grown in diverse regions worldwide, adapted to a range of climatic conditions and agricultural practices. They have become an important vegetable crop in many countries, providing nutritional value and culinary versatility to various cuisines (FAO, 2020).Cucumbers are highly appreciated for their refreshing flavor, high water content, and nutritional benefits, making them a popular ingredient in salads, pickles, and other culinary preparations (FAO, 2020).Despite the wide range of cucumber genotypes available, there is a lack of information on the comparative yield of cucumber genotypes. This lack of information makes it difficult for farmers and breeders to select the best cucumber varieties for their specific needs. By unveiling high-yielding genotypes and pinpointing areas for further exploration, this study contributes valuable knowledge to the ongoing pursuit of sustainable and productive cucumber cultivation in Nigeria.

MATERIALS AND METHOD

The experiment was carried out in Anambra State at the Ifite-Ogwari Campus of Nnamdi Azikiwe University. The study region is situated at latitude 6.6041° North and longitude 6.9507° East, in Southeast Nigeria. The experiment was laid out in a Randomized Complete Block Design (RBCD) with 3 replications. Five cucumber genotypes (C*ucumis sativus L.*) was sown as treatments.

The treatments include; T1- Oliveira bold F1, T2- Amarisa super F1, T3- Jorald, T4- CU99 and T5-Darina. The experimental field size of 183.75m² was marked using measuring tape, rope and peg. Land clearing was done and debris was packed using rake. Poultry manure was integrated into the soil. Total of nine (9) planting holes were made on each bed. Four seeds were planted in each hole. The planting depth was 2.5cm. The four seeds planted were later thinned to two (2) seedlings per hole, four (4) days after germination. Each planting space was 0.5m(50cm) apart vertically and horizontally. After thinning, total of 18 seedlings were left on each bed with two (2) seedlings per hole.

Data Collection:

Data was collected on the following parameters: Vegetative parameters (leaf width, number of leaves, petiole length, vine length), Floral parameters (days to flowering, days to 50% flowering), and Yield parameters (Number of fruits, fruit length, fruit weight, fruit width).

Statistical Analysis:

Analysis of variance (ANOVA) was computed using Genstat Release 10.3 Discovery Edition 9PC/Windows) for the agronomic traits. Separation of means was done using LSD at ($P>0.05$) probability level.

RESULTS

Number of Leaves of Cucumber genotypes at 3, 5 and 7 Weeks after planting

Table. 1 revealed a significant difference ($p<0.05$) in the number of leaves among the cucumber genotypes studied at 3 weeks after planting. Jorad recorded the highest number of leaves while Amarisa Super F1 has the lowest number of leaves at 3 weeks after planting. At 5 weeks after planting, there was no significant difference ($p>0.05$) in the number of leaves among the cucumber genotypes. Amarisa Super F1 had the highest number of leaves followed by Oliveira Bold F1, CU999 and Jorad while Darina has the lowest number of leaves. There was also no significant ($p>0.05$) difference in the number of leaves among the genotypes at 7 weeks after planting. Oliveira Bold F1 had the highest number of leaves (44.67) while Darina had the lowest number of leaves (18.56).

Table 1. Number of Leaves of Cucumber genotypes at 3, 5 and 7 weeks after planting

Cucumber genotype	Number of leaves at 3 WAP	Number of leaves at 5 WAP	Number of leaves at 7 WAP
Olievera Bold F1	6.78	23.56	44.67
Amarisa Super F1	6.00	24.44	36.11
Jorad	11.89	20.56	22.56
CU99	13.55	23.11	24.78
Darina	10.00	16.22	18.56
LSD (0.05)	4.556	12.539	18.011

WAP= Weeks After Planting

The result of the analysis of variance showed no significant difference ($p>0.05$) among the genotypes at 3 weeks after planting. America Super F1 had the lowest leaf width (11.89cm) while Jorad has the highest leaf width (17.56cm). There was a significant difference ($p<0.05$) among the genotypes at 5 weeks after planting. Oliveira Bold F1 had the highest leaf circumference with a mean value of 19.44cm followed by Jorad(18.22cm). At 7 weeks after planting, there was also a significant difference ($p<0.05$) among the cucumber genotypes in terms of leaf width. Oliveira Bold F1 had the highest leaf width with a mean value of18.23cm while CU999 had the lowest leaf width with a mean value of 14.89cm (Table 2).

Table 2. Leaf width of the cucumber genotypes at 3, 5 and 7 (cm) Weeks after planting.

Cucumber genotype	3 WAP (cm)	5 WAP (cm)	7 WAP (cm)
Olievera Bold F1	12.67	19.44	18.23
Amerisa Super F1	11.89	16.28	16.28
Jorad	17.56	18.22	17.67
CU99	15.44	16	14.89
Darina	15.33	16.11	15.67
LSD (0.05)	5.697	1.659	2.066

WAP= Weeks After Planting

Vine Length of the Cucumber genotypes at 3, 5 and 7 weeks after planting

From the analysis, there is a significant difference ($p<0.05$) among the five cucumber genotypes at 3 weeks after planting in the vine length parameters. Oliveira Bold F1 and AmarisaSuper F1 have the lowest mean values of 15.33cm and 15.56cm respectively. CU999 recorded the mean

Table 3: Vine Length of the Cucumber genotypes at 3, 5 and 7 weeks after planting

Cucumber Genotype	3 WAP (cm)	5 WAP (cm)	7 WAP (cm)
Olievera Bold F1	15.33	88.11	158.67
Amarisa Super F1	15.56	88.39	157.78
Jorad	50.78	131.67	132.78
CU99	60.11	136.67	134.67
Darina	43.67	111.89	157.78

LSD (0.05)	12.044	44.96	51.982

Petiole length parameters of the five cucumber genotypes measured at 3, 5 and 7 WAP.

The result of the analysis of variance showed that there was a significant difference (*$p<0.05$*)in petiole lengths of the cucumber genotypes studied. CU99 had the longest petiole with a mean value of 12.55cm, Amarisa Super F1 showed the shortest petiole with a mean value of 6.67cm (Table 4).At 5 weeks after planting, there was also a significant difference ($p<0.05$) among the cucumber genotypes in their petiole length. CU999 had the shortest petiole with a mean value of 10.11cm While Darina had the longest petiole with a mean value of 16.00cm. Moreover, at 7 weeks after planting, there was no significant difference ($p>0.05$) among the genotypes. CU999had the shortest petiole having recorded a lowestmean value of 12.11cm and Amarisa Bold F1 had the longest petiole with a mean value of 16.44cm.

Table 4: Petiole Length of the Cucumber genotypes at 3, 5 and 7 weeks after planting

Cucumber genotype	3 WAP (cm)	5 WAP (cm)	7 WAP (cm)
Olievera Bold F1	7.11	11.28	14.33
Amarisa Super F1	6.67	10.39	13.11
Jorad	11.45	14.78	13.22
CU99	12.55	10.11	12.11
Darina	11.22	16.00	16.44
LSD (*0.05*)	3.091	2.915	3.153

Percentage Flower Initiation of the cucumber genotypes

The cucumber genotypes displayed no significant differences ($p>0.05$) in percentage flower initiation at 5 weeks after planting (Table 5). Nevertheless, Amarisa Super, Jorad, CU99 and Olievera Bold F1, showed slight differences in their mean values.Amarisa Super, Jorad, CU99 and Darina recorded 100% flower initiation at 5 weeks after planting while Darina differ slightly with 83% flower initiation. The genotype that recorded lowest percentage flower initiation was Oliveira Bold F1 both at 3 and 5 weeks after planting respectively.

Table 5. Percentage Flower initiation of Cucumber genotypes at 3 and 5 weeks after planting

Cucumber Genotype	Flower initiation at 3WAP (%)	Flower initiation at 5WAP (%)
Olievera Bold F1	0.00	83.33
Amarisa Super F1	0.00	100.00
Jorad	50.00	100.00
CU99	50.00	100.00
Darina	50.00	100.00
LSD(*0.05*)	NS	24.307

Yield parameters of the Cucumber Genotypes

There were significant differences ($p<0.05$) among the genotypes in their yield parameters. Darina had the moderate fruit length with a mean value of 22.22cm while Amarisa Super F1 and CU99 had the longest fruits with mean values of 23.45cm and 23.44cm respectively.

Amerisa Super F1 had the highest fruit weight (22.0t/ha) while Jorad had the lowest fruit weight (11.56t/ha). Number of fruits revealed significant difference. Jorad, had the highest number of fruits(7.00) while Olievera Bold F1 had the lowest number of fruits (4.00).

Table 6: Yield parameters of the Cucumber genotypes

Cucumber Genotype	Fruit width (cm)	Fruit Length (cm)	Fruit weight(t/ha)	Number of Fruits
Olievera Bold F1	20.67	22.89	21.8	4.00
Amarisa Super F1	20.56	23.45	22.0	4.33
Jorad	17.45	20.78	11.56	7.00
CU99	19.56	23.44	14.8	5.00
Darina	19.56	22.22	14.2	4.33
LSD (*0.05*)	NS	1.823	121.443	2.228

DISCUSSION

The evaluation of the cucumber genotypes in Ifite Ogwari, Southeastern Nigeria, revealed varying growth and yield performances. The number of leaves parameter indicated significant differences at 3 weeks after planting, with Jorad having the highest leaf count. At 5weeks after planting, Amarisa Super F1 displayed the highest leaf count. This aligned with the findings of Md. Nabiul *et al.*(2020), who observed that variation in leaf numbers can be attributed to genotype-specific growth patterns. At 7 weeks after planting, Oliveira Bold F1 demonstrated the highest leaf count, while Darina had the lowest, showcasing genotype-specific growth trajectories.

Leaf width parameters exhibited significant differences at 5 weeks after planting. Gul *et al*. (2019), emphasized on the influence of genotype on leaf development. At 5 weeks after planting, Oliveira Bold F1 excelled in its leaf width, suggesting its potential for robust foliage as a result of the influence of its genotype on the leaf development. However, the leaf width differences observed at 7 weeks after planting indicate genotype-specific growth patterns influencing cucumber plant development.

Vine length parameters showed significant differences at 3 weeks after planting, with CU999 displaying the longest vine. At 7 weeks after planting, there were no significant differences among genotypes, suggesting convergence in vine lengths. This may indicate that while initial growth patterns differ, the genotypes eventually reach similar vine lengths (Justine *et al*., 2016).

The percentage flower initiation parameter highlighted differences in flowering among genotypes (Teixido *et al*., 2018). Notably, Oliveira Bold F1 exhibited the lowest flower initiation at both 3 and 5 weeks after planting. This was in conjunction with the works of Justine *et al*., 2016, who opined that potential delay in flowering could affect fruit production timelines.

Significant differences persisted in fruit length, weight, and the number of fruits. Darina excelled in fruit length, while Amarisa Super F1 had the highest fruit weight(22t/ha),Jorad produced the highest number of fruits(7), suggesting its potential as a high-yielding genotype (Gul *et al*., 2019).

CONCLUSION

In conclusion, the evaluation of cucumber genotypes in Ifite -Ogwari, Southeastern Nigeria, provided valuable insights into their growth and yield performances. The study identified genotype-specific characteristics influencing leaf development, vine length,flowering and yield parameters. The findings contribute to the knowledge base for cucumber cultivation in the region.Selection of cucumber genotypes should align with specific cultivation objectives, considering factors such as growth patterns , yield potential, and adaptability (Md. Nabiul *et al.,* 2020).

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Shelf-Life Prediction Model of Bambara Nut (*Vigna Subterranea*) Flour: Polynomial Model, Sorption Isotherms and Physico-Mechanical Properties

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KEYWORDS

Bambara nut
Model,
Multiple Regression,
Polynomial,
Shelf-life,

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ABSTRACT

Bambara nut samples were obtained, milled, packaged in Low Density Polyethylene and stored for a period of 12 weeks under controlled temperatures of 20°C, 30°C and 40°C respectively. At weekly intervals, the flours were analyzed for proximate composition, Physico-mechanical properties and sorption isotherms. The data obtained from the study were analyzed using the Design-Expert software (Version 7.0.0, Stat-Ease Inc., Minneapolis, USA). The experimental data generated was fitted to a polynomial regression model for predicting maximum shelf-life. In order to correlate the response variables to the independent variables, multiple regressions were used to fit the coefficient of the polynomial model. The quality of fit of the model was evaluated using analysis of variance (ANOVA). The suitability of the models was compared and evaluated using correlation coefficient (R^2). The study showed that all the parameters studied were significant in predicting the shelf-life of Bambara nut flour. The results obtained in the study showed that the response surface model developed is a good one. The model correlation coefficient (R^2) of the responses was found to be 0.9983, 0.9701, 0.9688, 0.9862, 0.9138 and 0.9531 for the flour moisture, ash, protein, fat, fibre and carbohydrate contents, respectively. Levels of significance obtained were 0.001, 0.02, 0.03, 0.01, 0.03 and 0.02 for the flour moisture, ash, protein, fat, fibre and carbohydrate contents which were high and attested to the fitness of the model in evaluating the responses. Optimum moisture content and storage time were found to be 6.32% (wb) and 23.62 weeks. The study confirmed that the model developed is adequate to optimize these process conditions.

INTRODUCTION

Control of Diabetes with the use of plant foods has become an area of interest in research globally. Studies have shown that the fibre and protein contents of Bambara nut can weaken the absorption of sugar, reduce sugar response and increase insulin sensitivity and therefore recommended as a supplement for type II diabetes. Ngabea, (2022) reported that diabetic patients in Nigeria rely on Bambara nut flour as food because of its insulin building ability in the body system, but the challenge is the unavailability of the processed one in the market when needed. Presently, there is paucity of information on the storage techniques of Bambara nut flour that can prolong the shelf-life for later usage.

Temegne *et al*., (2018) reported that Bambara nut is now widely cultivated throughout tropical Africa, Indonesia, Malaysia, India, Sri Lanka, Philippines, South Pacific, parts of Northern Australia, Central and

South America. Nigeria is one of the major producers of the crop and it is locally called Fyegbankpo (Jukun), Okpa (Ibo), Epiroro (Yoruba) and Gurjiya (Hausa). It is the third most important grain legume after ground nut and cowpea in Nigeria (Lacroix *et al*., 2003; Ngabea, 2022). Beyond Africa, Bambara nut is cultivated in Brazil where it is known as Mandubi d‟Angola‟ as well as in West Java and southern Thailand. Other tropical locations such as Middle East, Syria and Greece could also grow Bambara nut. Small-scale cultivation trials of Bambara nut have been successful in Florida, United States (Ferry, 2002; Ngabea *et al.*, 2021) Bambara nut is extensively cultivated in West Africa, Nigeria produced over 100,000 metric tons, follow closely by Niger with 30,000 metric tons and Ghana 20,000 metric tons annually (Asiedu, 1989). The seeds are ground into powder, which is used for bread making or prepared into stiff porridge, a very popular semi-fluid food in some parts of Nigeria (Ngabea *et al*., 2020).

Torrieri, (2016) defined Shelf-life as the period of time, established under intended conditions of distribution, storage, retail and use, that the food would remain safe and suitable. Ngabea *et al*., (2019) reported that shelf-life is the length of time food can be held without loss of nutritive value and quality. The shelf life of many foods can be extended through various means including controlled storage. It may be possible to manipulate certain factors to extend the shelf life. Although the composition of food material, its formulation, processing or packaging also some of the factors that may inadvertently lead to a decrease in the shelf life or make the food more susceptible to the growth of spoilage or even pathogenic microorganisms.

Aris, (1994) opined that a model is a simplified representation of a system at some particular point in time or space intended to promote understanding of the real system. Modeling involves identifying and selecting relevance features of a real work situation, representing those features symbolically, analyzing and reasoning about the model and characteristics of the situation and considering the accuracy and limitation of the model (Law, 2007).

Fangchao *et al*., (2023) reported in a review and classified shelf life models, detailed the application background and characteristics of commonly used models to better understand the different uses and aspects of the commonly used models. In particular, the structural framework, application mechanisms, and numerical relationships of commonly used models were elaborated. In addition, the study focused on the application of commonly used models in the food field. Besides predicting the freshness index and remaining shelf life of food, the study addressed aspects such as food classification (maturity and damage) and content prediction.

Stephanie *et al.*, (2013) also developed a model for predicting the safe storage of fresh fish under modified atmospheres with respect to *Clostridium botulinum* toxigenesis by modeling length of the lag phase of growth.

Various models for monitoring food quality have been developed and applied to predict food shelf life (Tanoj *et al*., 2018; Hybertson, 2009). Most of the studies on shelf-life prediction models in the literature are on the composition of the stored materials. No study has been reported considering both the compositions and the environmental parameters. In this study, both the compositional and environmental conditions are put into consideration. This study is the first to be carried out on predicting the shelf-life of Bambara nut flour considering its hygroscopic nature and sorptive behavior under controlled storage conditions; all the equations used in this study were formulated, and first used in this study.

The objective of this study was to use sorption isotherms and response surface methodology to optimize the process variables for predicting maximum shelf life, appropriate temperature and relative humidity for storing Bambara nut flour.

MATERIALS AND METHODS

Study and Experimental Locations

The study was conducted at the Department of Agricultural Engineering, Federal University Wukari while the experiments were carried out at the laboratories of the Departments of Food Science and Technology, University of Nigeria Nsukka and Modibbo Adama University of Technology Yola, respectively.

Research Materials

The materials used for this study were Bambara nuts- *Vigna subterranean,* low density polythene bags, plastic containers, food grade chemicals and water.

Source of Bambara nut

Bambara nut was purchased from a local market in Donga Township, Taraba State. North-eastern Nigeria. To remove foreign matter, immature and damaged seeds, the seeds were manually washed.

Chemicals and reagents

All the chemicals used were of analytical grade (Distilled water, sulphuric acid, sodium Hydroxide, Selenium tablets, Boric acid, Methyl red, Hydrochloric acid and Refined Vegetable oil). Some were purchased from Nsukka market while others from VEKO Scientific Chemical Shop, Jimeta-Yola.

Methods

The experiment was in three stages, the first stage was conducted for the determination of Proximate Composition of the stored packaged Bambara nut flour. The second stage involved the determination of the Physico-mechanical and functional properties. The third stage involved the determination of Bambara nut flour Moisture Sorption characteristics.

Preparation of experimental samples

The Bambara seeds were milled into flour using a magnetic sieve grinding machine as described by Ngabea *et al*, (2015). Particle size distribution using sieve analysis was carried out to separate the flour at a range of 20 - 100 mesh numbers (850 - 150µm) as designed in the face central composite design (FCCD) response surface methodology of Design Expert 7.0.0 software.

Determination of Proximate Composition of Bambara nut flour

The crude protein, crude fat, moisture, ash and crude fibre contents of the Bambara nut flour were determined using the methods of AOAC (2010). The carbohydrate content was calculated by difference as% Carbohydrate = 100 – (% Protein + % Ash) + % Moisture + % Fat (Egan *et al.,* 1981).

Determination of moisture content

Five grams of each sample were weighed into pre-weighed aluminium drying dish. The sample was dried to a constant weight in an oven at 105ºC for four hours (AOAC, 1990).

The moisture content was determined as follows:

$$\frac{M1 - M2}{M1 - M0} \times 100 \qquad (1)$$

Where: M_0 = Weight of aluminium dish, M_1 = Weight of fresh sample + dish, M_2 = Weight of dried sample + dish

Determination of Ash Content

Five grams of each sample were weighed into a porcelain crucible. The material was ignited and charred on a hot plate in the fume cupboard. The sample on the crucible was placed in the Vecstar Muffle Furnace in a controlled temperature of 550ºC for six hours. When the sample was fully charred, it was then cooled in a dessicator and was weighed out.

Plate 1: The Muffle Furnace used for the determination of Ash Content

The percentage ash content was determined as shown in equation 2

$$\% \text{ Ash} = \frac{(Weight\ of\ crucible\ and\ sample)(Weight\ of\ empty\ crucible)}{Weight\ of\ sample} \times 100 \quad (2)$$

Determination of crude fibre

Defatted sample (2g) was placed in a 600 ml conical flask, 1.25% sulphuric acid solution was added to 160 ml boiling. The sample was digested for 35 min and washed with boiling distilled water after when the acid was drained out. Then, 1.25% sodium hydroxide solutions (160 ml) were added. The sample was then digested for 35min, thereafter the sodium hydroxide solution was drained out and the sample was then washed with boiling distilled water. Lastly, the sample was placed in a dried crucible and oven dried at 120ºC overnight. The sample was allowed to cool in a desiccator and then weighed (W_1). The sample was ashed at 550ºC in a muffle furnace for two hours, cooled in a desiccator and then reweighed (W_2). Extracted fibre was articulated as percentage of the original sample and calculated according to the formula:

$$Crude\ Fibre\ (\%) = \frac{Digested\ sample\ (W1) - Ashed\ sample (W2)}{Weight\ of\ sample} \times 100 \quad (3)$$

Determination of crude protein content

Kjedahl nitrogen method was used for the determination of the protein. 1.5 gram of the sample from each treatment was introduced into 900 ml digestion flask. 5 selenium tablets were added to the sample as catalyst. 25 ml of concentrated H_2SO4 was added to each sample and fixed to the digestion flask until a clear solution was obtained. The cooling digest was poured into 100 ml volumetric flask and was made up to mark with distilled water.

The distillation apparatus were rinsed and arranged for 15 minutes. The apparatus were boiled, 20 ml of 4% boric acid was pipetted into conical flasks, 6 drops of methyl red was added to each flask as indicator and the digest was diluted with 75 ml distilled water. Alkaline was produced from 10 ml of the digest with 20 ml of 20% sodium hydroxide and distilled. The steam exit of the distillatory was closed and the boric acid solution colour changed to green. The mixture was distilled for 15 minutes (AOAC, 1990) and boric acid along with distillate was then titrated against 0.1N Hcl and thus, the percentage total nitrogen was calculated as shown in equations 4 and 5:

$$\% \text{ total of nitrogen} = \frac{\text{Titre} \times \text{Normality} \times 0.014}{Weight\ of\ sample} \times 100 \quad (4)$$

$$\% \text{ Crude Protein} = \% \text{ total nitrogen} \times 6.25 \quad (5)$$

Where: is a constant (AOAC, 1990)

Determination of crude fat content

Five grams of the sample was weighed in a thimble and plugged with cotton wool. The thimble was then inserted in a soxhlet apparatus. A formerly weighed clean dried 250 ml flask was filled with 180 ml of petroleum ether of 45 – 65ºC boiling points.

Plate 2: Soxhlet apparatus for fat determination (DHG-9023A, England)

The soxhlet apparatus (plate 2) were assembled and allowed to reflux for 6.5 hours, the solvent was recovered and the flask with the extract was dried in the oven (DHG-9023A, England) at 105ºC for 30 minutes. It was then cooled in the dessicator and weighed. The crude fat was calculated as stated in equation 6

$$\% \text{ Fat} = \frac{W3\ - W2}{W1} \times 100 \qquad (6)$$

Where: W_1 = weight of sample, W_2 = weight of empty flask, W_3 = weight of flask extracted oil

Determination of carbohydrate content

The determination of carbohydrate was obtained by subtracting the sum of the percentage protein, ash, fibre,moisture and fats from 100 as described by Egan *et al*, (1981).

% Carbohydrate = 100 – (% Protein + % Ash) + % Fibre + % Moisture + % Fat (7)

Determination of Moisture Sorption Isotherm

The adsorption isotherms of the samples were obtained using static gravimetric method as described by Labuza, (1984). An incubator was used as temperature control chamber. The experimental set up consists of saturated salt of lithium chloride, potassium acetate, Mgcl, KCO_2, MgN_2, sodium nitrate, Nacl, ammonium sulphate and barium chloride solutionswhich created different relative humidity environmental storage conditions with the corresponding water activities of 0.11, 0.21, 0.33, 0.43, 0.50, 0.67, 0.76, 0.86 and 0.90, respectively. The samples were arranged in dessicators. The duplicate flour samples of 3g each were placed on the saturated salt solutions in the dessiators and kept in a cabinet at a controlled temperatures of 20, 30, 40 and 50ºC, respectively. The weight of the samples was taken after every 24 hours with a digital weighing balance until constant weight is attained. Each of the samples was oven dried at 110ºC to a constant weight to obtain the equilibrium moisture content (dry basis). Graph of equilibrium moisture content against water activities (relative humidity) was plotted.

Experimental design and data analysis

A face central composite design (FCCD) of Response Surface Methodology (RSM) was used for the experimental design. The factors or independent variables were storage time and particle size, while the responses were the proximate composition (moisture, protein, fat, carbohydrates, ash and fibre contents).

The outline of experimental design with the coded levels is given on Table 1

Table 1: Variation of parameter for two (2) numerical factor designs in surface response

Numerical Factor		
Variable	Low level (-1)	High level (+1)
Time (weeks)	8	24
Particle size	20 mesh number	100 mesh number

Note that, the low level and high level interval of 8 and 24 for the time (weeks) was obtained from the result of the preliminary investigation conducted to study the changes of the values of proximate composition of Bambara nut flour under controlled storage condition.

Modeling of the flour shelf-life with respect to particle size and time

Each design point was performed in duplicates, except the centre points that were performed four times. The experiment was carried out according to design. The data obtained were analyzed using the Design-Expert software (Version 7.0.0, Stat-Ease Inc., Minneapolis, USA). The experimental data generated was fitted to a polynomial regression model for predicting maximum shelf-life. In order to correlate the response variables to the independent variables, multiple regressions were used to fit the coefficient of the polynomial model of the response. The quality of fit of the model was evaluated using analysis of variance (ANOVA).

Validation of the regression model

The model developed was examined for Test for significance, lack-of-fit and coefficient of determination (R^2) which was integrated into the analysis of variance (ANOVA) to examine the adequacy of the regression model while response surface and contour plots were designed with the Design-Expert software (Version 7.0.0, Stat-Ease Inc., Minneapolis, USA). R^2 was calculated as:

$$R^2 = \frac{\text{Sum of square residual}}{\text{Model sum of square} + \text{sum of square residual}} \quad (10)$$

$$R^2\ \text{adj} = 1 - \frac{n-1}{n-p}(1 - R^2) \quad (11)$$

Process Optimization

To optimize the response variables, contour and surface plots were plotted using the Design Expert software as described by Floros and Chinnan (1988). A second order polynomial was used to predict the experimental behavior (Equation 3.12).

$$Y = \beta o + \beta_1 X_1 + \beta_2 X_2 + \beta_1 X^2_1 + \beta_2 X^2_2 + \beta_{11} X_1 X_2 + \beta_{12} X_1 X_2 + \varepsilon \quad (12)$$

Where,

X_1, and X_2 are the factors: storage time and particle sizes

β is a constant coefficient of linear, interaction and square terms respectively

ε is the random error term.

Pearson correlation analysis ($p = 0.05$) was performed using the Design-Expert software (Version 7.0.0, Stat-Ease Inc., Minneapolis, USA).

RESULTS AND DISCUSSIONS

The results of the proximate composition (moisture, ash, protein, fat, fibre and carbohydrate contents) of Bambara nut flour are presented on Table 2. The mean effect of storage duration on the percentage proximate composition of Bambara nut flour showed that there were substantial differences in the moisture content of the flour sample at the beginning (week zero) of the storage period and at the end of the storage period.

Modeling the effect of storage time and particle size on the proximate composition of Bambara nut flour

The experimental ranges and levels of the independent variables for the experimental design for proximate analysis of Bambara nut flour are summarised in Table 2 as presented.

Table 2: Experimental ranges and levels of the independent variables for the proximate analysis of Bambara nut flour

Run	Storage Time (Weeks)	Particle Size (Mesh.number)	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	Carbohydrate (%)
1	24.00	20.00	6.33	3.33	36.76	8.10	2.96	42.53
2	8.00	60.00	12.0	3.00	20.13	4.67	2.33	57.87
3	8.00	100.0	11.67	3.00	21.01	5.33	2.00	56.12
4	8.00	20.00	9.33	2.67	22.76	5.33	2.67	56.36
5	16.00	100.00	9.33	3.00	19.26	7.33	3.00	58.08
6	16.00	20.00	7.67	3.30	21.01	8.00	3.33	56.69
7	16.00	60.00	10.0	3.30	20.13	7.67	2.67	56.23
8	24.00	60.00	8.00	3.33	29.76	7.50	2.66	48.75
9	16.00	60.00	10.0	3.30	20.13	7.67	2.67	56.23
10	16.00	60.00	10.0	3.30	20.13	7.67	2.67	56.23
11	24.00	100.0	7.33	2.67	33.26	7.00	3.00	46.74
12	16.00	60.00	10.0	3.30	20.13	7.67	2.67	56.23
13	16.00	60.00	10.0	3.30	20.13	7.67	2.67	56.23

The coefficient of the regression equations for the measured responses, the linear, quadratic and interaction terms of the selected variables are presented in Table 3.The results of the proximate composition of the flour showed that the linear (A, B), interaction (AB) parameters and square (A^2,B^2) terms were all significant at $p<0.05$ as shown in Table 3.

Table 3: Regression coefficients of predicted quadratic model for proximate composition of Bambara nut flour

			Dependent	Variables		
Coefficients	**Moisture**	**Ash**	**Protein**	**Fat**	**Fibre**	**Carbohydrate**
Intercept	9.98	3.31	19.65	7.62	2.72	56.79
A	-1.89	0.11	5.98	1.21	0.27	-5.39
B	0.83	-0.11	-1.17	-0.30	-0.16	0.89
AB	-0.33	-0.25	-0.44	-0.27	0.18	1.11
A^2	0.080	-0.18	6.50	-1.41	-0.34	-4.86
B^2	-1.42	-0.20	1.69	0.17	0.33	-0.79
R^2	0.9983	0.9701	0.9688	0.9862	0.9138	0.9531
Adj. R^2	0.9971	0.9488	0.9465	0.9763	0.8522	0.9197
C.V (%)	0.95	1.77	5.76	2.51	4.61	2.55
Adeq. Precision	94.538	18.900	17.203	26.362	12.962	14.459
Mean	9.36	3.14	23.43	7.05	2.71	54.18
Std. Dev.	0.089	0.056	1.35	0.18	0.13	1.38

A = Storage time, B = Particle size

Fitting of the quadratic model

The quadratic model fittings are shown in Table 4. The analysis of variance (ANOVA) showed that the model was significant ($p<0.05$) for the predicted flour moisture, ash, protein, fat, fibre and carbohydrate contents. The correlation coefficient (R^2) 0.9983, 0.9701, 0.9688, 0.9862, 0.9138 and 0.9531 for the flour moisture, ash, protein, fat, fibre and carbohydrate contents, respectively were obtained. The R-squared value is an indication of the level of responses that can be explained by a particular model. These results showed that 99.83%, 97.01%, 96.88%, 98.62%, 91.38% and 95.31% of the responses could be explained by the model. Levels of significance obtained were 0.001, 0.02, 0.03, 0.01, 0.03 and 0.02 for the flour moisture, ash, protein, fat, fibre and carbohydrate contents, respectively. These levels were high and attested to the fitness of the model in evaluating the responses. The results obtained in the study showed that the model employed is a good one and could be used for the prediction of the flour maximum shelf life, particle size and storage time in respect to the proximate composition of Bambara nut flour for the production, handling and storage of the flour.

Table 4: Moisture content ANOVA for Response Surface Quadratic Model

Source	SS	Df	MS	F - Value	P - Value
Model	32.31	5	6.46	820.75	<0.0001
A	21.43	1	21.43	2722.38	<0.0001
B	4.17	1	4.17	529.25	<0.0001
AB	0.45	1	0.45	57.02	0.0001
A^2	0.018	1	0.018	2.23	0.1793
B^2	5.57	1	5.57	707.73	<0.0001
Residual	0.055	7	7.873E-003		
Lack of fit	0.055	3	0.018		
Pure Error	0.000	4	0.000		
Total	32.36	12			
	R^2 = 0.9983	Adj. R^2 = 9971	Pred. R^2=0.9846		

Using the experimental data in Table 4, second degree polynomial equation model for the flour moisture, ash, protein, fat, fibre and carbohydrate contents, respectively were regressed and the final equations in term of coded factor for the linear, interaction and square terms, respectively are shown in equations 13 – 18

$$\text{Moisture content} = +9.98 - 1.89A + 0.83B - 0.33AB + 0.08A^2 - 1.42B^2 \quad (13)$$
$$\text{Ash content} = +3.31 + 0.11A - 0.11B - 0.25AB - 0.18A^2 - 0.2B^2 \quad (14)$$
$$\text{Protein content} = +19.65 + 5.98A - 1.17B - 0.44AB + 6.50A^2 + 1.69B^2 \quad (15)$$
$$\text{Fat content} = +7.62 + 1.21A - 0.30B - 0.27AB - 1.41A^2 + 0.17B^2 \quad (16)$$
$$\text{Fibre content} = +2.72 + 0.27A - 0.16B + 0.18AB - 0.34A^2 + 0.33B^2 \quad (17)$$
$$\text{Carbohydrate content} = +56.79 - 5.39A + 0.89B + 1.11AB - 4.86A^2 - 0.79B^2 \quad (18)$$

Numerical Optimization of particle size and storage duration on the proximate composition of Bambara nut flour

The graphical representation of 3 dimensional surface and contour plots of response surface in Figures 1-12 showed the relationships between the dependent and independent variables of the proximate compositions for predicting the shelf-life of Bambara nut flour.

Figures 1 showed 3D dimensional surface plots of moisture content and figure 2 plots contours. The function has the optimizer values 11.1972%, 10.2074%, 9.2176%, 8.2278% and 7.2971% with the maximum response moisture content value of 6.33%. The optimal particle size, moisture content and storage duration was estimated to be 120.12µm, 6.32% (wb) and 23.62 weeks, respectively. However, the optimized result from the moisture content is significantly influenced by particle size and storage time for Bambara nut flour. The predicted result is in agreement with the recommended moisture content (6 – 14%) for storing food flour by Standard Organization of Nigeria (SON, 2003).

Figures 3 and 4 showed the 3 dimensional plots of the effect of particle size and storage duration on the ash content of Bambara nut flour. The ash content has the optimizer values of 3.28%, 3.16%, 3.04%, 2.92% and 2.80% with the maximum response ash content value of 3.39%. However, there were no significant differences on the ash content. The ash content slightly decreased with storage. The reduction could be as result of biochemical activities of microorganisms. This is in perfect agreement with the result of Awoyale *et al*, 2013.

Figures 5 showed 3D dimensional surface plots of protein content and figure 6 plots contours. The protein content has the optimizer values 21.03%, 23.91%, 26.78%, 29.63% and 32.54% with the maximum response protein content value of 35.17%. The optimal particle size, protein content and storage duration was estimated to be 120.12µm, 35.17% (wb) and 23.62 weeks, respectively. However, the optimized result from the protein content is significantly influenced by particle size and storage time for Bambara nut flour handling and storage. The protein content of the flour increased with decrease in particle size. The increase on the protein content of the flour with storage might be due to the decrease in the moisture content of the flour. This response finding is in agreement with Adebowale *et al.,* (2005) who reported that liquid retention is an index of the ability of proteins to absorb and retain oil/water which is in turn influences the texture and mouth feel characteristics of foods and food products.

Figures 7 and 8 showed the effect of particle size and storage time on the fat content of Bambara nut flour. There was no significant difference (P>0.05) in the fat content of the flour within the first three months of storage. *At al*l the particle sizes (850 - 150µm) the fat content ranged between 5.0 – 6.3%.The 3 dimensional plots in figures 9 and 10 showed the effect of particle size and storage duration on the fibre content of Bambara nut flour. The fibre contents of the flour ranged from 2.00 – 3.33%. It was not significantly affected by the storage duration and particle size. The fibre content was slightly increased as the storage period progressed due to the decrease in moisture content of the flour. This is in agreement with result reported by Mpotokwane *et al.,* (2008) for wheat flour during storage.

Figures 11 showed three dimensional surface plots of carbohydrate content and figure 12 plots of contours. The carbohydrate content has the optimizer values 56.87%, 53.44%, 51.01%, 48.59% and 46.16% with the maximum response carbohydrate content value of 43.94%. The optimal particle size, carbohydrate content and storage duration was predicted to be 120.12µm, 43.94% and 23.62 weeks, respectively. However, the optimized result from the carbohydrate content is significantly influenced by particle size and storage time for Bambara nut flour. The predicted result is in agreement with Awolu *et al.,* (2017) on the carbohydrate contents of five different varieties of cassava flour. The measured responses were very much close to the predicted values of which confirming the adequacy of the response models. Hence, the optimized storage conditions ware recommend for handling and storage of Bambara nut flour.

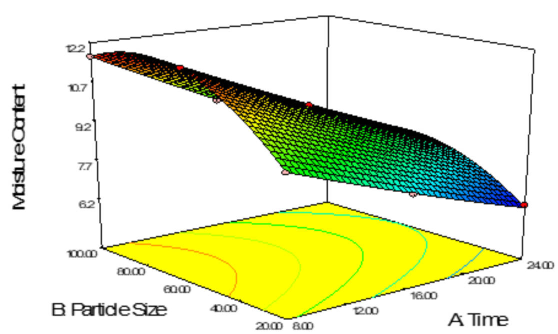


Fig. 1: 3D Surface plot of the effect of particle size and storage time on the moisture content of Bambara nut flour

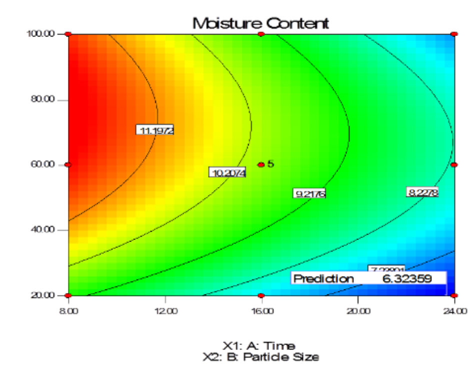
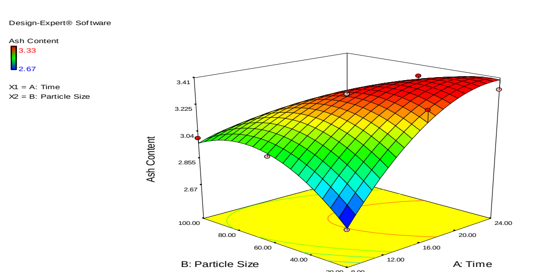


Figure 2: Contour plot of the effect of particle size and storage time on the moisture content of Bambara nut flour



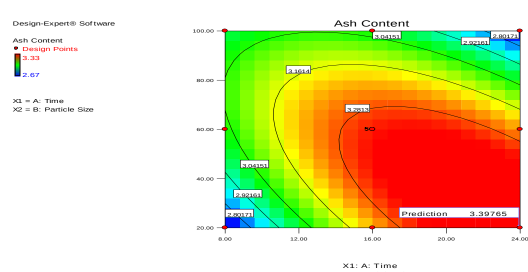
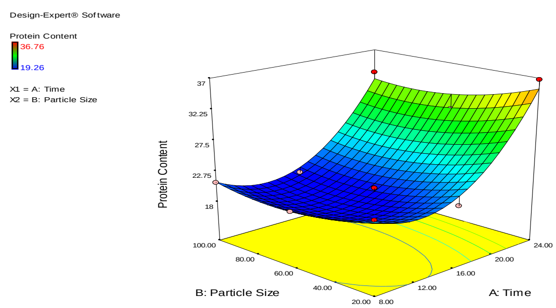


Figure 3: 3D surface plot of the effect of particle size and storage time on the Ash content of Bambara nut flour

Figure 4: Contour plot of the effect of particle size and storage time on the Ash content of Bambara nut flour



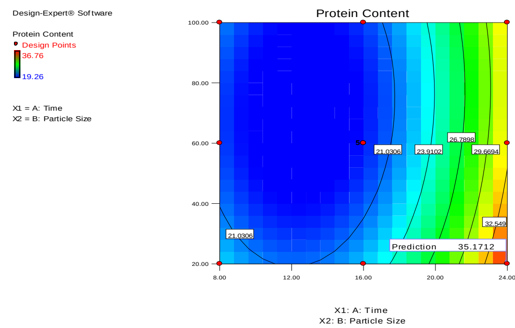
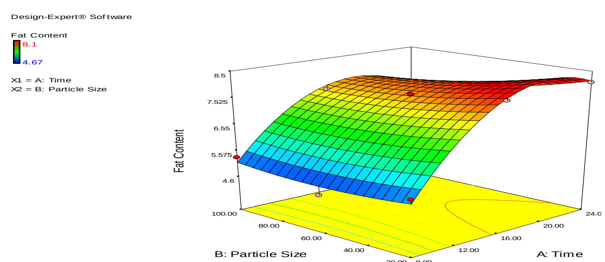


Figure 5: 3D surface plot of the effect of particle size and storage time on the Protein content of Bambara nut flour

Fig. 6: Contour plot of the effect of particle size and storage time on the Protein content of Bambara nut flour



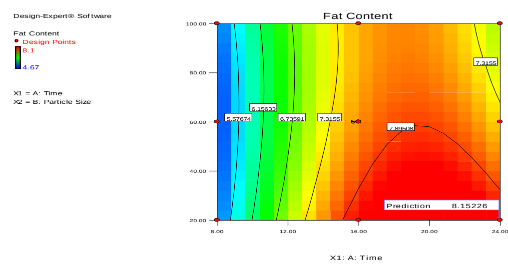
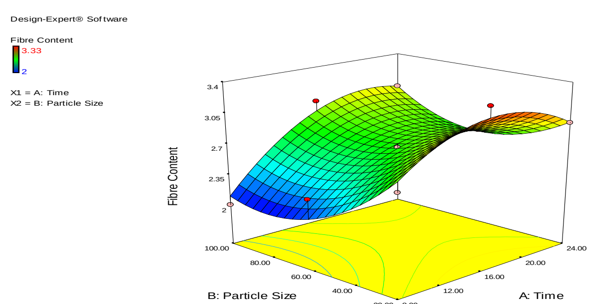


Figure 7: 3D surface plot of the effect of particle size and storage time on the fat content of Bambara nut flour

Fig. 8: Contour plot of the effect of particle size and storage time on the fat content of Bambara nut flour



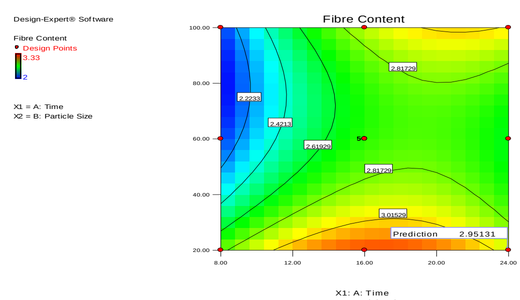


Fig. 9: 3D surface plot of the effect of particle size and storage time on the Fibre content of Bambara nut flour

Fig. 10: Contour plot of the effect of particle size and storage time on the Fibre content of Bambara nut flour

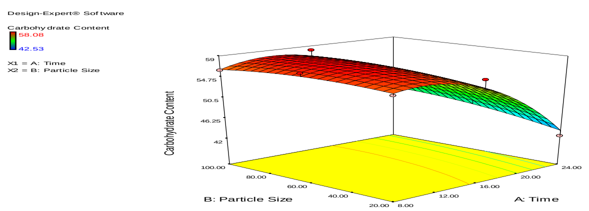


Fig. 11: 3D surface plot of the effect of particle size and storage time on the carbohydrate content of Bambara nut flour

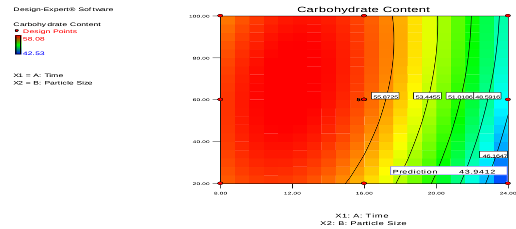


Fig. 12: Contour plot of the effect of particle size and storage time on the carbohydrate content of Bambara nut flour

Predictive model verification

In verifying the capacity of the model to predict the optimum storage conditions, maximum desirability was used for the proximate composition of the flour. Optimum particle size and storage times were generated by the software and were found to be 250.12µm, 6.32% (wb), and 23.62 weeks, respectively as shown in Figure 13. These values were close with the experimental values presented on Table 2. This showed the reliability of the model in optimizing the process.

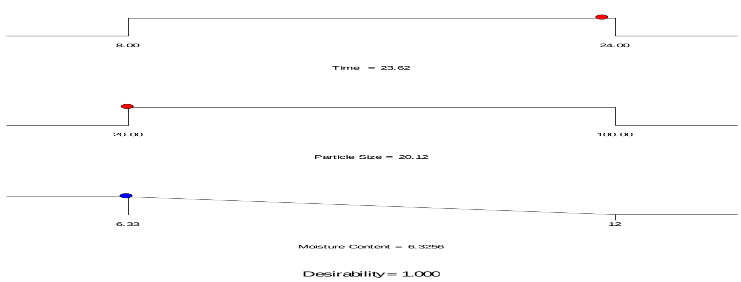


Fig. 13: Graphical representation of optimized levels of independent variables of Bambara nut flour

CONCLUTION

Response surface methodology was successfully used to predict and optimize the process conditions for the storage of Bambara nut flour. Based on the results obtained, Shelf life of Bambara nut flour depends on the moisture content, temperature and relative humidity of the storage environment. The result revealed the temperature dependence of the sorptive behavior with increase in temperature, the moisture adsorption capacity of the flour also increased. The equilibrium moisture content of Bambara nut flour at the three temperatures studied increased slowly at low water activities of 0.1 – 0.6 but increased rapidly at high water activity of 0.6 – 0.9. The equilibrium moisture content of the flour increased with increase in temperature at high water activity. The central composite design of Response surface methodology was found to be effective to determine the model parameter, sorptive behavior, particle size and storage duration for Bambara nut flour. The optimal storage conditions of the flour parameters can, therefore, be used for the storage and optimum shelf-life determination of Bambara nut flour. The results obtained in the study showed that the response surface model employed is a good one and could be used for the prediction of the responses (proximate composition) from the production and storage of Bambara nut flour.

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Effect of Plant Growth Response of *Ocimum species* to Diverse Population Densities in Southern Nigeria

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KEYWORDS

Growth parametres.
Ocimum gratissimum;
Ocimum sanctum nursery,
Plant population density,

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ABSTRACT

A field study was conducted to evaluate the growth performance of Ocimum species at five population densities at the research farm of Agricultural Development Programme (ADP) Awka, Anambra State, The research was a 2 x 5 factorial experiment laid out in randomized complete block design (RCBD) which was replicated three times. Two species of Ocimum spp (Ocimum sanatum and Ocimum gratissium) represented the main factor while the sub-factor consisted of five population densities (60,000 plant/ha, 100,000 plant/ha, 200,000 plant/ha, 300,000 plants/ha and 400,000 plant/ha The nursery was done on 3rd of May 2021 while transplanting was done on the 29th of May 2021 at a plant spacing of 50 x 33.3cm, 50 x 10cm, 25 x 20cm, 33.3 x 10cm and 25 x 10cm. Data were collected on plant height (cm), number of leaves, number of branches, leaf area (cm^2), stem girth (cm). Data collected were subjected to analysis of variance (ANOVA) using GENSTAT release 7.2DE Statistical software and means were separated using Fishers least significant difference (LSD). Plant density of 400,000 plants/h (25 x 10cm plant spacing) significantly improved biomass attribute of Ocimum gratissium and Ocimum Sanctum. While under the plant density of 300,000 plants/ha (33.3cm x 10cm plant spacing) gave best performance for the growth parameters measuerd. Ocimum sanctum grew more luxuriantly and performed better than Ocimum gratissimum; in all the growth parameters measured.

INTRODUCTION

The wellbeing of human is directly proportional to the wellbeing of botanicals around them, including agricultural, horticultural and ornamental plants as well as forest products, Gbadamosi *et al.* (2009). In recent years, the effluxion of many diseases which have developed resistant to many synthetic drugs and the effect of many organic waste (including crude oil) have called for planting of large production of botanicals. It is believed that plants that are medicinal contained numerous phytochemicals (Ngonadi and Awodoyin, 2019, Ade-Ademiilua and Obi, 2013). Researchers have concentrated more on plant species with medicinal values as exploitatory means of disease control and public awareness of the values associated with them; especially *Ocimum gratissium* and *Ocimum Sanctum* are increasing rapidly (Du Plooy *et al.*, 2012).

Ocimum is a genus of 35 species of aromatic annual and perennial herbs and shrubs in the family Laminaceae found in the tropics and subtropics, both wild and cultivated (Ojeifo and Denton, 1993). *Ocimum gratissimum* and *Ocimum sanctum* are important members. Their leaves ad distinctive flavour to many foods and are listed among species that have a long history as culinary herbs (Eze *et al.,* 2006). The antioxidants like present in high concentration in the plants makes them important botanicals in the prevention of various diseases; including upper respiratory tract infections, diarrhoea, headache, diseases of the eye and skin, pneumonia, cough, fever and conjunctivitis (Adebolu and Salau, 2005; Sidhu *et al.,* 2007). The oil extracted from the plants clearly shows antimicrobial, insect repellent and anti-helmet potential (Oboh, 2008). The flowers and leaves of the plants are rich in essential oils, and so it is used in preparation of teas and other infusions (Rabelo *et al.,* 2003). Based on the above mentioned qaulities about ocimum, there is the need to multiply and propagate them in large quantities in order to meet the public demands (Du Plooy *et al.,* 2012). In Nigeria, the full potential and leaf yield of the plant to meet the need of the increasing demands have not been attained because plant population densities are at the discretion of the farmers. Thus, there is need to determine the suitable plant density for Ocimum to reduce inter or intra-specific competition between the plant and weed which reduce yield (Barros *et al.,* 2004).

Materials and Methods

The experiment was conducted at Agricultural Development (ADP) farm, Anambra State. ADP is located at Awka which lies between latitude 7º 00' and 7º10'N and Longitude of 6º5' and 6º15'E in the rain forest zone of Nigeria. The area experienced bimodal rainfall pattern that peaked in June and subsequently decreased with a daily temperature range of 20ºC – 30ºC. The study was a factorial experiment laid out in a randomized complete block design (RCBD) and replicated three times. Ocimum seeds were obtained from Agricultural Development Programme (ADP) Center, Anambra. The experimental area was cleared of other vegetation, ploughed and harrowed on the 1st of May, and seedlings transplanted on the 29th May, The field was marked out into blocks of $3x3m^2$ covering ($93m^2$). Cured poultry droppings was applied in each plot and sub plots at 1100g. Weeding was done manually using hoe twice, to keep the plots weed free, at 4WAP and 6WAP. Insecticide (scorpion) was sprayed to control insect pest at 3ml to 15 litres of water at 8WAP. Morphological differences between *Ocimum gratissimum* and *Ocimum sanctum* include leaf shape and size: *O. gratissimum* has broader leaves with serrated edges, while *O. sanctum* has narrower leaves with smooth edges (Adedapo *et al*., 2020).

Data Collection

- **Plant Height***:* The height was measured with a meter rule from ground level to the stem apex in site. Five middle row plants per plot were tagged and used for record at 4, 6, 8 and 10 weeks after planting (WAP).
- **Number of leave:** Number of leave per tagged plants was counted at 4, 6, 8 and 10 weeks after planting (WAP).
- **Number of branches:** Number of branches per tagged plants was counted at 4, 6, 8 and 10 weeks after planting (WAP).
- **Leaf Area:** leaves of the tagged plants was measured with a meter rule to obtain the Leaf area, actual measurement was obtained by multiplying the Leaf area by a factor 0.715 (Koyama *et al*., 2022) and was recorded at 4, 6, 8 and 10 (WAP).
- **Stem girth:** stem girth of the tagged plant in each plot was measured above the ground level of the plant using rope which was later measured out using a meter rule to get the accurate reading and record.

Data Analysis:

Data collected were subjected to Analysis of Variance (ANOVA) using Gen-stat release 10.3 statistical soft wear. While the mean were separated using Least Significant Difference at 5% probability level.

RESULTS

Ocimum height

The interaction effect of species and plant spacing on the height of Ocimum at 4, 6, 8 and 10 WAP is presented in Table 2. The results obtained showed that the height of *Ocimum* species and plant spacing at 4, 6, 8 and 10 WAP were significant ($P<0.05$). Whereas, the interaction between species and plant spacing was only significant at 10 WAP. At 4 WAP, *O. sanctum* under 25 x 10 cm significantly had the tallest plants (23.2cm) followed by *O. sanctum* under 33.3 x 10 cm plant spacing (22.4cm). While the significantly shortest plants were recorded by *O. gratissium* under 50 x 10 cm plant spacing. At 6 WAP, *O. sanctum* under 33.3 x 10 cm plant spacing had the highest plant height (48.2cm) followed by *O. sanctum* under 25 x 10 cm plant spacing (47.8cm). Whereas, *O. gratissium* under 50 x 10 cm plant spacing had the lowest plant height (22.5cm). At 8 WAP, plant height followed similar trend as observed at 6 WAP. The plant species at the same plant spacing as observed at 6 WAP had the highest (89.4 cm) and the lowest plant heights (41.4 cm). At 10 WAP, *O. sanctum* under 33.3 x 10 cm plant spacing recorded the highest plant height (119.3cm) followed by *O. sanctum* under 25 x 10 cm plant spacing (112.4cm). While, *O. gratissium* under 50 x 10 cm plant spacing recorded the lowest plant height (62.3 cm).

Table 1. Physical and chemical properties of soil of the experimental site

Parameters	Value
Clay	230 (g/kg)
Silt	210g (g/kg)
Fine sand	420 (g/kg)
Coarse sand	160 (g/kg)
Textural class	Sandy clay loam
Bulk Density	1.39gm-3
Total porosity	48.92 (%)
Moisture Content	20.52 (%)
Dispersion Ratio	0.87 (%)
Aggregate Stability	17.02 (%)
Hydraulic conductivity	4.59 (cmhr-1)
pH (H2O 1:1)	5.98
Nitrogen	0.055 (%)
Available Phosphorus	3.89mgkg-1
Ca2+	1.5(cmolkg-1)
Mg2+	1.3 (cmolkg-1
Na+	0.24 (cmolkg-1)
EC	4.99 (cmolkg-1)
B S	87 (%)

Source: Agricultural Development Programme (ADP) Soil Laboratory Unit.

Ocimum number of leaf

The interaction effect of species and plant spacing interaction on the number of leaf of *Ocimum* at 4, 6, 8 and 10 WAP is presented in Table 3. The results obtained showed that the number of leaf of *Ocimum* species and plant spacing at 4, 6, 8 and 10 WAP were significant (P<0.05). Whereas, the interaction between specie and plant spacing was only significant at 10 WAP. At 4 WAP, *O. sanctum* under 25 x 10 cm significantly had highest number of leaves (34.5cm) followed by *O. sanctum* under 33.3 x 10 cm plant spacing (33.5cm). While the significantly shortest plants were recorded by *O. gratissium* under 25 x 20 cm plant spacing. At 6 WAP, *O. sanctum* under 25 x 10 cm plant spacing had the highest number of leaves (98.1 cm) followed by *O. sanctum* under 50 x 33.3 cm plant spacing (86.4 cm). Whereas, *O. gratissium* under 33.3 x 10 cm plant spacing had the lowest number of leaves (19.4 cm). At 8 WAP, plant number of leaf followed similar trend as observed at 6 WAP. The plant species at the same plant spacing as observed at 6 WAP had the highest (170.6 cm) and the lowest number of leaves was recorded in 50 x 10 spacing (31.9 cm) under *O. gratissium*. At 10 WAP, *O. sanctum* under 25 x 10 cm plant spacing recorded the highest number of leaf (199.5 cm) followed by *O. sanctum* under 50 x 33.3 cm plant spacing (189.6 cm). While, *O. gratissium* under 50 x 10 cm plant spacing recorded the lowest number of leaves (46.3 cm).

Table 2: Interaction effect of species and plant spacing on plant height (cm) of Ocimum at 4, 6, 8 and 10 weeks after planting (WAP).

Weeks / Ocimum species	50x33.3cm	50x10cm	Plant spacing 25x20cm	33.3x10cm	25x10cm	Mean
At 4WAP						
grattissium	7.14	6.67	7.55	9.97	9.53	**8.17**
O. sanctum	18.2	14.4	17.2	22.4	23.2	**19.1**
Mean	**12.7**	**10.54**	**12.41**	**16.22**	**16.40**	**13.3**
At 6WAP						
O. grattissium	23.44	22.50	25.69	25.95	25.97	**24.72**
O. sanctum	37.1	39.2	40.3	48.2	47.8	**42.5**
Mean	**30.28**	**30.86**	**33.03**	**37.10**	**36.89**	**33.63**
At 8WAP						
O. grattissium	51.8	41.4	58.2	57.0	57.0	**53.1**
O. sanctum	62.5	67.3	68.9	89.4	71.2	**72.9**
Mean	**57.2**	**54.4**	**63.6**	**73.3**	**64.1**	**62.5**
At 10WAP						
O. grattissium	81..2	62.3	92.6	77.3	77.3	**78.4**
O. sanctum	99.1	107.1	103.7	119.3	112.4	**108.4**
Mean	**85.4**	**84.7**	**98.2**	**98.4**	**94.8**	**93.2**
				Weeks after planting (WAP)		
			4	6	8	10
LSD (0.05)	For 2species	mean	1.74	3.20	6.39	5.72
LSD	5plant spacing	mean	2.75	5.07	10.10	9.04
LSD	5plant spacing	X specie	ns	ns	ns	12.78

Note: WAP= Weeks after planting, ns= not significant

Table 3: Interaction effect of species and plant spacing on number of leaves of Ocimum at 4, 6, 8 and 10 weeks after planting (WAP).

Weeks / Ocimum species	50x33.3cm	50x10cm	Plant spacing 25x20cm	33.3x10cm	25x10cm	Mean
At 4WAP						
O, grattissium	9.44	7.39	9.0	11.5	11.1	**9.7**
O. sanctum	34.3	19.7	27.5	33.5	34.5	**29.9**
Mean	**21.8**	**13.58**	**18.3**	**22.5**	**22.8**	**19.8**
At 6WAP						
O. grattissium	24.3	20.5	22.6	19.4	19.6	**21.3**
O. sanctum	86.4	74.6	67.3	75.5	98.1	**80.4**
Mean	**55.4**	**47.6**	**44.9**	**47.5**	**58.8**	**50.8**
At 8WAP						
O. grattissium	56.0	31.9	43.2	45.7	45.6	**45.5**
O. sanctum	156.7	127.5	11.7	128.4	170.6	**140.6**
Mean	**107.8**	**79.7**	**79.9**	**87.1**	**108.1**	**92.5**
At 10WAP						
O. grattissium	73.8	46.3	70.6	71.4	71.4	**66.7**
O. sanctum	189.6	154.3	142.8	154.7	199.5	**168.2**
Mean	**131.7**	**100.3**	**106.7**	**113.1**	**135.5**	**117.4**
				Weeks after planting (WAP)		
			4	6	8	10
LSD (0.05)	For 2species	mean	2.96	12.7	12.5	12.5
LSD	5plant spacing	mean	4.6	ns	19.8	19.8
LSD	5plant spacing	X specie	ns	ns	ns	28.0

Note: WAP= Weeks after planting, ns= not significant

Ocimum number of branches

The interaction effect of species and plant spacing interaction on the number of branches of *Ocimum* at 4, 6, 8 and 10 WAP is presented in Table 4. The results obtained showed that the number of branches of *Ocimum* species and plant spacing at 4, 6, 8 and 10 WAP were significant (P<0.05). Whereas, the interaction between specie and plant spacing was only significant at 4, 8 and 10 WAP. At 4 WAP, *O. sanctum* under 33.3 x 10 cm significantly had highest number of branches (9.27 cm) followed by *O. sanctum* under 25 x 10 cm plant spacing (8.61 cm). (While the significantly shortest plants were recorded by *O. gratissium* under 50 x 10 cm plant spacing.) At 6 WAP, *O. sanctum* under 33.3 x 10 cm plant spacing had the highest number of branches (16.7 cm) followed by *O. sanctum* under 25 x 10 cm plant spacing (13.9 cm). Whereas, *O. gratissium* under 50 x 10 cm plant spacing had the lowest number of branches (1.8 cm). At 8 WAP, plant number of branches was highest at 50 x 33.3 spacing (19.6 cm) followed by *O. santum* under 33.3 x 10 (19.0 cm) and the lowest number of branches was recorded in 50 x 10 cm spacing (1.8 cm) under *O. gratissium*.

At 10 WAP, *O. sanctum* under 50 x 33.3 cm plant spacing recorded the highest number of branches (25.7cm) followed by *O. sanctum* under 33.3 x 10 cm plant spacing (25.4cm). While, *O. gratissium* under 50 x 10 cm plant spacing recorded the lowest number of branches (6.4 cm).

Ocimum stem girth

The interaction effect of species and plant spacing interaction on the stem girth of *Ocimum* at 4, 6, 8 and 10 WAP is presented in Table 5. The results obtained showed that the stem girth of *Ocimum* species and plant spacing at 4, 6, 8 and 10 WAP were significant (P<0.05). Whereas, the interaction between specie and plant spacing was only significant at 4 WAP. At 4 WAP, *O. sanctum* under 25 x 10 cm significantly had the highest stem girth (2.3 cm) followed by *O. sanctum* under 33.3 x 10 cm plant spacing (2.2 cm). While the significantly shortest plants were recorded by *O. gratissium* under 50 x 33.3 cm plant spacing. At 6 WAP, *O. sanctum* under 25 x 10 cm plant spacing had the highest plant height (3.7 cm) followed by *O. sanctum* under 33.3 x 10 cm plant spacing (3.6 cm). Whereas, *O. gratissium* under 50 x 10 cm plant spacing had the lowest plant height (2.1 cm). At 8 WAP, plant stem girth was highest at 50 x 33.3 spacing (5.4 cm) followed by *O. santum* under 25 x 20 (5.2 cm) and the lowest stem girth was recorded in 50 x 10 cm spacing (2.8 cm) under *O. gratissium*.

At 10 WAP, *O. sanctum* under 33.3 x 10 cm plant spacing recorded the highest stem girth (9. 0 cm) followed by *O. sanctum* under 50 x 10 cm plant spacing (6.8 cm). While, *O. gratissium* under 50 x 10 cm plant spacing recorded the lowest plant height (3.5 cm).

DISCUSSION

This research evaluated two species of *Ocimum* for growth performance under five population densities in tropical rainforest zone. The result of this study varied with previous results obtained from other *Ocimum* species and other vegetables like black cumin (*Nigella sativa).* Kafi, (2003) reported that *Ocimum basilium*, has average of 1551kg/ha-1 green herb yield in terms of number of leaves. The growth of *Ocimum minimum* is 1320kgha-1 and highest number of leaves was reached using 15cm between rows. Since the higher the number of leaves results in greater yield, Gill and Randhawa, (1992) indicated that the high drug herb was obtained from 40 x 20cm plant density. According to Serin and Ozguven, (1997) drug leaves yield of *Ocimum* was 173.78 kg/ha-1. On the other hand, Tani and Nacar, (1999) reported that the yield was possible 571.52 kg/ha-1. Also, Ahmed and Haque, (1986) studied the effect of row spacing (15, 20, 25 and 30cm) on growth and yield of black cumin (*Nigella sativa*) in Bangladash, they found that closer row spacing (15cm) was the best for higher yield of black cumin.

Generally, *O gratissium* and *O sanctum* under the plant density of 30 plants/m2 of population density of 300,000 plants/ha with spacing of 33.3cm x 10cm gave good performance for the growth parameters *O. sanctum* grew more luxuriantly than *O gratissium;* it performed better in all the growth parameters. The number of leaf per branch is affected by environmental, field management and varies under varying plant densities. Kafi, (2003) also reported that the weight of Ocimum varied in different experiments. It ranges from 2.79g to 2.99g under varying plant densities. And interaction between specie and population densities was significant at various parameters.(No data on leaf weight)

CONCLUSION

Ocimum species should be grown under the population density of 400,000 plants/ha with plant spacing of 25cm by 10cm for high leaf yield in terms of number of leaves especially the *O. gratissimum* (edible specie). While *O. sanctum* (wild species) has tolerance based on all the growth parameters. Ocimum species should be harvested at 12 weeks and at 2 weeks intervals with appropriate agronomic practices.

RECOMMENDATION

Further studies is needed to be conducted to investigate the economic viability of increased plant density in relation to cost of seedling or cuttings.

Plate 1: *Ocimum sanctum*

Plate 2: *Ocimum gratissimum*

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Effect of Different Organic Manure Rates on Yield and Post Harvest Storage of Okra (*Abelmoschus esculentus*)

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KEYWORDS

Deterioration,
Growth and yield parameters
Okra pods,
Post- harvest,
Poultry and pig manure,

ABSTRACT

The experiment was conducted at the Research Farm of the Department of Crop Science and Horticulture, Nnamdi Azikiwe University, Awka, Nigeria to study the effect of different organic manure rates on yield and okra. Different manure sources from poultry and pig and the rates were: 0 ton/ha, 5 tons/ha, 10 tons/ha, 15 tons/ha, and 20 tons/ha. The 2 x 5 factorial experiment was laid out in a Completely Randomized Design (CRD) and replicated three (3) times. Data were collected on growth and yield. For yield parameters, pig manure at15 t/ha rate gave the highest yield however, the interaction effects showed that 15t/ha poultry manure x yield produced the highest number and weight yield of pods, while 15 t/ha pig manure out performed in the length and width of okra pods. Hence, poultry manure at 15t/ha and 20t/ha pig manure were recommended. Considering the effect of postharvest storage materials on the physiological deterioration rates of okra pods, newspaper, and dried plantain leaves maintained better postharvest storage quality of okro than other storage materials.

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INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) also known as Ladies Fingers is a member of the Malvaceae family (The Plant List, 2020). It is a vital fruit vegetable found in the tropical and subtropical regions of the world (Senjobi *et al*. 2013)..In Nigeria, okra is grown mainly for its green pods by peasant farmers, in-home gardens or in mix-cropping with cereals. The pods of Okra contain a mucilaginous substance used to thicken soups and stews, and as plasma replacement or blood volume expander (Onunkun, 2012). The young leaves and fruits are boiled or fried and eaten as a vegetable or in soup. It is a nutritious and delicious vegetable, rich in vitamins and minerals (Gemede, 2016). Okra seeds are used as a non - caffeinated substitute for coffee and as a source of seed oil (Olawuyi *et al.*, 2012). Industrially mature pods and stems contain fiber that can be used for the manufacture of paper, rope, jute etc. (Olawuyi *et al.*, 2012)..Among the relevant aspects of okra cultivation, its post-harvest management stands out as one of paramount interest to maintain optimum production and utilization. After harvesting, vegetables become quite perishable owing to their high-water content (90%) and intense metabolism that is characterized by high respiratory rate (Mota *et al*., 2010). Okra pods can be kept at ambient temperatures for short periods of time (up to a week) if there is enough ventilation to prevent heat buildup from respiration. Persistent use of inorganic fertilizer has a lasting negative effect on soil properties and soil fertility status due to its effect on soil nutrient balance (Unagwu, 2019). Importantly, Organic manures not only balance the nutrient supply but also improve soil's physical and chemical properties. With the challenges associated with inorganic fertilizer application, the use of organic manure to replenish soil nutrients is a viable alternative. This is because organic manure improves plant nutrient use efficiency, and enhances soil conditions by improving the physical, chemical biological, and hydrological properties of the soil (Unagwu *et al.*,2019). . Hence, Organic manure stands as a beneficial and better alternative to inorganic fertilizers in crop production. This necessitates not just the use of organic manures in okra production but as well using the right application rate for optimum production.(Unagwu *et al.*,2019).

One notable challenge facing okra production in the tropics, especially in Nigeria is poor soil health. ~~T~~ This study in broad view therefore seeks to determine the most effective means of producing okra using different rates of organic manure from different sources (poultry manure and pig manure), the response of okra fruits to different organic manure, and storage materials that improve the shelf life of okra.

MATERIALS AND METHODS

Experimental Site: The study was carried out using polythene bags ~~pot~~s at the Department of Crop Science and Horticulture Nnamdi Azikiwe University, Awka, Anambra State. Awka is characterized by tropical rain forest with temperature of 27^0 -30^0. The area is located between latitude $06^0 15^1$ N and longitude 07^0 08^1 E.

Materials: Okra seeds was sourced from a reputable seed marketer; the organic manures (poultry manure and pig manure) were all obtained from the ~~d~~ Department of Animal Science and Technology, Nnamdi Azikiwe University, Awka and the bags/pots to be used were ~~was~~ sourced from Eke – Awka market in Awka, Anambra state.

Experimental Treatments: The treatments comprised of different manure sources at different rates which included poultry manure at 0 tons/ha, 5tons/ha,10 tons/ha,15tons/ha and 20tons/ha and pig manure at 0 tons/ha, 5tons/ha, 10 tons/ha,15tons/ha and 20tons/ha.

Data Collection: Growth Parameters included, Emergence, plant height, leaf area, leaf number etc. Yield parameters: The following were collected: Number of pods, Length of pods, Width of the pods:, Fresh weight of pods:,

Postharvest storage: Indicators of shelf life such as firmness, freshness of pod, appearance, texture and colour were observed and recorded to know which of these materials increased shelf life of okra as was observed between 3 – 7 days before the postharvest got terminated.

Statistical Analysis: All data collected were subjected to analysis of variance (ANOVA) using GenStat 2012 and significant differences among treatment means were separated using the least significant difference (LSD) at a 5% level of significance.

RESULTS

Effects of Manure Types and Rates on Fresh Weight of Pods of Okra

The result of the fresh pods weights as presented in Tables 1, there was no significant difference for the manure types however, pig manure gave higher fresh weight (12.16 g/fruit) of pods than poultry manure (11.18 g/fruit). On the rates 15t/ha gave the highest fresh weight of pod with mean value 13.98 and was statistically similar to 5, 10 and 20 t/ha which gave mean values 12.04, 13.45 and 12.67 g/fruit respectively. The least fresh weight was recorded from 0t/ha with mean value 6.20 g/fruit.

Interaction Effects of Manure Types and Rates on Fresh Weight of Pods of Okra

The result of fresh weight of pods in Table 2 shows that 15t/ha poultry manure gave the highest fresh weight of pods with mean value 14.32 g/fruit and was statistically similar to 10t/ha poultry manure, 15t/ha pig manure, 10t/ha pig manure and 5t/ha pig manure with mean values 12.83, 11.51, 10.67 and 11.49 g/fruit respectively which all gave significantly higher fresh weight of pods when compared with the control treatment. The least fresh weight of pods was recorded at 0t/ha pig manure and poultry manure with 1.82 and 2.95 g/fruit respectively.

Table: 1 Effects of manure types and rates on fresh weight of pods of okra

Manure	Fresh Weight of Pods
PG	12.16
PM	11.18
LSD	NS
Manure rates	
0	6.20
5	12.04
10	13.45
15	13.98
20	12.67
$LSD_{0.05}$	4.261

***PG (Pig Manure), PM (Poultry Manure)

Table: 2 Interaction effects of manure types and rates on fresh weight of pods of okra

Manure Type	rates (ton/ha)	fresh weight of pods
Pig	0	1.82
5	11.49	
10	10.67	
15	11.51	
20	9.25	
Poultry	0	2.95
5	8.24	
10	12.83	
15	14.32	
20	3.95	
$LSD_{0.05}$	5.167	

***PG (Pig Manure), PM (Poultry Manure)

Interaction Effects of Manure Type and Rates on Number, Length and Width of Pods of Okra

From Table 3, 15t/ha poultry manure gave significantly ($P<0.05$) the highest number of pods and width of pods with mean values 3.80 and 7.25cm respectively. Also pig manure at rates 5,10,15,20 t/ha all were significantly different significantly ($P<0.05$) from the control treatment in number of pods and width of pods. Poultry manure *at al*l the rates of application gave significantly ($P<0.05$) higher number of pods and width of pods than the control treatment 0t/ha of poultry manure. On the length and width of pods at 5t/ha and 15 t/ha pig manure gave significantly the highest length of pods (8.76cm and 6.87cm respectively) and was statistically similar to all the other pig manure rates which significantly showed higher length of pods compared to the control treatment.

Table 3 Interaction effects of manure type and rates on number, length and width of pods of okra

Manure Type	Rates(ton/ha)	Number of pods	length of pods	width of pods
Pig	0	0.53	1.58	2.02
	5	3.13	8.76	6.14
	10	3.33	5.22	6.31
	15	3.67	5.41	6.87
	20	2.20	3.84	5.09
Poultry	0	1.00	2.52	3.13
	5	2.47	4.47	5.67
	10	3.73	6.16	7.07
	15	3.80	5.53	7.25
	20	0.87	2.38	2.76
$LSD_{0.05}$		1.533	3.628	1.979

***PG (Pig Manure), PM (Poultry Manure)

Effects of Storage Material on Post harvest Physiology of Okra Pods

Concerning the effects of storage materials on post-harvest storage, looking at level of deterioration, for white nylon the first day after harvest all the pods were still green, firm and fresh as well as the second day with droplets of moisture inside, but on the 3rd day deterioration started as the firmness reduced and dark spots seen on some of the pods. On the 4th day full discoloration was observed changing from green to yellowish coloration and the pods became slimy. On the 5th day over 50% of the pods had deteriorated and not good for consumption. The 6th day all the pods were completely deteriorated. For the black nylon as a storage material, on the first and 2nd day after harvest the pods still maintained their fresh green colour and firmness with presence of moisture observed on the 2nd day. On the 3rd day pale coloration was observed and reduction in firmness and deterioration seen. On the 4th day the pods were softer, and more pods started deteriorating up to 50% of the pods. On the 5th day deterioration continued and by the 6th day all the pods had deteriorated, and the presence of maggot observed. While fresh plantain leaves were used as storage material, the pods maintained their freshness, firm and greenish state only on the first day. Day 2 deterioration was observed as colour of pods became pale and by the 3rd day more than 50% of the pods were deteriorated, discoloured with dark spots all over. Day 4, most of the pods turned darkish and soft while all became slimy, discoloured entirely by day 5 and in day 6 maggots were observed.Using dry plantain leaves as storage material preserved the pods more compared to the other storage materials used in this study. The pods maintained their fresh, greenish and firm state day 1, 2 and 3 after harvest while at day 4 a few began to develop black spots but maintained their firmness and these spots spread a lot more by day 5 and pods began to soften. On the 6th day over 50% of the pods were shrinked and turned black but not slimy. All the fruits turned black, and presence of maggots observed at the 7th day.For newspaper, the first and second day all the pods were intact but started discolouration at day 3 yet maintained firmness. At day 4 more discoloration of pods while still firm. Day 5 discolouration to yellow started and most pods began to soften while the pods became pale and drying up at day 6. The presence of mold was observed at day 7 with over 50% of the pods turned black.

Table 4. Effects of storage material on postharvest physiology of okra pods

Storage material	Days to Deterioration	Days to 50% Deterioration
White nylon	3	5
Black nylon	3	4
Fresh plantain leaves	2	3
Dry plantain leaves	4	6
Newspaper	4	7

DISCUSSION

This study investigated the effect of different organic manure rates on vegetative growth and yield of okra and the effect of storage materials on post-harvest of okra. Application of manures generally improved the growth and yield parameters of okra. The positive effect of organic manure on growth and okra yield could be due to the contribution made by the soil amendments to the fertility status of the soil (Adekiya *et al.*, 2020). Also, the type of storage materials used for okra fruit storage had influence on the postharvest of the okra pods. Pig manure showed superior performance on the yield parameters (length and width of pods and the number and fresh weight of pods). This corroborates the finding of Oseni *et al.,* (2016), who reported that okra responded well to the application of pig manure. The application of pig manure improved soil organic matter and nutrient availability and gave high yield parameters such as the number of pods and weight of pods. Pig manure application also showed better performance in okra as reported by Iderawumi and Omogoye, (2019). Different rates of organic manure application had variable impacts on the yield parameters of okra which were better than the control~~,~~ This is similar to the findings of Adesina and Wiro, (2020) where organic manure at the higher rate significantly improved the yield performance of okra comparable to the increase in number of pods followed increase in pig manure rates except for 20t/h increased pod/fruit production with increase in manure rate is in consonant with the report of Olatunji and Oboh (2012) in okra (*Abelmoscus esculentum*) where pod yield was increased by 52% as a result of the application of pig waste. However, the interaction effect indicated that both the number and weight of okra pods had their peak performances when poultry manure was applied at the rate of 15 t/ha. Whereas the length and width of okra pods were highest at the application of pig manure at the rates of 5 and 15 t/ha respectively. Based on the finding of the study by Onwu, (2020), okra responded well to poultry manure compared to the control treatment and the effect of poultry manure at 15 t/ha performed better than other treatments. From the standpoint of days to deterioration and days to 50% deterioration, fresh plantain leaves stimulated the deterioration process compared to the two plastic bags (white and black nylon. Fresh fruits and vegetables tend to have a very high moisture content which facilitates the activities of spoilage organisms Iderawumi and Omogoye, (2019), and this high deterioration property explains why okra pods stored in fresh plantain leaves deteriorated fastest. Eziamaka *et al.,* (2021), reported that storage temperature has a better impact in slowing down the respiration rate, weight loss and decay, while maintaining the fruit firmness and overall quality in …….?. The higher the temperature ~~ranges~~ the faster the rate of spoilage, hence the ~~stimulated~~ deterioration rates of plastic bags used in storage as it ~~the~~ tend to generate more heat as the fruit respires aiding the activities of spoilage microbes. Also dried storage materials such as dried plantain leaves and newspaper were found to increase shelf life of stored produce (Olayinka *et al.,* 2016).

CONCLUSION

In conclusion a very positive influence of organic manure on the growth and yield of okra was seen in this experiment. The positive effect of organic manure on growth and okra yield could be due to the contribution made by amendments to fertility status of the soils.

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Morphological Variation in Bitter Leaf Accessions (*Vernonia amygdalina*) in Ifite-Ogwari, Southeastern Nigeria

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KEYWORDS

Accessions,
Growth,
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ABSTRACT

In spite of the increasing relevance and benefits of bitter leaf, especially in southern part of Nigeria were the leaves are mostly used to prepare unique delicacy, there is still dearth information on the genetic variability among different Vernonia amygdalina found in Southern part of Nigeria especially Anambra State.The major aim of this work is to; assess the morphologicalcharacteristics of various accessions collected. Determine if variation in bitter leaf can be assessed by its morphological features. The research was conducted at the Teaching and Research farm of Crop Science and Horticulture, Nnamdi Azikiwe University, Ifite-Ogwari, Anambra state, Nigeria. The experiment was carried out as a Randomized complete block design (RCBD) which was replicated three times. Statistically there was no significant difference among the accessions. Ifite-Ogwari and Umunze gave a significant increase in both growth parameters and yield. Therefore, planting of the accessions respectively is well recommended for optimum production of bitter leaf plant in southern part of Nigeria.

INTRODUCTION

Bitter leaf botanically known as *Vernonia amygdalina* is a small tree or shrub that is commonly found in the Sub-Sahara Africa (Echem and Kabari, 2013). Belonging to the family of Asteraceae, it can grow up to 10 m tall with petiole leaf of about 6 mm in diameter. The crop has been domesticated in various parts of West Africa including Nigeria, where it is locally processed and used as vegetable in soups (Etim*et al*., 2012; Habtamu and Melaku, 2018). The commercial production of bitter leaf has been established in Anambra State due to its nutritional, medicinal and economic values. Plant contains not only the active drug molecules but also other substances which are necessary for the maintenance of health and physiological functions of the body without manifestation of toxicity (Iwu, 2002). As a result of these, the crop serves as a low cost and readily available source of important nutrients to human when consumed (Ojiako and Nwanjo, 2006). The variation in the duration and habit of the various species of *V. amygdalina* is of taxonomic and horticultural importance. *Vernoniaamygdalina* (non-bitter variety) which is a perennial plant can be propagated through seedlings and has less longevity compared to that of *V. amygdalina* (bitter leaf). The non-bitter variety also does not need several washing in water to remove the bitter taste before it is used for soup. This research work will help in providing useful information to farmers, researchers and medical field in the selection of *V. amygdalina*based on their morphology and determine if the different varieties available for commercial production and research purpose can be identified based on the morphological features.

Therefore, the objective of this research is to assess the morphological and growth characteristics (such as plant height, leaf shape and colour, flowering, etc.) of various accession collected and also determine if variation in bitter leaf can be assessed by its morphological features.

MATERIAL AND METHODS

Experimental Site

The experiment was carried out at the Teaching and Research Farm of Crop Science and Horticulture Department, Nnamdi Azikiwe University Ifite-Ogwari, Anambra State. Ifite-Ogwari area in Anambra state is a tropical rain forest zone with temperature of about 6°C - 21°C. The area is located within latitude 6°38'11''N N and longitude 6°57'20''E with an altitude of 422 m and an average rainfall of 1650 mm to 2000 mm per annum. The experimental area is mostly, waterlogged during raining season and dominated with grasses, and the soil type have silt clay properties.

Planting Materials

Stem cuttings of bitter leaf were obtained from Awka zone (Nimo accession), Aguata zone (Umunze accession), Anambra West zone (Ifite-Ogwari accession) and Onitsha zone (Ogbaru accession) all from the different local government area in Anambra state. The stems were cut into an average of 15 -20 cm length bearing 4-5 nodes.

Treatments and Experimental Design

The experiment was laid out as a Randomized Complete Block Design (RCBD) with three replications.

Agronomics Practices/ Management

Land Preparation

The experimental site was mapped out using a measuring tape, ropes and pegs. The land were cleared of existing vegetation and the plant residues appropriately removed from the field.

Media composting

Poultry manure was incorporated and allowed to decompose for a period of one to two weeks on all beds measuring 1 m x 1.5 m each. Using 10kg of poultry manure per bed at 10-20% moisture content.

Planting

Planting commenced after the beds had been ploughed and soil amendments applied. The stem cuttings were inserted into the soil at 45° to the soil level, with at least two nodes inserted into the soil while two nodes remains exposed. Weeding was carried out 4 times after planting at two weeks interval manually.

Data collection

Data were collected on phenology; growth (plant height, stem girth, number of leaves, number of branching) and leaf yield (fresh leaf weight) at two weeks interval. Equipment/Implement to be used would include, automated weighing balance, verniercaliper, flexible meter rule, recording book, coverall and a pair of rain boot.

Harvesting commenced two months after planting, the leaves were harvested by hand and data were collected at 2 weeks interval.

RESULTS

Plant height (cm) of bitter leaf accessions at 3, 5, 7, 9, and 10 weeks after planting.

Table 1 shows the Plant height (cm) of bitter leaf at 3, 5, 7, 9, and 10 weeks after planting. There was no significant difference ($P>0.05$) in the plant height at 5 and 7 weeks among the accessions. However, at 9, and 10 WAP, plant heights of bitter leaf varied among accessions.At 5, 7, 9, and 10weeks after planting, the plant height progressively increased with increase in Ifite-Ogwari and Umunze accession. It was observed that the mean values (5.86cm, 6.05cm, 7.70cm and 8.43cm) obtained with Umunze accession gave the highest mean of plant height. But the plant height were not significantly influenced by the various accessions.

Table 1: Plant height (cm) of bitter leaf accessions at 3, 5, 7, 9, and 10 weeks after planting (WAP).

Plant height (cm) of tallest branch in weeks after planting					
Accessions	**3 WAP**	**5 WAP**	**7 WAP**	**9 WAP**	**10 WAP**
Ifite-Ogwari	4.33	5.72	5.84	6.19	6.51
Nimo	4.17	5.53	4.38	5.90	6.68
Ogbaru	3.69	5.25	6.02	5.08	5.56
Umunze	4.06	5.88	6.05	7.70	8.43
$LSD_{0.05}$	ns	ns	ns	ns	3.103

Stem girth (mm) of bitter leaf accessions at 3, 5, 7, 9, and 10 weeks after planting.

The results in Table 2. shows the stem girth of the bitter leafaccessionsat 3, 5, 7, 9, and 10 weeks after planting. No significant difference (P>0.05) was observed in the stem girth at 9 and 10 weeks after planting with respect to the other weeks. At 3 weeks after planting,there was significant (P<0.05) differences in the stem girth.

At 9 weeks after planting, Ifite-Ogwari and Ogbaru produced the widest stems (21.2mm and 10.4mm), although there was no significant difference in the means with Nimo and Umunze. At 10 weeks after planting, it was observed that Ifite-Ogwari produced widest stem (6.22mm) even though the mean did not differ significantly (P>0.05) at Nimo, Ogbaru and Umunze accessions. However, at 5 and 7 weeks after planting, it can be observed that Nimo and Ogbaru were not significantly (P>0.05) differ in their means.

Table 2: Stem girth (cm) of bitter leaf at 3, 5, 7, 9, and 10 weeks after planting

Stem girth (mm) of tallest branch in weeks after planting					
Accessions	3	5	7	9	10
Ifite-Ogwari	2.017	3.20	3.28	21.2	6.22
Nimo	1.947	2.15	2.54	4.0	3.82
Ogbaru	2.070	3.96	3.85	10.4	4.17
Umunze	2.320	2.75	2.86	4.1	3.82
$LSD_{0.05}$	ns	ns	1.920	37.59	3.443

Number of leaves of bitter leaf accessions at 3, 5, 7, 9, and 10 weeks after planting (WAP).

Table 3, shows thenumber of leaves of bitter leaf accessions at 3, 5, 7, 9, and 10 weeks after planting. The number of leaves (on the tallest branch) was significantly (P<0.05) different among the accessions at 5, 7, 9, and 10 weeks after planting.

At 3 weeks after planting, the highest mean value of leaves (7.56mm) was obtained on Ifite-Ogwari accession though the means did not differ significantly at Nimo, Ogbaru and Umunze. At 7 and 9 weeks after planting, Umunze gave the highest mean of leaves (67.7mm and 65.7mm) while at 5 and 10 weeks after planting, the highest mean value of leaves (49.2mm and 49.8mm) was obtained at Umunze and Ifite-Ogwari. At 3, 5, 7, and 9 weeks after planting, there was significant (P<0.05) increase in the number of leaves for Ifite-Ogwari and Nimo compared to the Ogbaru and Umunze accessions that decrease from 7, 9, and 10 weeks after planting.

Table 3: Number of Leaves of bitter leaf accessions at 3, 5, 7, 9, and 10 weeks after planting.

Number of leaves on tallest branch in weeks after planting					
Accessions	3	5	7	9	10
Ifite-Ogwari	7.56	29.5	36.5	54.8	49.8
Nimo	5.56	22.8	33.5	46.2	39.6
Ogbaru	6.44	21.3	45.6	42.8	32.4
Umunze	7.11	49.2	67.7	65.7	48.2
$LSD_{0.05}$	ns	29.21	41.89	50.49	39.18

Number of Branchesof bitter leaf accessions at 3, 5, 7, 9, and 10 weeks after planting.

The results in Table 4, shows the number of branches of bitter leaf accessions at 3, 5, 7, 9, and 10 weeks after planting. At 5weeks after planting there was a significant difference (P<0.05) between the accessions. From the result obtained, a progressive increase was observed at 3, 5, 7, and 9 weeks after planting on Ifite-Ogwari and Umunze accessions.

Table 4. Number of Branches of bitter leaf accessions at 3, 5, 7, 9, and 10 weeks after planting.

Number of branch weeks after planting					
Accessions	**3**	**5**	**7**	**9**	**10**
Ifite-Ogwari	2	3.5	3.5	4.67	3.67
Nimo	1.444	3.22	2.44	3.06	2.67
Ogbaru	1.556	2.82	3.5	3.19	2.39
Umunze	1.278	2.83	3.22	3.44	2.94
LSD0.05	ns	ns	2.209	2.93	ns

Fresh leaf weight (g) of harvested bitter leaf accessions at 7, 9, and 10 weeks after planting.

Table 5, shows the fresh leaf weight (g) of harvested bitter leaf accessions at 7, 9 and 10 weeks after planting (WAP). The fresh weight of leaves harvested at 9 and 10 weeks after planting were significantly (P<0.05) with the highest mean weight of fresh leaves observed with Ogbaru accession at 7.00g. The weight of fresh leaves harvested at 9 and 10 weeks after planting did not differ significantly (P>0.05), however the highest mean weight was also observed at Ifite-Ogwari and Umunze with 1.347g and 1.192g respectively. The total fresh leaf weight per plant gotten from harvested leaves at 7, 9 and 10 weeks after planting differed significantly (P<0.05) with Ogbaru having the highest mean weight (7.00g).

Table 5: Weight of leaf of bitterleafaccessions at 7, 9, and 10 weeks after planting.

Weight of leaves weeks after planting			
Accessions	7	9	10
Ifite-Ogwari	5.00	1.347	0.873
Nimo	1.00	1.185	0.716
Ogbaru	7.00	1.249	1.031
Umunze	2.00	1.274	1.192
$LSD_{0.05}$	9.50	0.384	0.2963

Total number of leaves of bitter leaf at 3, 5, 7, 9, and 10 weeks after planting.

Table 6, shows the total number of leaves of bitter leaf at 3, 5, 7, 9, and 10 weeks after planting. There was significant difference (P<0.05) in the total number of leaves at 3, 5 and 7 weeks among the accessions. However, at 9, and 10 weeks after planting, total number of leaves did not vary among accessions.At 3, 5, 7, 9, and 10 WAP, the total number of leaves progressively increased with increase in Ifite-Ogwari accession. It was observed that the mean values (112.3, 155.0, and 149.0) obtained with Umunzeaccession gave the highest mean for total number of leaves.

Table 6: Total number of leaves of leaf of bitter leaf at 3, 5, 7, 9, and 10 weeks after planting.

Total number of leaves weeks after planting					
Accessions	**3**	**5**	**7**	**9**	**10**
Ifite-Ogwari	22. 67	41.7	56.0	87.0	98.0
Nimo	16.67	40.0	65.0	84.0	78.0
Ogbaru	19.33	53.8	92.0	73.0	48.0
Umunze	21.33	112.3	155.0	149.0	94.0
$LSD_{0.05}$	4.837	47.75	60.85	74.3	74.5

DISCUSSION

Growth parameters

Optimum plant height had been reported to positively correlate with the productivity of plant (Saeed *et al*., 2001). The height of a plant is an importance growth parameter that is directly linked with the productivity potential of a plant. There was a progressive increase in the means of plant height observed.

Yield parameters

The study showed that there was a progressive decrease which did not differ significantly in the fresh weight of harvested bitter leaf at 7, 9 and 10 weeks after planting. Significant decrease in the weight of harvested bitter leaf was however observed among all accessions at 7, 9 and 10. although there was an increase but the increase was not significantly ($P>0.05$) different with the values obtained at 7weeks after planting.

The result of the study showed that the total number leaves of bitter leaf plants harvested from Umunze accession at 5, 7, and 9 gave the highest number of leaf. There was a progressive increase on the total number of leaves from IfiteOgwari accession. Obtaining a higher yield of the leaves is the desire of every bitter leaf farmer. According to Agriculture and Volume (2016), marketable leaf yield, number of branches/plant and number of leaves and plant are important characters. It was discovered from the trend, that Umunze gave the highest means in plant height, no of leaves and total number of leaves. While Ifite-Ogwari gave the highest mean for stem girth and no. of branches, and Ogbaru with the highest mean for the weight of harvested leaves. Although no significant difference was observed.

CONCLUSION AND RECOMMENDATION

It is observed from the research work that the four different bitter leaf accessions exhibited the same features at different time of their growth and development among the accession with respect to their morphological characteristics. Therefore, these accessions cannot be selected just based on their morphology alone.

Ifite-Ogwari and Umunze produced most vigorous plants and highest fresh leaf yield. This trend was also consistent in the number of branches and stem girth in the field.

Therefore, for optimum production of *Vernonia amygdalina in* Ifite-Ogwari, Ifite-Ogwari and Umunze accessions are recommended.

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Effects of Organic Soil Amendment on the Growth and Yield of Okra (*Abelmoschus esculentus*) in Ifite Ogwari, Southeastern Nigeria

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ABSTRACT

The experiment was conducted at Ifite Ogwari, Anambra State to evaluate the effects of some soil amendments on thegrowth and yield performance of Okra (Abelmoschus esculentus). The experiment was laid out in a completely randomized design (CRD) with three (3) replications and an Okra variety made up my treatment. This experiment was carried out in a pottedbag with a total of (24) treatments including the control experimental bag. Data on growth and yield parameters were collected and analyzed using analysis of variance (ANOVA) for completely randomized design. The treatment means were separated using least significant difference at 5% probability level. The results obtained showed that treatment T8 (poultry manure + rice husk + compost + cow dung) performed significantly well in plant height and number of leaves, while on the other hand treatment T5 (poultry manure + rice husk + top soil),T2 (poultry manure + top soil) and T3(cow dung + top soil) performed notably better with respects to leaf area , number of fruits, stern girth and fruit weight.

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is an annual crop grown mainly as fruits and leafy vegetables in both green and dried state in the tropics (Gibbon and Pain, 1984). The crop is used as soup thickener which may also be served with rice and other food types. The fresh fruit is a good source of vitamins, minerals and plant protein (Eke *et al*., 2008). The mature stem contains crude fibre which is used in paper industries and for making ropes. Okra’s flower can be very attractive and sometimes used in decorating the room (Schippers, 2000).

Okra is cultivated under rainfed and in irrigated areas on a wide range of soils. The production is seriously affected by non-utilization of organic materials in soil fertility management. The use of inorganic manure has not been helpful under intensive agriculture because it is often associated with reduced crop yield, soil acidity and nutrients imbalance (Ojeniyi, 2000). This has encouraged scientists towards making use of organic materials (both organic manures as well as organic wastes) for improving the physical properties of soils th*at al*low profitable crop production (Somani and Totawat, 1996). There is dearth published works on the organic manure and waste use in Okra production. In view of the above, this study aimed to evaluate the effects of sources of some organic manure on the growthand yield performances of Okra.

MATERIALS AND METHODS

The potted experiment was conducted at Ifite Ogwari,Anambra State, Nigeria. Ifite Ogwari is a town located at latitudes 6°36'14.8''N and longitudes 6°57'02.5"E.

Planting media preparation

The planting media for each treatment was produced by mixing each treatment thoroughly ie top soil, poultry manure, cow dung, rice husk depending on treatment in use in a ratio of 6:1:1:1. Using a perforated cement bag as pot, painter of custard bucket of equal volume of treatment was filled into each pot, each medium was replicated three times making a total of 24 pots of media.

Sowing of Okra Seeds

Five (5) seeds was sown per bag and watered daily.Thinning of seedlings was done once they are grown.Eight (8) treatments were used in total and was replicated (3) three times. Treatments used include:

T1- Top soil (control),T2 - Top soil + poultry manure , T3 - Top soil + Cow dung , T4 - Top soil + rice husk , T5 - Top soil + poultry manure + rice husk , T6 - Top soil+ rice husk +cow dung, T7 - Topsoil + poultry +cow dung, T8 - Topsoil + poultry manure +rice husk +cow dung). In a situation where the treatments occur in pairs e.g rice husk and cow dung, rice husk and poultry manure, rice husk and poultry manure, cow dung and poultry manureis 6:1.5:1:5 and 6:1:1:1 Top soil 6, poultry manure 1, cow dung 1 and ricehusk 1 respectively. The experiment was laid in a completely randomized design (CRD) with three replications. Treatment T1 (top soil) was the control. The layout was in 5m by 4m, a potted experiment with 0.5m between treatments and 1m breadth between replicates.

Data Collection:

Data was collected on the following parameters:

Growth parameters (plant height, number of leaves, leaf area and stem girth)

Yield parameters (Number of fruits and weight of fruits).

Data Analysis:

The data generated from the pot study were subjected to Analysis of variance (ANOVA) using GenStat 4th edition statistical package (2013). Separation of means was done using the probability level significant difference at 5%.

RESULTS

Effects ofsome Organic Soil Amendments on Okra height 2-8 weeks (cm) after sowing

The results indicated th*at al*l treatments had a significant ($p<0.05$) effect on the plant height , compared to T1(Top soil only) the control at 2 weeks after sowing T8(Top soil +poultry manure + rice husk + cow dung), T2 (Top soil + poultry manure), T7 (Top soil + poultry manure +cow dung) and T5 (Top soil + rice husk + poultry manure) had the highest plant height with values ranging from 10.50cm to 9.83cm . At 8 weeks after sowing T7 (Top soil + poultry manure + cow dung), T8(Top soil + poultry manure + rice husk + cow dung) ,T2 (Top soil + poultry manure) and T5 (Top soil + rice husk + poultry manure) had the tallest plant height with mean values ranging 60.33cm to 67.57cm.

Table 1. Effects ofsome organic soil amendments on Okra height at 2-8 weeks (cm) after sowing

Treatment	Weeks						
	2 WAP	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
T1=Top Soil	3.18	8.45	12.79	16.78	20.95	25.57	29.33
T2 =Top Soil + Poultry Manure	10.50	22.00	34.57	45.33	53.07	57.17	65.33
T3 = Cow dung + topsoil	8.07	17.07	26.33	31.57	43.00	44.43	51.77
T4 = Rice husk + topsoil	9.50	16.20	22.67	26.50	31.67	33.33	35.50
T5 =Top soil + rice husk + poultry Manure	9.83	20.57	33.20	41.50	54.50	56.67	60.33
T6 = Rice husk + top soil + cow dung	8.33	18.83	30.50	39.00	47.33	54.67	56.33
T7=Top soil + poultry manure + cow dung	10.50	19.90	33.80	40.33	48.07	59.83	67.57
T8=Top soil+ poultry manure + rice husk + cow dung	10.83	21.40	34.23	43.00	53.33	61.17	67.33
LSD (*0.05*)	1.971	1.335	2.997	3.158	6.786	4.903	3.742

WAP – Weeks after planting

Effects of some organic soil amendments on Okra leaf area at 5-8 weeks after sowing.

Table 2 showed the effects of some organic soil amendments on the Okra leaf area from 5-8weeks. The result showed that T5 (Topsoil + rice husk + poultry manure) had the largest leaf area with a mean value of 250.30cm at 5 weeks after sowing and increased to 325.00cm at 8 weeks after sowing.However, T4 (Top soil + rice husk) had the least leaf area with a mean value of 61.0cm at 5weeks after planting which later increased to 95.0cm at 8weeks after planting.Top Soil showed the least followed by Rice husk + topsoil. Top soil + rice husk + poultry manurerecorded the highest mean value for leaf area.

Table2. Effects some oforganic soil amendments on Okra leaf area (cm) at 5-8 weeks after sowing.

Treatment	Weeks			
	5	6	7	8
T1=Top Soil	64.60	84.00	90.00	99.40
T2=Top Soil + Poultry Manure	240.30	280.00	318.80	330.30
T3=Cow dung + topsoil	200.30	273.00	270.00	300.30
T4=Rice husk + topsoil	61.00	75.00	86.00	95.00
T5=Top soil + rice husk + poultry Manure	250.30	290.00	320.00	325.00
T6=Rice husk + top soil + cow dung	139.90	160.40	180.30	200.10
T7=Top soil + poultry manure + cow dung	229.90	270.00	296.70	335.00
T8=Top soil+ poultry manure + rice husk + cow dung	197.70	202.3	220.00	335.00
LSD (*0.05*)	5.389	36.50	5.298	3.827

Effects of someorganic soil amendments on okra number of leaves at 2-8 weeks after sowing.

The results showed that at 2 weeks T8 (Top soil + poultry manure + rice husk + cow dung) had the highest number of leaves (4.66), while T1 (Top soil only) had the lowest number of leaves at 2 weeks after sowing

(2.85). At week 8, T2 (Top soil + poultry manure) had the highest number of leaves (31.00) while T1 (top soil only) had the lowest number of leaves at week 8 (13.46). The significant difference ($p<0.05$) observed indicates that different soil amendments had a significant effect for number of leaves at different times.

Table 3. Effects some of organic soil amendment on number of leaves from 2-8 weeks after sowing

Treatment	Weeks						
	2	3	4	5	6	7	8
T1=Top Soil	2.86	5.74	7.67	9.62	11.52	13.02	13.36
T2=Top Soil + Poultry Manure	3.33	9.00	11.33	19.00	22.67	27.67	31.00
T3=Cow dung + topsoil	3.00	8.00	11.67	16.67	19.67	21.00	23.00
T4=Rice husk + topsoil	3.67	8.00	10.67	13.67	14.33	15.67	17.00
T5=Top soil + rice husk + poultry Manure	3.33	6.00	7.00	11.57	13.67	15.33	16.00
T6=Rice husk + top soil + cow dung	3.00	7.33	11.33	15.67	18.67	20.67	22.00
T7=Top soil + poultry manure + cow dung	4.00	8.67	12.00	19..67	24.67	27.00	28.00
T8=Top soil+ poultry manure + rice husk + cow dung	4.67	8.67	12.67	19.00	26.00	28.33	30.00
LSD (0.05)	1.751	1.204	1.809	2.723	1.971	1.814	2.109

Effects of some organic soil amendments on the stem girth of okra plant from 4-8 weeks after sowing

It's observed from Table 4,that treatment T2 (Top soil + poultry manure) had the highest stem girth throughout the weeks with the highest stem girth of mean value of 5.53 cm at 8 weeks. Treatment T1 (top soil) only had the lowest stem girth from week 5 - 8 and had the highest value of 3.35cm at week 8 . Treatment 2 (Top soil + poultry manure) had the biggest stern girth mean valueat 4-8 weeks after sowing while treatment T1 (Top soil) performed the least of all treatment.

Table 4. Effects ofsome organic soil amendments on the stem girth (cm) of Okra plant from 4-8 weeks after sowing

Treatment	Weeks				
	4	5	6	7	8
T1=Top Soil	2.27	2.44	2.75	3.24	3.55
T2=Top Soil + Poultry Manure	3.93	4.90	5.30	5.50	5.53
T3=Cow dung + topsoil	3.80	4.15	4.30	4.70	5.00
T4=Rice husk + topsoil	2.25	2.63	3.00	3.40	3.70
T5=Top soil + rice husk + poultry Manure	3.68	3.95	4.17	4.58	5.00
T6=Rice husk + top soil + cow dung	3.00	3.60	4.00	4.70	5.40
T7=Top soil + poultry manure + cow dung	3.10	3.67	4.20	4.48	4.75
T8=Top soil+ poultry manure + rice husk + cow dung	2.90	3.40	3.70	3.90	4.38
LSD (*0.05*)	0.3396	0.3483	0.2223	0.2029	0.2431

Effects of someorganic soil amendments on the number of Okra fruits at 4-8 weeks after sowing.

The data shows the number of fruits produced by each treatment at different weeks at week 4 - 8.Treatment T3 (Top soil + cow dung) had the highest number of fruits in most of the weeks ranging from 5.0 to 5.0. On the other hand, treatment T1 (Top soil) had the lowest number of fruits produced at most week intervals ranging from 1.9 to 1.2 fruits.

Table 5. Effects of someorganic soil amendments on the number of okra fruits at 4-8 weeks after sowing.

Treatment	Weeks				
	4	**5**	**6**	**7**	**8**
T1=Top Soil	1.93	3.93	3.00	4.79	1.29
T2=Top Soil + Poultry Manure	2.00	5.00	4.00	6.00	5.00
T3=Cow dung + topsoil	5.00	5.00	6.00	4.00	5.00
T4= Rice husk + topsoil	2.00	5.00	4.00	3.00	3.00
T5=Top soil + rice husk + poultry Manure	5.00	5.00	6.00	5.00	4.00
T6 =Rice husk + top soil + cow dung	3.00	4.00	5.00	5.00	3.00
T7= Top soil + poultry manure + cow dung	2.00	3.00	3.00	3.00	2.00
T8=Top soil+ poultry manure + rice husk + cow dung	2.00	2.00	5.00	4.00	4.00
LSD (*0.05*)	1.675	2.060	1.362	1.730	1.230

Effects of some organic soil amendments on the fruit weight of Okra plant at 4-8 weeks after sowing.

The result of the analysis showed that, Treatment T6 (top soil + rice husk + cow dung) had the highest fruit weight at week 4 and 5 after sowing with values of 12.60g and 17.60g respectively. At week 6, Treatment T2 (top soil + poultry manure) had the highest fruit weight with a mean value of value of 18.67g. However, treatment T1 (top soil only) had the lowest fruit weight value at 5 , 7 and 8 and Treatment T8 (top soil + poultry manure + rice husk + cow dung) had the lowest fruit weight value at week 4 and Treatment T4 (rice husk + top soil) had the lowest fruit weight value at 6 weeks after sowing.

Table 6. Effects of some organic soil amendments on the fruit weight of okra plant from 4-8 weeks after sowing.

Treatment	Weeks				
	4	**5**	**6**	**7**	**8**
T1=Top Soil	8.51	13.07	12.53	11.11	10.48
T2=Top Soil + Poultry Manure	12.50	15.57	18.67	13.37	16.27
T3=Cow dung + topsoil	10.50	16.50	15.23	17.20	12.80
T4=Rice husk + topsoil	8.40	13.33	11.37	19.30	15.00
T5=Top soil + rice husk + poultry Manure	8.43	16.50	15.20	17.10	12.73
T6=Rice husk + top soil + cow dung	12.60	17.60	14.40	15.70	16.27
T7=Top soil + poultry manure + cow dung	8.27	16.73	14.97	17.50	12.50
T8 = Top soil+ poultry manure + rice husk + cow dung	5.20	16.33	14.63	16.30	13.80
LSD (*0.05*)	0.3113	0.4711	0.4056	0.3799	0.4849

DISCUSSION

Growth Parameters

Plant Height

Plant height of Okra is genetically determined (IAR, 1995). The height of okra studied is perhaps more of genetic than environmental trait. The positive effect of organic manure on plant height could be due to its genetic makeup as well as the contributions made by manure to fertility status of the soil. Thus, the results suggests that the use of soil amendments had a positive effect on development and growth of okra plants and the combination of Top Soil, poultry manure, rice husk and cow dung, proved to be the most effective treatment in terms of plant height. The results obtained collaborated with the findings of Ajari *et al*. (2003) in okra production in which they reported that organic manure especially poultry manure could increase plant height of crops when compared to other sources of manure.

Leaf Area

The importance of leaf area in relation to basic plant metabolic processes such as photosynthesis and respiration is generally recognized. The result suggests that the use of Top soil, rice husk and poultry manure can significantly increase leaf area and increase photosynthesis and respiration efficacy in plants (Bueno, 1979).

Number of leaves

It appears that different soil amendments had varying effects on number of leaves of okra over time. From the results, T3, T7 and T8, had the highest mean values for number of leaves at different weeks, implying that these soil amendments maybe more effective in promoting leaf growth and development. T1 had comparatively low number of leaves at most times suggesting that this amendment may be less effective.

Okra Stem girth

The results obtained shows the effect of different soil amendments on stem girth at 4-8 weeks after sowing at Ifite Ogwari. The stern girth is principal parameter in determining plant growth and development.The results suggest that the addition of poultry manure to top soil has a positive effect on stern girth, while the addition of cow dung to the mixture further enhances growth.

Number of fruits and Fruit Weight

The results suggest that adding cow dung to top soil can positively affect the number of fruits produced. Treatment T3 (Top soil + cow dung) been the most effective for number of fruits, Treatment T6 (top soil + rice husk + cow dung) had the highest fruit weight at week 4 and 5 after sowing with values of 12.60g and 17.60g respectively. At week 6 Treatment T2 (top soil + poultry manure) had the highest fruit weight value of 18.67g. The results was in consonance with the findings ofSanwel*et al*. (2007) who observed that organic manure produce higher pods and improved productivity. The results also aligned with the findings of Abou El magd*et al.* (2006) who observed that animal manure nutrientsreleased more slowly and stored for a longer time in the soil, improves root development and high crop yield.

CONCLUSION

The use of different soil has a consequential effect on the growth and yield of Okra plant. Generally, the treatments that included a combination of organic soil amendments like poultry manure, rice husk, cow dung and top soil resulted in higher plant growth, plant height and number of leaves.

These treatmentsT8(poultry manure + rice husk + cow dung + top soil) and T7 (poultry manure + cow dung + top soil) consistently showed highest mean values for plants height and number of leaves across different weeks after sowing. Treatment T2 (poultry manure + top soil), T3 (cow dung + top soil) and T5 (poultry manure + rice husk and top soil) also showed congruous performances in terms of leaf area,number of fruits, stem girth and fruit weight. While Treatment T4 (rice husk + top soil) and treatment T1(top soil only) showed inconsistent mean values. Treatment T6 (rice husk + cow dung + top soil) showed mixed results with no clear course in terms of growth and yield. In conclusion the results suggest that the use of organic soil amendments can improve growth and yield of Okra.

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Comparative Effect of Storage Materials on Quality of Okra (*Abelmoschus esculentus* L. Moench) in Awka-South Local Government Area, Nigeria

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ABSTRACT

An investigation was carried out at the research Laboratory of Plant protection of Crop Science and Horticulture, Nnamdi Azikiwe University, Awka to compare effects of storage materials on quality of okra fruits (Abelmoschus esculentus L. Moench). The experimental design was a completely randomized design (CRD) replicated six times. The experiment consisted of storing of freshly harvested okra fruits in two storage media viz: woven baskets (lined with bitter leaves and unlined baskets) and perforated Paper Cartons (lined with bitter leaves and unlined cartons). The baskets and perforated cartons containing the okra fruits were then kept on laboratory benches. Okra fruits in the storage media were covered with white transparent nylon material and observed for 14 days. At the end of the period, the fruits were sorted out into relatively healthy fruits, rotted fruits, green fruits, light green fruits, spotted fruits and shriveled fruits. The weight loss of okra fruits was recorded to an accuracy of 0.01g using mettle balance model (P1200). Results showed that packaging materials had significant effect on physical qualities of Okra fruits after two weeks of storage, where unlined cartons had the highest (38.3%) number of relatively healthy fruits followed by 37.5% in unlined baskets while the least (30.8%) was obtained in lined baskets. The results also showed that packaging materials had significant effect on moisture content of Okra fruits stored in different storage materials where there was lesser moisture loss in Okra fruits stored in lined cartons compared to other storage packages. The results as well showed that 20.55% moisture was lost from Okra fruits stored in lined cartons from the first day to the seventh day while 32.48% moisture loss occurred from the same number of Okra fruits from the seventh day to the fourteenth day. From this study it could therefore be recommended that farmers should adopt the use of unlined perforated cartons for the storage and transportationof their freshly harvested okra fruits since it showed the best extension of shelf-life of Okra fruits.

INTRODUCTION

Okra plant was formerly addedin the genus Hibiscus, Abelmoschus in the family Malvaceae. The Abelmoschus was subsequently proposed to be raised to the rank of distinct genus. Okra is grown in many parts of the world, especially in tropical and sub-tropical countries. This crop can be grown on a large commercial farm or as a garden crop. Okra plants are grown commercially in many countries such as India, Japan, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Myanmar, Malaysia, Thailand, Brazil, Ethiopia, Cyprus and in the Southern United StatesThe okra production of Nigeria increased from 300,000 tons in 1972 to 1.92 million tons in 2021 growing at an average annual rate of 5.59%.The importance of fruits and vegetable cannot be overemphasized due to the vitamin content of fruit vegetable, which is known to be nutritionally superior when compared to many cereals and leguminous crops (FAO, 1992). They are highly perishable due to high water content and thereby susceptible to rapid detoriation, soon after harvest, therefore they have to be properly packaged and stored if not consumed immediately (Weichman, 1987), traditionally storage materials such as calabash, earthen pots, baskets have been used for the purposes of extending shelf life of crops few days after harvest (Kordylas, 1991). Okra, when left for more than two days tend to become fibrous and unsuitable for direct use. Thus, proper packaging and storage allows for better quality and extended shelf life for some days (Schippers, 2000). Certain type of containers typically made from paperboard which is sometimes also known as cardboard are used. Many of these cardboards are used in packaging food, pharmaceutical wares, and may other types of products. Inadequate storage of okra results in color fading by oxidation and enzymatic activities which affects the commercial value of fresh okra when stored at a room temperature (lsiong, 1997). Unfortunately, okra belongs to the group of crops commonly referred to as perishables (NSPRI, 2000). In their fresh form under hot tropicalconditions, they suffer extensive deterioration within a short period of time after harvest. Consequently, large amount of the okra is produced annually but a great percent is lost through spoilage caused by high respiration and transpiration rates, in addition to bacterial and fungal attack and also lack of hard texture make them bruise easily (NSPRI, 2000). Proper processing, preservation and marketing and also utilization of okra is necessary to arrest the wastage being experienced during the peak season.Such effort should involve the development of appropriate technologies for processing and preserving okra for high market value. The loss in quality and limited shelf life are the major problems faced in marketing fresh okra in Nigeria due to its high respiration rate at warm temperatures. Therefore, in order to extend the shelf life of okra, it is essential to package it in appropriate packaging materials to reduce the rate of post-harvest spoilage. Okra can be preserved in many ways, either by refrigerating of fresh okra or by canning of okra pods or by freezing of okra pods or by drying. Therefore, the objective of this research was to investigate effects of two storage methods on quality of okra fruits (*abelmoschus esculentus* L. Moench) in Awka-South Local Government Area.

MATERIALS AND METHODS

Twelve small baskets woven with the radius of palm were used. Six (6) of these baskets were lined with bitter leaf (*Vernonia amygdalina*) containing 20 freshly harvested okra fruits. The freshly harvested okra fruits were sourced from a reliable farmer from Asaba, Delta State and transported to the Laboratory same morning in a Sackbag with the mouth properly tied. The other six baskets were not lined with any leaf and also contained twenty okra fruits each, which served as the control. Similarly, twelve small paper cartons, six of which were perforated (small holes of 10 cm diameter) and lined with bitter leaf and the other six were perforated (same number of holes and dimension) and used as control for the cartons. The okra fruits in the baskets and cartons were covered with transparent nylons and were completely randomized on the Laboratory bench in the Crop Science and Horticulture Laboratory, Nnamdi Azikiwe University, Awka. The prevailing temperature and humidity in the laboratory were 34°C and 78%RH respectively. The Okra fruits were observed for two weeks in storage. At the end of the 2 weeks, the fruit were sorted into relatively healthy fruits, rotten fruits, green fruits, light green fruits, spotted fruits, and shriveled fruits. Each of the above character of the fruits in the storage were counted and recorded for in 2 weeks. Data were collected on okra fruits contained in the basket lined with bitter leaf, unlined basket (control), carton lined with bitter leaf, unlined carton (control)The treatments were laid out in Completely randomized design (CRD) replicated six times. Temperature and relative humidity were recorded with Laboratory Thermometer and Hygrometer respectively. The weight loss of okra fruits was recorded to an accuracy of 0.01g using mettle balance model (P1200) and percentage weight loss was calculated using the methods of analysis AOAC (2005).

% Moisture content is given with the relation $\%\, mc_{ab} = \frac{W_w - W_d}{W_w} \times \frac{100}{1}$

where mc is expressed on wet basis (Ww is wet weight and Wd is dry weight).

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) in CRD using SPSS the means were compared by the use of New Duncan Multiple Range Test (NDMRT) at 5% level of probability.

RESULTS

Table 1 shows that packaging materials had significant effect on the physical qualities of stored Okra fruits where unlined carton had the highest number (65%) of Okra fruits that were relatively healthy on the seventh day of storage, followed by 55% obtained in lined basket while the least (37%) which occurred in unlined basket. Table 1 also shows that unlined baskets had the highest (20.8%) number of rotten fruits which is significantly higher than 5,0% obtained in lined baskets but statistically same as 7.5% and 13.3% obtained in unlined and lined cartons respectively. The results shows that unlined cartons had the highest colour retention with 64.2% of Okra fruits retaining their green colour followed by 52.5% in lined baskets while the least (42.5%) colour retention occurred in unlined baskets. Table 1 also shows that lined cartons had the least (9.2%) number of shriveled Okra fruits, followed by 11.7% obtained both in lined and unlined baskets while the highest (15.8%) number of shriveled Okra fruits occurred in unlined cartons.

Table 1. Effects packaging materials on Okra fruits at day 7

Packaging materials	RHF	RF	GF	LGF	SPF	SHF
Basket only	37.5^{b}	20.8^{a}	42.5	21.7^{ab}	11.7	11.7
Basket lined	55.0^{ab}	5.0^{b}	52.5	32.5^{a}	11.7	11.7
Carton lined	51.7^{ab}	13.3^{ab}	51.7	17.5^{ab}	8.3	9.2
Carton only	65.0^{a}	7.5^{ab}	64.2	7.5^{b}	6.7	15.8
SE	3.783	2.205	3.723	3.062	1.409	2.148

Means with same superscripts or means without superscripts are not significantly different from each other. Where: RHF = Relatively healthy fruits, RF = Rotten fruits, GF, = Green fruits, LGF = Light green fruits, SPF = Spotted fruits and SHF = Shriveled fruits.

Table 2 shows that packaging materials had significant effect on physical qualities of Okra fruits after two weeks of storage, where unlined cartons had the highest (38.3%) number of relatively healthy fruits followed by 37.5% in unlined baskets while the least (30.8%) was obtained in lined baskets. Results also shows that lined baskets had the highest number (52.5%) of rotten Okra fruits followed by 48.3% which occurred in lined cartons while the least number of rotten Okra fruits (32.5%) was obtained in unlined baskets. Table 2 also shows that the highest number of green fruits (31.7%) was obtained in unlined cartons followed by 22.5% which occurred in lined cartons while the least (13.3%) occurred in lined baskets. Unlined baskets had the highest (17.5%) number of shriveled Okra fruits followed by 11.7% obtained in unlined cartons while the least (1.7%) occurred in lined cartons. Generally unlined cartons had Okra fruits with better physical qualities than lined cartons and baskets

Table 2. Effects packaging materials on Okra fruits at day 14

Packaging materials	RHF	RF	GF	LGF	SPF	SHF
Basket lined	30.8	52.5	13.3	15.8	6.7	10.0^{ab}
Basket only	37.5	32.5	24.2	13.3	12.5	17.5^{a}
Carton lined	36.7	48.3	22.5	10.8	13.3	1.7^{b}
Carton only	38.3	39.2	31.7	7.5	10	11.7ab
SE	2.974	3.769	3.226	2.568	1.356	1.915

Means with same superscripts or means without superscripts are not significantly different from each other. Where: RHF = Relatively healthy fruits, RF = Rotten fruits, GF, = Green fruits, LGF = Light green fruits, SPF = Spotted fruits and SHF = Shriveled fruits.

Table 3 shows that packaging materials had significant effect on moisture content of Okra fruits stored in different storage materials where there was lesser moisture loss in Okra fruits stored in lined cartons compared to other storage packages. The results show that 20.55% moisture was lost from Okra fruits stored in lined cartons from the first day to the seventh day while 32.48% moisture loss occurred from the same number of Okra fruits from the seventh day to the fourteenth day. This is quite lower than 40.54% moisture loss which occurred in Okra fruits stored in unlined baskets on the seventh day and 44.10% moisture loss that was obtained on the fourteenth day. It is very clear that there was more moisture loss in Okra fruits stored in unlined baskets than any other storage package.

Table 3. showing the weight of okra fruits after storing in different storage media for 14 days

Containers	Day 1	Day 7	Day 14
Basket only	275.83^{a}	164	91.67^{b}
Basket lined	232.67^{b}	181.17	111.00^{ab}
Carton only	232.33^{b}	165.17	117.33^{ab}
Carton lined	228.67^{b}	181.67	122.67^{a}
SE	6.283	4.523	4.83

SE= Standard error. Means with same superscripts or means without superscripts are not significantly different from each other. Where: RHF = Relatively healthy fruits, RF = Rotten fruits, GF, = Green fruits, LGF = Light green fruits, SPF = Spotted fruits and SHF = Shriveled fruits.

Table 4 shows that Okra fruits stored in different packaging materials had different microbial qualities which include: blackening of fruits, soft rots, slimy mucilage and white mass of mold growth observed in Okra fruits stored in baskets lined with bitter leaves, while massive fungal growth, blackening of fruits and grey mold growth were seen in Okra fruits stored in unlined baskets. The results also shows that there was presence of egg-shaped insect larva and whitish molds in Okra fruits in lined cartons while whitish spots and whitish mold growth were observed in unlined cartons.

Table 4. Effect of Packaging Materials on Microbial Growth and deterioration on the Stored Okra Fruits after 7 and 14 Daysrespectively

Packaging Materials	Symptoms of Disease/Spoilage
Baskets lined with bitter leaves	Blackening of fruits
	Soft rots
	Slimy mucilage
	Black spots and necrotic tissues
	White mass of mold growth
Baskets only	Massive fungal growth
	Blackening of fruits
	Grey mold
Cartons lined with blades bitter leaf	Presence of egg -shaped insect larva
Cartons only	Whitish spot, White mold growth

Where: RHF = Relatively healthy fruits, RF = Rotten fruits, GF, = Green fruits, LGF = Light green fruitsSPF = Spotted fruits and SHF = Shriveled fruits.

DISCUSSION

Effect of storage methods had significant effect on quality of okra fruits after the 14th day storage. This is in agreement to the finding of Indhupriya *et al* (2021), who reported that cold storage gave better performance than ambient condition in shelf- life extension of okra fruits. This could be as a result of slowing down of some physiological processes such as respiration, which leads to deterioration of the stored produce as well as reduction of excessive loss of water occasioned by reduced temperature in cold storage. The result also corroborated with Paulus, *et al* (2021), who reported that packaging materials had significant effect on physiological qualities of okra fruits wrapped with low-density polyethylene (LDPE) compared to other storage materials. Okra fruits storage media showed that unlined perforated cartons had the best relatively healthy fruit (RHF) on 14thday.This is dissimilar to Chukunda and Nwonuala, (2013), who reported that in terms of relatively healthy fruits, rotten fruits, spotted fruits, light green fruits, green fruits and shriveled fruits in cartons lined with bitter leaf retained their quality. This could have been as a result of difference in the size of perforations in the cartoon. While theirs had wider holes, narrow holes were used in the present study. This is also dissimilar to findings of Iwuagwu *et.al*, (2014), who reported that the physical qualities of fruit vegetables stored in evaporative coolants lined with polythene materials were considerably depressed.

Okra fruits had highest weight retention at day 14 in lined cartons than the other storage methods. This is in agreement Chukunda and Nwonuala, (2013), who found that okra fruits stored in cartons lined with bitter leaves retained up to 86% of their moisture compared to other storage media.

CONCLUSION

The results showed that unlined cartons had the highest (38.3%) number of relatively healthy fruits followed by 37.5% in unlined baskets while the least (30.8%) was obtained in lined baskets on the fourteenth day. But it was observed that it was quite better to store okra fruits in lined cartons since it enhanced more moisture retention than other packaging materials. Also, unlined cartons had fewer microbial deterioration than other storage methods.

RECOMMENDATIONS

From this study it could therefore be recommended that farmers should adopt the use ofunlined perforated cartons for the storage and transportationof their freshly harvested okra fruits since it showed the best extensionof shelf-life of Okra fruits.

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Distribution of Plant Parasitic Nematodes on Pepper in Ilorin, Kwara State, Nigeria

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KEYWORDS

Distribution, Meloidogyne, Nematodes, Pepper

ABSTRACT

A survey was conducted in pepper-producing farms in Ilorin, Kwara State between July and November 2021 to study the distribution of plant-parasitic nematodes affecting pepper and to investigate the effects of soil physico-chemical properties on the nematodes. A total of twenty four plant roots and nine soil samples collected from thirty pepper farms were examined. Result showed that seven genera of plant-parasitic nematodes were identified. The location with the highest occurrence was the Ilorin township Stadium with 100% frequency. Relative abundance of Meloidogyne was greater than that of the other nematode species. The results indicate that, apart from the direct influence of the host plant, soil properties play an important role in the abundance, distribution and structure of plant parasitic nematode communities. This validates the potential of nematodes as bioindicator organisms of soil health.

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INTRODUCTION

Pepper (*Capsicum* spp.) is a vegetable and spice crop which belongs to the *Solanaceae* family and is mostly cultivated for consumption (Ogunbo *et al*., 2015). Its history and origin can be traced back to the Americans and today, it is cultivated all over the world (Idowu-Agida *et al*., 2012).

Fresh pepper is cultivated in 126 countries of the world in all the continents. The world's largest producer is China with over 18 million tons annually, followed by Mexico with about 3.5 million tons (FAOSTAT, 2017). The nutritional value of pepper merits special attention as it is a rich source of vitamins A and E (AgMRC, 2011). Both hot (*C. fruitescens*) and sweet peppers (*C. annum*) contain more vitamin C to prevent flu than any other vegetable crop. Despite the importance of pepper crop to the economy, little attention is paid to problems limiting the production of pepper. In general, plant health problems particularly those caused by plant parasitic nematodes are neglected.

Plant Parasitic Nematodes (PPNs) alone or in combination with other factors reduce crop productivity and they cause farmers thousands of naira in crop loss annually (Pokharel *et al*., 2009). Losses due to PPNs are estimated at over $150 billion globally (Abad *et al*., 2008), without considering other losses by interactions with other pathogens. The damage of crop caused by PPNs depends on agro-climatic conditions, host susceptibility, pathogenicity and other climatic factors.

The main objective of this study was to carryout survey study on the occurrence and distribution of plant parasitic nematodes associated with pepper in Ilorin, Kwara State.

OBJECTIVES

The objectives of this study were to;

i. identify the plant parasitic nematodes associated with pepper;
ii. determine the population density of plant parasitic nematodes associated with pepper and,
iii. evaluate the physical properties of soil around pepper farm.

MATERIALS AND METHODS

Materials used in this study were tray, sieve, auger, tissue paper, sample bottles, paper tape, blender, soil and root samples, polythene bags and electron microscope.

Study Area

The surveyed vegetable sites are located in Ilorin, the capital of Kwara State, North Central of Nigeria. The study area is located approximately on latitude 8º30'N of the equator and longitude 4º35'E of the Greenwich Meridian and has an area of about 100km2. Ilorin experiences a tropical wet and dry climate with mean annual rainfall of 1,200mm. Its temperature varies between 25ºC to 30ºC. The sites for the surveyed vegetable farms are Sango, Sobi, Stadium, Isale-koko, Lasoju, Alalubosa, Oloje, Alagbado and Kulende. They were selected on the basis of the importance of vegetable production, acceptance of vegetable farmers, variability of the vegetable crops produced and geographical distribution. The geographical coordinates of each of the sites were recorded using a Global Positioning System (GPS) and used to plot the map on the next page.

Nematode Extraction from soil and root samples

Nematodes were extracted separately from soil and root for each of the collected samples. Nematodes were extracted from the soil using the modified Baermann tray method as described by Whitehead and Hemming (1965).

Data Analysis

All numeric data obtained were analysed using descriptive statistics and analysis of variance (ANOVA) where mean difference was determined by Duncan's new multiple Range test (DMRT) at 5% level of significance

RESULTS

From the table 1 below it is observed that for soil nematode, *Meloidogyne* was the most abundant with 37.53% followed by *Pratylenchus* with 26.83%, *Helicotylenchus* with 17.96%, *Hopolaimus* with 10.26%, *Radopholus* with 6.75% And *Tylenchus* with 0.61%, while *Xiphinema* recorded the least with 0.05%.

For the root nematodes, there were four nematode genera found in the root of pepper that were obtained from the study area. It was observed that *Meloidogyne* recorded the highest abundance with 51.69 followed by *Pratylenchus* with 32.56 and *Helicotylenchus* with 15.30. *Xiphinema* recorded the least occurrence with 0.45.

Table 1: Relative abundance of soil and root nematode

Genus	Abundance in soil	Abundance in root
Radopholus	6.75	-
Xiphinema	0.05	0.45
Pratylenchus	26.83	32.56
Meloidogyne	37.53	51.69
Hopolaimus	10.26	-
Helicotylenchus	17.96	15.30
Tylenchus	0.61	-

From the Table 2 below, it was observed th*at al*l survey area recorded a mean density of soil nematodes which ranged 0.42 to 1.00. Stadium recorded the highest population density with 1.00 followed by Sango, Isale koko and Oloje with mean density of 0.71. Sobi, Lasoju, Alalubosa and Kulende recorded a mean density of 0.57 while Alagbado recorded the least with mean density of 0.42.

For root nematodes, the mean population density ranged from 0.25 to 1.00. Stadium also recorded the highest mean population density with 1.00 followed by Alagbado with 0.75. Sobi, Isale koko, Lasoju, Oloje and Kulende recorded mean density of 0.50 while Alalubosa recorded the least with mean density of 0.25

Table 2: Mean population density of soil and root nematodes

Survey Area	Soil nematode	Root nematode
Sango	0.71	-
Sobi	0.57	0.50
Stadium	1.00	1.00
Isale koko	0.71	0.50
Lasoju	0.57	0.50
Alalubosa	0.57	0.25
Oloje	0.71	0.50
Alagbado	0.42	0.75
Kulende	0.57	0.50

The soil physical characteristics of the survey area were reported in the Table 3. The surveyed locations were slightly acidic to slightly basic. It was revealed that the textural class of soils for all surveyed locations were sandy, which was detailed from that composition of the clay, silt and sand from the soil analysis carried out. The Table revealed that soil sample collected from Alagbado recorded the highest sand percentage composition with least clay percentage composition 92.00% and 6.45% respectively, closely followed by soil samples collected from Sobi, Stadium, Alalubosa and Oloje with 91.52% and 6.48% respectively, followed by soil samples collected from Sango, Isale koko and Kulende 89.52% and 8.48% respectively while soil sample collected from Alalubosa recorded the least sand percentage composition of 87.52% and the highest clay percentage composition of 10.48%. All soil samples had 2% silt composition irrespective of their survey location.

Table 3: Physical characteristics of soil

Survey Area	% Clay	% Silt	% Sand
Sango	8.48	2	89.52
Sobi	6.48	2	91.52
Stadium	6.48	2	91.52
Isale koko	8.48	2	89.52
Lasoju	10.48	2	87.52
Alalubosa	6.48	2	91.52
Oloje	6.48	2	91.52
Kulende	8.48	2	89.52
Alagbado	6.45	2	92.00

DISCUSSION

A survey study of pepper farms in nine locations in Ilorin, Kwara State of Nigeria revealed some genera of plant parasitic nematode number in soils and roots of pepper plants. The seven nematode genera recovered from the study were *Tylenchus*, *Meloidogyne*, *Pratylenchus*, *Helicotylenchus*, *Radophulus*, *Hopolaimus* and *Xiphinema*. This result is also in agreement with a previous report by Apalowo *et al.* (2023), that most plant parasitic nematodes are usually found in mixed infections.

The biological diversity observed in this study is related to the one reported by Paiko *et al*.(2019), in another study on abundance of plant parasitic nematodes from rhizosphere of pepper plants as influenced by soil physical and chemical properties. The results of this study showed that pepper is a host to economically important PPN which cut across the nine surveyed locations. All nematodes reported in this study have been infecting pepper in Ilorin, Kwara State and other parts of the world.

The amount of sand in the soil is an important factor that affects the density of root-lesion nematodes. Sandy soil with high pore size is also another factor for nematode penetration and movements through the soil. The high prevalence can be attributed to low quantities of organic matter in the soils. Another reason for this high prevalence was that pepper was grown in lands which was in constant usage last few years. The findings of other researchers also confirmed this fact that fallowing resulted in an increase in the contents of organic matter and consequently caused a decline in nematode populations (Fajardo *et al*., 2011).

CONCLUSION AND RECOMMENDATION

This study has established the occurrence and prevalence of plant parasitic nematodes, which may consequently cause severe yield reduction in pepper. The study has also confirmed soil property influence on the PPNs. There is need to identify the recovered nematode genera using molecular characterisation. Also, extension agents should always create awareness to the farmers.

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Organic Fertilizer Sources and Rates for Potted Bitter Leaf (*Vernonia amygdalina* Del.) Production

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KEYWORDS

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ABSTRACT

Bitter leaf possess medicinal, pharmaceutical and bioprotective properties aside its nutritional importance. However, there is a dearth of documented information on the production requirements of this important crop as pot-plants with regards to fertilizer source and rates. A pot experiment was conducted at Crop Science and Horticulture Teaching and Research Farm, Nnamdi Azikiwe University, Awka to study the effect of organic fertilizer types (poultry manure, cow dung, poultry manure + cow dung) and rates (0, 5, 10, 15 t ha^{-1}) on the growth, fresh leaf yield and dry matter partitioning of bitter leaf. The experiment was laid out as 3x4 factorial experiment fitted into completely randomized design (CRD) and replicated ten times. Data were collected on growth and fresh leaf yield. Organic fertilizer types and rates and the interaction significantly ($P<0.05$) influenced the growth and yield of bitter leaf. Applications of 10 t ha^{-1} poultry manure or combined application of poultry manure and cow dung at 10 t ha^{-1} significantly ($P<0.05$) produced tallest plants and highest number of leaves. The combined application of poultry manure and cow dung also produced highest fresh leaf yield (2.15 t ha^{-1}). This was followed with poultry manure applied at either 10 or 15 t ha^{-1} (1.96 and 1.97 t ha^{-1}, respectively). It was therefore recommended that growers should apply poultry manure at 10 t ha^{-1} or combination of poultry manure and cow dung at 10 t ha^{-1} for enhanced growth and leaf yield of bitter leaf in containers.

INTRODUCTION

Bitter leaf (*Vernonia amygdalina* Del.) is a shrub that grows in tropical Africa and belongs to the Asteraceae family (Singha, 1966). The leaves of bitter leaf are used as soup condiments after washing and boiling to get rid of the bitter taste (Hamzah *et al*., 2013). Specifically, the leaves are used to prepare the popular Nigerian bitter leaf soup called 'onugbo' soup (Ho *et al*., 2012) which is a special soup and delicacy in Anambra state. Hence, there is scarcely any household in the state that do not have a stand of bitter leaf in the homestead.

In some part of Africa, the plant is made into tonic and drank for medicinal purposes (Igile *et al*., 1994). Other popular use of *Vernonia amygdalina* in Africa includes traditional treatment of diseases such as malaria, infertility, diabetes, gastrointestinal problems and sexually transmitted diseases (Argheore *et al*., 1998; Farombi and Owoeye, 2011). The bitter leaf extracts also possess ability to prevent kidney and liver damage because of the antioxidant properties (Minari, 2012). Recently, Anambra state government had commenced the exportation of bitter leaf which has resulted to increased bitter leaf farming in the state. Despite these numerous importance of bitter leaf, there is scarcity of information on the appropriate agronomic practices for optimum production of the crop.

Low soil fertility is considered as one of the main factors responsible for the low productivity of vegetables (Hamden and Fadni, 2010). The additions of fertilizers to the soil or directly on the crops have enhanced crop production. The prevailing exorbitant prices and shortage in supply of mineral fertilizers resulted in a shift of attention by many farmers towards making better use of organic fertilizers as an alternative source of plant nutrients (Agyenim-Boateng *et al*., 2006). The value of organic fertilizer as a source of plant nutrients has long been recognized, due to their ability to supply essential elements, improve soil structure and aeration, increase soil organic matter and encourage good root growth (Udom *et al*., 2007).

Poultry manure and cow dung are among the commonest organic fertilizers that farmers in Anambra state utilize for crop production. This is attributed to the fact that poultry manure are relatively available within the state because of increased production of broilers and layers. In addition, there exist abattoirs where cow dung are dumped. At present, there are no recommended standards with respect to rate of poultry manure and/or cow dung for optimum yield of *Vernonia amygdalina* in southeastern Nigeria and the country at large. Therefore, the objectives of this study were to determine the effects of organic fertilizer types and rates on the growth and fresh leaf yield of bitter leaf.

MATERIALS AND METHODS

Experimental site, planting materials and treatments

The experiment was conducted at the Teaching and Research Farm of the Department of Crop Science and Horticulture, Nnamdi Azikiwe University, Awka (latitude 6° 25' North and longitude 7° 11' East). The coordinate of the experimental site is latitude 6° 13' 8.209" North and longitude 7° 04' 38.773" East During the experiment (February - August, 2019), the meteorological data of the experimental site was as follows - maximum and minimum temperature of 28.74°C and 28.96°C, respectively with average rainfall of 1828 mm and relative humidity of 72.3%.

The planting materials used were stem cuttings of bitter leaf obtained from the teaching and research farm of the Department of Crop Science and Horticulture, Nnamdi Azikiwe University, Awka, Anambra state. The stems were cut into 15 cm length bearing 8 to 10 nodes. The poultry manure utilized was poultry dropping obtained from a battery cage system of a commercial farm while the cow dung was gotten from ‘Amansea’ cattle abattoir, Awka South Local Government of Anambra State, Nigeria. The results of physicochemical analyses of the organic manure and soil utilized are presented in Table 1.

Table 1: Physicochemical properties of the soil before planting, cow dung and poultry manure utilized

Parameter	Soil	Cow dung	Poultry manure
Sand (%)	70.8	-	-
Silt (%)	16.8	-	-
Clay (%)	12.4	-	-
pH (H_2O)	6.88	-	-
Organic carbon (%)	0.65	12.45	18.35
Total Nitrogen	2.55	1.08	1.58
Av. Bray P (mg/kg)	2.55	0.006	0.02
Ca^{2+} (cmol/kg)	1.2	1.48	6.0
Mg^{2+} (cmol/kg)	0.4	1.90	1.50
K^+ (cmol/kg)	0.20	0.007	0.03
Na^+ (cmol/kg)	0.09	0.03	0.20
Total exchangeable acidity (cmol/kg)	1.13	-	-
CEC (cmol/kg)	2.49	-	-
Base saturation (%)	75.9	-	-

The experimental treatments comprised two factors namely organic fertilizer types and application rates. The organic fertilizer types were poultry manure, cow dung and combination of poultry manure and cow dung while organic fertilizer rates included 0, 5, 10 and 15 t ha^{-1}. The treatment combinations were laid out, in a pot experiment, as a 3x4 factorial experiment in completely randomized design, replicated ten times.

Media preparation, treatment allocation and cultural practices

The top soil, collected at 0-15cm depth, from the plantain plantation of Department of Forestry and Wildlife, Nnamdi Azikiwe University, Awka, were mixed with the poultry manure or cow dung or both organic fertilizers according to the organic fertilizer rates earlier stated. The substrates were composted for one month before potting into 7-litre nursery pots. The actual quantities of the organic manure applied to the soil were 200 g, 400 g and 600 g representing 5, 10 and 15 t ha^{-1}. These actual quantities were determined considering the weight and moisture content of the soil as well as the moisture content of the poultry manure. The topsoil that received no organic manure irrespective of the rates represented the control.

The stem cuttings with 15 cm length and possessing 3-5 nodes were planted in the 7-litre nursery pots filled with the composted media in a slanting position (45° to the soil level). The stem cuttings were watered daily using watering can, while dry grass mulch was applied six days after planting to help conserve moisture during the dry season. The experiment became rain fed when the wet season commenced. At 8 weeks after planting (WAP), each plant was pruned to two most vigorous shoots from the stem cuttings. These shoots were maintained throughout the experiment period (Ndukwe *et al*., 2022).

Data collection and analysis

The growth data measurement commenced at 8 weeks after planting from the two most vigorous shoots. Thereafter, the growth data were collected at two weeks interval. Data were collected from each of the ten (10) plants representing the 10 replicates. Growth data collected from the bitter leaf plants included height of tallest branch (measured from the soil level to the point of attachment of the last leaf on the shoot obtained with a the aid of a flexible meter tape in centimeter), stem girth of the tallest branch (measured with the aid of a digital venier caliper at 10 cm above soil level), total number of leaves obtained from counting. Fresh leaves were harvested at monthly interval and weighed.

All the data collected was subjected to analysis of variance following the procedure laid out for factorial experiment in completely randomized design using GENSTAT (2007). Separation of means was done using least significance difference at 5% level of significance.

RESULTS

The interaction of organic manure types and rates significantly ($P<0.05$) influenced plant height at 8, 12, 16, 20 and 24 weeks after planting (WAP) (Table 2). Plants were tallest when poultry manure was applied at 10 t ha^{-1} specifically at 8, 12 and 16 WAP. At 20 WAP, the application of poultry manure at either 10 or15 t ha^{-1} significantly produced tallest plants. However, at 24 WAP, plants were tallest (66.5 cm) with the combined application of poultry manure and cow dung at 10 t ha^{-1} but the mean value was not significantly difference with the mean height (62.7 cm) obtained with 10 t ha^{-1} poultry manure application.

Table 2: Interaction effects of organic manure types and rates on plant height (cm) of bitter leaf

		Weeks after planting				
Organic manure types	Organic manure rates (t ha^{-1})	8	12	16	20	24
Cow dung (CD)	0	3.29	7.02	8.54	13.43	25.60
	5	3.16	9.56	15.66	26.42	43.10
	10	2.83	7.72	14.34	22.34	40.10
	15	4.02	6.65	16.29	27.26	56.60
PM + CD	0	3.29	7.02	8.54	13.43	25.60
	5	5.87	8.86	15.54	26.44	48.20
	10	3.93	9.41	19.48	34.04	66.50
	15	4.23	6.49	15.55	26.44	54.50
Poultry manure (PM)	0	3.29	7.02	8.54	13.43	25.60
	5	4.84	11.00	13.60	28.05	41.70
	10	8.15	20.31	24.28	39.71	62.70
	15	4.28	14.61	18.61	41.00	58.40
$LSD_{0.05}$		1.43	3.35	4.27	7.23	11.70

The total number of leaves of bitter leaf was significantly (P< 0.05) influenced by the interaction effects of organic manure types and rates at 8 and 16 WAP (Table 3). Highest number of leaves was produced by the application of poultry manure at 10 t ha^{-1}. Whereas at 16 WAP, the application of poultry manure at either 10 or 15 t ha^{-1} produced highest number of leaves. Although the mean number of leaves did not significantly (P>0.05) differ among the organic manure types and rates combinations at 24 WAP but highest mean values (55.5 and 75.3) were recorded with the application of poultry manure at 10 t ha^{-1}.

Table 3: Interaction effects of organic manure types and rates on total number of leaves of bitter leaf

		Weeks after planting				
Organic manure types	**Organic manure rates (t ha^{-1})**	**8**	**12**	**16**	**20**	**24**
Cow dung (CD)	0	16.30	20.40	12.10	22.8	29.3
	5	15.67	28.50	27.10	39.9	42.6
	10	17.75	27.22	26.08	38.0	45.0
	15	16.30	21.51	26.87	42.1	62.8
PM + CD	0	16.30	20.40	12.10	22.8	29.3
	5	17.49	21.80	22.20	35.2	48.9
	10	14.48	25.80	31.30	47.7	63.3
	15	14.77	20.75	21.85	37.4	72.6
Poultry manure (PM)	0	16.30	20.40	12.10	22.8	29.3
	5	16.30	23.84	18.26	31.8	50.2
	10	31.34	26.30	38.20	55.5	75.3
	15	21.28	27.08	42.01	51.1	69.0
$LSD_{0.05}$		5.83	ns	8.74	ns	ns

Highest fresh leaf yield of bitter leaf was obtained with the combined application of 10 t ha^{-1} poultry manure and cow dung (Fig. 1). However, the mean value (2.152 t ha^{-1}) was not significantly (P>0.05) different with the mean value (1.956 t ha^{-1}) obtained with the application of 10 t ha^{-1} poultry manure.

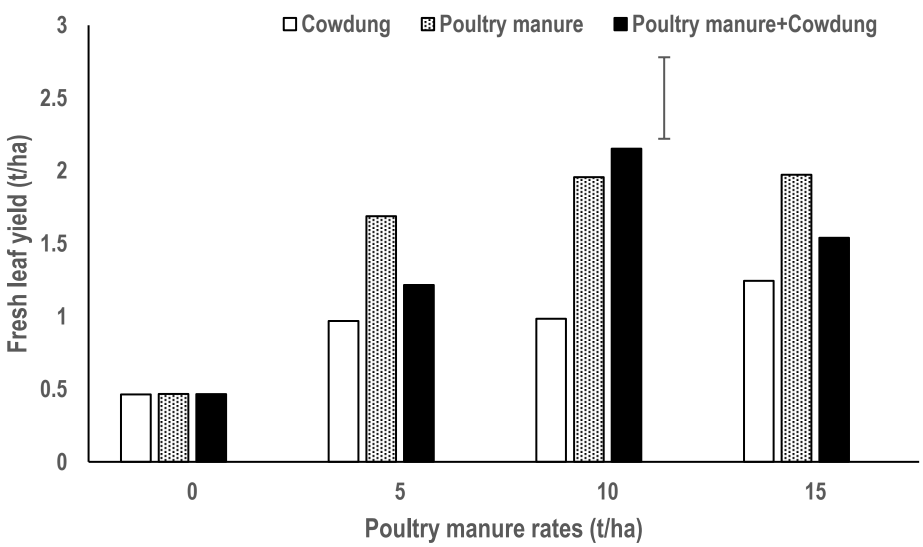

Fig. 1: Interaction of organic manure types and rates on fresh leaf yield (t ha^{-1}) of bitter leaf after 24 weeks of planting. Vertical bars represents $LSD_{0.05}$ = 0.56.

DISCUSSION

Results from the study had revealed that bitter leaf yield can be increased with the application of organic fertilizer at certain rates. The most vigorous plants (tallest plants, widest stems and highest number of leaves) observed in plots that received poultry manure at 10 t ha^{-1} affirmed that poultry manure is a veritable material in the production of the bitter leaf. The soil amendment must have improved the soil biophysical properties as was also noted in previous study (Adeyemo *et al*., 2019) that the application of poultry manure at 10 Mg/ha improved the organic matter, soil water infiltration as well as the biomass and cob yield of maize. The poultry manure might have released essential soil nutrients and conditioned the soil needed by the bitter leaf for optimum growth and leaf yield. The enhanced performance of the bitter leaf as a result of 10 t/ha poultry manure application could be attributed to the increased availability and subsequent accessibility of nutrients to the plants by the application of optimum rate of poultry manure. This is in agreement with the study of Ndubuaku *et al*. (2015) who reported that the application of 10 t/ha poultry manure to potted Moringa produced consistent increase in the plant height, number of leaves, and branches, stem length as well as number of pods, number of seeds, pod length and circumference. .

Poultry manure is perhaps the most desirable manures as it contains high amount of nitrogen (Delgado *et al*., 2010; Anjum *et al*., 2017). Evidently the poultry manure utilized in the study possessed higher amounts of organic carbon, nitrogen and calcium than the cow dung. Composted poultry manure has been reported to provide organic matter, nitrogen, phosphorus and other nutrients (Delgado *et al*., 2010; Oyedeji *et al*., 2014). It was also observed that increasing organic manure rate (up to 10 t ha^{-1}) increased the growth of the bitter leaf. This could have been caused by the increased mineral content as the manure decomposed and released more minerals with the increased rate of organic manure.

CONCLUSION

The application of poultry manure at 10 t ha^{-1} or combined application of poultry manure and cow dung at 10 t ha^{-1} produced most vigorous plants and highest leaf yield compared to organic manure sources and rates hence either 10 t ha^{-1} poultry manure or combined application of poultry manure and cow dung at 10 t ha^{-1} should be utilized for improved potted bitter leaf production especially by the urban dwellers who have limited space for field cultivation of crops. .

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Effect of Formulated Plant Extract and Cypermethrin on Growth and Yield of Cucumber (*Cucumis sativus* L)

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Plant extract.

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ABSTRACT

This study set out to evaluate the performance of formulated plant extracts such as insecticide and cypermethrin on the growth and yield of cucumber (Cucumis sativus L). The treatments Azadrachta indica, and Jatropha curcas leaves formulated as insecticides, Control (Unsprayed), and Cypermethrin (Synthetic insecticide) were applied in the control of insect pests of cucumber, and the characteristics studied included the Number of leaves, Number of defoliated leaves, Numbers of fruit/plot and Numbers of damaged fruit. A field experiment was conducted in the teaching and Research Farm of Oyo State College of Agriculture and Technology, Igboora during the planting season of 2023. The Experiment was laid in a Randomized Complete Block Design and replicated three times. 200ml of formulated plant extract mixed with 800ml of water while 1ml of synthetic insecticide mixed with 1000ml of water was sprayed using a hand sprayer in the early hours of the day and this was done every week throughout the study. Results showed that the number of leaves and the numbers of fruit/plot were significantly ($P < 0.05$) greater for plants sprayed with the formulated plant extracts and cypermethrin compared to the unsprayed plot. Thus it indicated the effectiveness of the plant extracts in controlling insect pests of cucumber, which significantly improve the growth and yield of the crop. It was observed that the application of J. curcas leaves formulated as insecticide exhibited insecticidal activity when compared to synthetic insecticide and unsprayed plots. However, the application of A. indica also improves the growth and yield of cucumber when compared to the synthetic and unsprayed plot but is not as effective as J. curcas. These findings suggest that the formulated plant extract can be used to enhance the growth and yield of cucumber as an alternative to synthetic insecticides in the study area.

INTRODUCTION

The cucumber (*Cucumis sativus* L.) is a well-known creeping vine plant from the Cucurbitaceae family. It produces cylindrical fruits that are widely used as culinary vegetables. Three main varieties of cucumber are grown, namely, slicing, pickling, and seedless, with several cultivars created within them. Although originating from South Asia, cucumbers now grow on most continents, with many different types traded on the global market. In North America, the term "wild cucumber" refers to plants in the genera Echinocystis and Marah, though the two are not closely related. Cucumbers are important vegetable crops and one of the most popular members of the Cucurbitaceae family. However, like other cucurbits, they are susceptible to damage by a wide array of insect pests from the initial stages of the crop to the harvest of the products. The extent of loss caused by these insect pests depends on the cucurbit species and environmental conditions, ranging from 20 to 100 percent (Raih *et al*., 2014). In the present scenario, a significant constraint in the sustainable production and productivity of cucurbits is mainly due to the attack of various insect pests which are responsible for adversely affecting the qualitative and qualitative yield. A wide range of pest complexes has been noticed infesting the cucumber. The melon fruit fly, red pumpkin beetle (*Aulacophora foveicollis* Lucas) Epilachna beetle (*Henosepilachna septima* Dieke), leaf roller, green semi looper, and white fly, etc. are the most destructive pests of cucurbits (Khan *et al*., 2012).

Bio-pesticide refers to all types of natural and beneficial pest control materials that notably contribute to reducing the pest population and increasing food production. (Prabha *et al*., 2016). They are safe and eco-friendly. They are more compatible with environmental components than synthetic pesticides. Thus in the present concept of green pesticides, some rational attempts have been made to include substances such as plant extracts, hormones, pheromones, and toxins of organic origin used to transform crops to express resistance to pests (Saxena. 1998).

Natural products are an excellent alternative to synthetic pesticides as a means to reduce negative impacts on human health and the environment. Many individuals and groups advocate the use of natural pesticides and insinuate that since they are found in nature, and are not synthetically produced, they are therefore safer to use. Therefore, green pesticides encompass both synthetic and natural products and processes that eliminate or repel pests but are benign, friendly, or harmless to the environment and ecosystem. (Thakore 2006). Therefore it is pertinent to evaluate the performance of selected plant extracts formulated as insecticides in the control of field insect pests of cucumber (*Cucumis sativus* L) as it affects the growth and yield of the crop.

MATERIALS AND METHODS

Experimental Site

The study was conducted at the Teaching and Research farm of Oyo State College of Agriculture and Technology in Igboora, Oyo State, Nigeria. Igboora is located between Latitude 7.42° North and 3.31° East (70 26’ 0’’N, 3 17’ 0’’E). The area experiences an average annual rainfall of 1278mm, with 80% of it occurring between August and September. In contrast, precipitation is low in January, with an average of 7mm. September is the wettest month, with an average rainfall of 175mm. The highest and lowest temperatures experienced in the area are 28°C and 21°C respectively. The average relative humidity of the area is 83%.

Land preparation

The land was cleared and ploughed manually by hoes and harrow and divided into 12 beds (4 treatments and replicated 3 times), the bed size used was 2 m by 2 m and treatments were randomly arranged using Randomized Complete Block Design (RCBD). Seeds were sown two seeds per hole at a distance of 0.75 m by 0.25 m. Thinning was carried out two weeks after planting while weeding was done as when due.

Procurement of seed and plant materials

The cucumber seeds used for the experiment were obtained from the National Centre for Genetic Resources and Biotechnology (NACGRAB) Moor Plantation Ibadan.

Formulations of Insecticides (Plant extracts)

The leaves of *Azadirachta indica* and *Jatropha curcas* were used to create plant pesticide formulations. To avoid chemical degradation, the selected plant parts were air-dried separately for two weeks at room temperature. Each dried plant part was then ground separately with a mortar and pestle into a powder with a volume of 700 g. This powder was mixed with 20g of black soap and 80g of salt. The resulting mixture was added to a 10-liter tank with 3000 ml of water and stirred vigorously with a rod. The mixture was then allowed to stay overnight. The mixture was filtered using a muslin cloth and the obtained filtrates were stored separately in a 5-liter plastic drum as a stock solution for later use. This botanical formulation method follows established procedures outlined by Alao *et al*. (2020).

Treatment application

A total of 1000 ml was measured from the stock solutions, and it was determined that the concentration of each botanical insecticide was 20% v/v. Further dilution was done by adding 800 ml of water to each botanical insecticide solution. In addition, 1 ml of the synthetic insecticide Cypermethrin was mixed with 1000 ml of water. For the plant extracts, they were applied at the concentration of 20% v/v, while for the synthetic insecticides, they were applied at the manufacturer's recommended rate of 1 ml/L. The application of treatments began three weeks after planting, and it was done in the early morning to avoid photodecomposition of the extracts. A hand-held sprayer was used to prevent drifting during application. Foliar application was carried out at 7-day intervals, and nine weekly observations were made. The applied treatments are Cypermethrin - 1 ml/L, *A. indica*, - 20 v/v, and *J. curcas.* - 20 v/v and Control.

Data collection

Each plot of cucumber had four plants that were tagged for data collection. The data collection on growth and yield parameters began three to four weeks after planting and focused only on the four tagged plants in the middle of each plot. The data collected included the number of leaves, the number of defoliated leaves, and the number of fruits and damaged pods per plot.

Data Analysis

All data collected on the growth and yield parameters were subjected to analysis of variance (ANOVA). The significance means were compared using the Duncan Multiple Range Test at a 5% probability level.

RESULT AND DISCUSSION.

Effect of Plants Extract Formulation and Synthetic Insecticides on Number of Leaves of Cucumber.

There were significant differences in the numbers of leaves both on the treated and the untreated plots of cucumber throughout observation Table 1. At week one after application of treatments (3WAT), the plot was treated with *A. Indica* leaves formulated as insecticides had the highest number of leaves while the untreated plot had the least number of leaves. The highest numbers of leaves were noticed on the plot treated with cypermethrin which was significantly higher when compared with the plots treated with plant extracts and the untreated plots which had similar counts of leaves (2WAT). At 3WAT, the untreated plot of cucumber had the highest count as regards to number of leaves while the lowest count was on the plot treated with *J. curcas*, similar observations were noticed at 4 and 5WAT.

The highest numbers of leaves were observed on the plot treated with cypermethrin at 6, 7, 8, and 9WAT which was significantly higher when compared with the untreated plot.

Table 1: Effect of Plants Extract Formulation and Synthetic Insecticides on Number of Leaves of Cucumber.

	Weeks after treatment								
Treatments	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
J. curcas	10.00c	14.00b	16.00d	18.00d	24.00d	30.00c	36.00b	36.00b	35.00b
A. Indica	12.00a	14.00b	18.00c	21.00c	27.00b	32.00b	35.00c	35.00c	35.00b
Cypermethrin	11.00b	15.00a	20.00b	23.00b	25.00c	33.00a	38.00a	38.00a	40.00a
Control	8.00d	14.00b	21.00a	25.00a	30.00a	32.00b	34.00d	34.00d	30.00d

Means with the same alphabet at $P \geq 0.05$ are not significantly different.

Effect of Plants Extract Formulation and Synthetic Insecticides on Number of Defoliated Leaves of Cucumber.

There were no significant differences in the numbers of defoliated leaves of cucumber at 1 and 2WAT both on the treated and the untreated plots Table 2. The number of defoliated leaves increased on the untreated plot as the weeks increased, significant differences were noticed in the numbers of defoliated leaves with the untreated plot exhibiting the highest numbers of defoliated leaves from 3 to 9WAT while the plot treated with *J. curcas* had the least numbers of defoliated leaves through the period of study.

Table 2: Effect of Plants Extract Formulation and Synthetic Insecticides on Number of Defoliated Leaves of Cucumber.

	Weeks after treatment								
Treatments	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
J. curcas	0.00a	0.00a	2.00a	2.00c	2.00c	2.00c	3.00c	3.00c	3.00c
A. Indica	0.00a	0.00a	1.00b	3.00b	3.00b	3.00b	4.00b	4.00b	4.00b
Cypermethrin	0.00a	0.00a	0.00c	1.00d	3.00b	3.00b	3.00c	4.00b	4.00b
Control	0.00a	0.00a	2.00a	4.00a	8.00a	10.00a	12.00a	12.00a	13.00a

Means with the same alphabet at $P \geq 0.05$ are not significantly different.

Effect of Plants Extract Formulation and Synthetic Insecticides on Number of Fruits of Cucumber.

The number of fruits of cucumber increases as the weeks under observation increases Table 5, also there were significant differences in the numbers of fruits of cucumber both on the treated and the untreated plot, however, there were no significant differences in the numbers of fruits produced on the treated and untreated plots at 1 and 2WAT. The plot is treated with *A. Indica* produced the highest numbers of fruits at 3WAT, while similar numbers of fruit counts were observed on plots treated with *J. curcas*, cypermethrin, and the untreated plot. The plot treated with cypermethrin had the highest numbers of fruits from 4 to 9WAT, while the lowest numbers of fruits were observed on the untreated plot throughout the study.

Table 3: Effect of Plants Extract Formulation and Synthetic Insecticides on Number of Fruits of Cucumber.

	Weeks after treatment								
Treatments	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
J. curcas	0.00a	0.00a	0.00b	1.00d	4.00d	7.00c	10.00c	10.00c	11.00c
A. Indica	0.00a	0.00a	1.00a	3.00b	6.00b	8.00b	12.00b	12.00b	12.00b
Cypermethrin	0.00a	0.00a	0.00b	4.00a	7.00a	10.00a	14.00a	15.00a	15.00a
Control	0.00a	0.00a	0.00b	2.00c	5.00c	5.00d	5.00d	6.00d	6.00d

Means with the same alphabet at $P \geq 0.05$ are not significantly different.

Effect of Plants Extract Formulation and Synthetic Insecticides on Number of Damaged Fruits of Cucumber.

There were significant differences in the numbers of damaged fruits of cucumber through the period under observation although there were no significant differences in the numbers of damaged fruits on the treated and untreated plots at 1, 2, 3, and 4WAT.

The highest numbers of damaged fruits were noticed on the untreated plot from 5 to 9WAT which is significantly higher than the plots treated with plant extracts and the plot treated with cypermethin however the plot treated with *J. curcas* had the least number of damaged fruits when compared to the plots treated with *A. Indica* and cypermethrin Table 4.

Table 4: Effect of Plants Extract Formulation and Synthetic Insecticides on Number of Damaged Fruits of Cucumber.

Treatments	Weeks after treatment								
	1	2	3	4	5	6	7	8	9
J. curcas	0.00a	0.00a	0.00a	0.00a	0.00b	1.00b	1.00b	1.00c	1.00c
A. Indica	0.00a	0.00a	0.00a	0.00a	0.00b	1.00b	1.00b	2.00b	2.00b
Cypermethrin	0.00a	0.00a	0.00a	0.00a	0.00b	0.00c	1.00b	1.00c	1.00c
Control	0.00a	0.00a	0.00a	0.00a	1.00a	2.00a	3.00a	3.00a	4.00a

Means with the same alphabet at $P \geq 0.05$ are not significantly different

CONCLUSION AND RECOMMENDATION

Botanical pesticides are an important group of naturally occurring, often slow-acting crop protectants that are usually safer to humans and the environment than conventional pesticides, and with minimal residual effects. It also contains mixtures of biologically active substances, no resistance is developed in pests and pathogens. The study also portaryed the effectiveness of plant extracts and the synthetic insecticides in controlling insect pests of cucumber which enhance its growth and yield however, the application of these formulated plant extracts performed effectively when compared with synthetic insecticides and is environmentally friendly.

It's therefore recommended to farmers that *Jatropha curcas* leaves formulated as insecticides be adopted as a means of controlling the insect pests of cucumber in the study area.

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SUB-THEME TWO

DIGITAL STRATEGIES FOR NATURAL RESOURCES AND ENVIRONMENTAL MANAGEMENT

Tree Species Diversity, Richness and Status in some Selected Market in Obi Local Government Area of Nasarawa State, Nigeria

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Diversity,
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ABSTRACT

The study was carried out to assess the abundances, richness, diversity and status of tree species across five markets vicinities in Obi Local Government Area of Nasarawa State Nigeria. The five markets randomly selected included Daddere, Obi, Tudun Adabu, Agyragu and Adudu markets with all selected tree species identified at species level and the number of individuals enumerated. The result revealed the presence of 196 trees species belonging to 10 families in 19 deferent tree species. Daddare market recorded the highest diversity index of 1.798, while Obi, Adudu, Agyeragu and Tudun Adabu markets was 1.573, 1.407, 1.340, and 1.214 respectively. The Gamma diversity value was 2.209 for the tree species with the tree species richness for the Gamma tree species highest for Margaleaf value (3.40), Daddare market (1.780), Obi (1.763), Adudu (1.698) while, TudunAdabu recorded Margaleaf value (1.365) and Agyeragu recorded the least value (1.202). The status of tree species is relatively stable with only few tree species endangered and Azahdracta indica was the only trees species found across all the markets. Consequently, the tree species diversity and richness were relatively low which can be improved by shops owners in the markets by planting at least a tree in their shop environ..

INTRODUCTION

Trees and forest resources play crucial roles in the lives of human populace through numerous benefits derived from the trees such as foods, shading, medicines, fodder, fibers and fuel wood, and other uses such as building constructions, fencing and furniture making (FAO, 2010). The abundance and status of tree species in a given location basically depend on climatic and edaphic factors such as sunlight, humidity, moistness, temperature, nature of canopy, nutrient availability, topography, land used history, characteristic of soil and bedrock geology (Saka *et al.*, 2018). Tropical forest has the highest degree of species richness compared to temperate land ecosystem on the earth surfaces which made it to be home to more than half of the total number of species globally and they are suffering from high level of deforestation and destructions due to industrialization, infrastructural development and agricultural expansion among others (Thomas and Baltzer, 2002: Abdullahi and Abba, 2021). The human population in Nigeria has increased resulting in increased exploitation of forest resources (Wakawa *et al*., 2018).

Trees species destruction can result to undermining the natural ecosystem and leading to environmental imbalance. Over one-tenth of known tree species of the earth are under threat (IUCN, 1994) with deforestation accounting for 5 to 15 percent of the world tree species between 1990 and 2020(UNDP, 2004). It is evidence that the diversity and density of tree species threatened by climate change, huge population pressure, deforestation, pest and diseases, drought, fires, acid rain among others (LEISA,2008). The diversity of trees is principal to add up to tropical woodland biodiversity, since trees give asset and environment for nearly all other timberland species (Cannon *et al.,*1998). Tree species diversity in tropical forest varies significantly from place to place mainly due to variety in biogeography, environment and unsettling influence (Whitmore, 1998).

Tree species diversity, richness and distribution are the most important characteristics of tropical rain forest ecosystem. Regardless of plot size, studies have shown that the number of tree species is far greater in tropical rain forest than in any other forest community (Adekunle, 2006), except in a situation where deforestation and encroachment have eaten deep into the forest reserves. In the recent years, forests have received priority in many multilateral agreements and global biodiversity conservation initiatives (IUCN, 2010; Swamy *et al*., 2010). Despite the numerous benefits and contributions of forest resources to human well-being, these resources have been subjected to varying degrees of anthropogenic disturbances for several centuries (Valentini *et al.*, 2014; Fischer *et al.*, 2016), which have led to substantial losses and degradation. Many communities and towns are located close to land natural resources and their central business areas known as market serve both the visitors and the residents which equally have the potentials of exploiting floral resources (Wolf, 2005). The vegetation of Obi local Government Area of Nasarawa State is not excepted from exploitation for various uses hence the need to investigate the tree species diversity, richness and status in some selected market in Obi communities in order to evaluate the status of forest trees stands and diversity.

MATERIAL AND METHOD

Study Area

The study was carried out in some selected community market in Obi Local Government Area of Nasarawa State Nigeria which has the total land area of 967km² with a human population of 148,874 reported during 2006 census. Obi town market is situated on longitude 008^{0}46’ 29.3” east and latitude 08^{0}21’ 50.7” north with altitude of 177m asl. Agyeragu market is located at longitude 008^{0}32’ 46.3”east and latitude 08^{0}24’ 53.1” north with altitude of 231masl.Daddaremarket is situated at longitude 008^{0}42’ 49.5”east and latitude 08^{0}26’26.1” north with altitude of 217m above sea level (asl). Adudumarket is located at longitude 009^{0}00’28.8”east and latitude 08^{0}17’33.2” north with altitude of 183m asl and TudunAdabu market which is the last and itis situated at longitude 008^{0}48’ 49.6”east and latitude 08^{0}25’ 20.4” north with altitude of 226m asl. It has a mean temperature range between 26^{0}C and 30^{0}C, mean rainfall of 1150mm to 1550mm, relative humidity of 60 – 80% and falls within the Guinea Savanna vegetation (Metrological Department, 2009).

Sampling techniques

The list of markets in Obi Local Government Area was used to select five markets randomly and includes Daddere, Obi, Tudun Adabu, Agyragu and Adudu markets in North Central Nigeria. A reconnaissance survey was carried out across the five selected markets in order to have an idea of the site conditions, to gather basic information on the accessibility, nature of the habitat among others.

Method of Data collection

A field data form was used to collect the data in each of the study market for all trees enumerated. Each of the tree species encountered were identified to species level and the number of individuals were counted and recorded as adopted by Soba *et al*., (2023). Only trees that are up to 6m in height were enumerated.

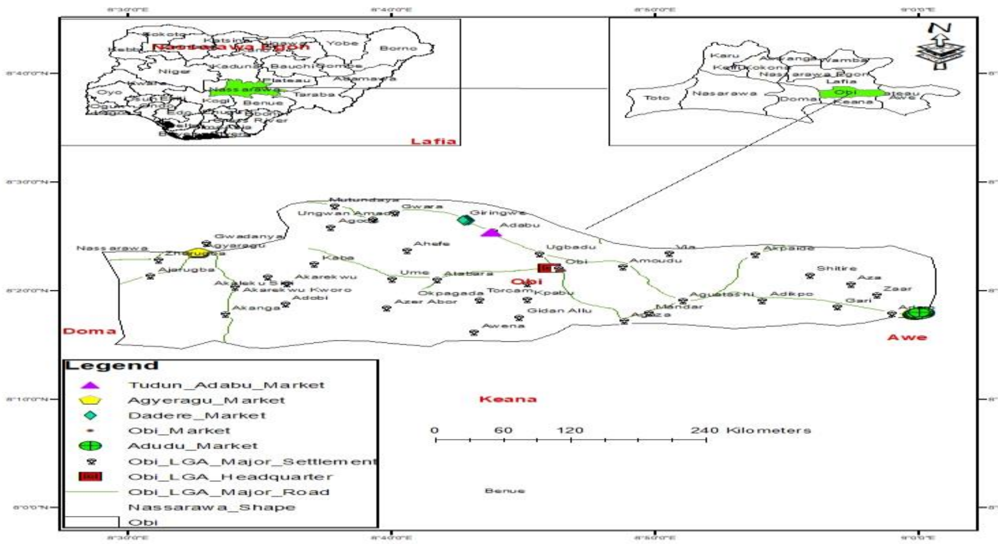

Figure 1: Map of Obi Local Government Showing the Market places

Data analyses

The diversity indices from each market place were used to determine the following trees species indices.

Shannon-Weiner diversity index (H)$= -\Sigma$ Pi In P......…………..............…………… 1

Where Pi = S / N, S = number of individuals of one species; N = total number of all individuals in the site and In = logarithm to base

Species richness index (d), were used as a simple measure of species richness according to Margalef (1958):$D = \frac{S-1}{lnN}$………………………………………………...……………………………...…2

Where S = total number of species; N = total number of individuals in the site and Ln = natural logarithm.

Relative Abundance of species (RA)

$RA = \frac{Number\ of\ individual\ Species}{Total\ Number\ of\ Trees}$……………………………………..…………….…………..3

Relative density of species (RD)

$RD = \frac{Number\ of\ Individual\ Species}{Total\ Number\ of\ Trees} \times 100$…..……........................……………………………4

The determination status of each tree species was conducted by classification based on the relative densities (RD) as adopted by Edet *et al*. (2011) and Adeyemi *et al*. (2015) as follows: Abundant = RD ≥ 5.00, Frequent = 4.00 ≤ RD ≤ 4.99, Occasional = 3.00 ≤ RD ≤ 3.99, Rare = 1.00 ≤ RD ≤ 2.99 and Threatened/Endangered = RD < 1.00.

RESULTS AND DISCUSSIONS

The result of families, number of species, species common name, species scientific name, species occurrences/frequency, relative abundance, relative density and status were presented in Tables 1, 2, and 3 while the result for tree species diversity and richness are presented in Table 4. The gamma results revealed a total of 19 trees species belonging to 10 families identified. The family *Moraceae* had the highest number of trees species (04) were; *Ficus religiosa*, *Ficus microcarpa*, *Ficus virens*, and *Ficus benjammna.* The second largest families were *Meliaceae* and *Malvaceae* with each having a total of three different species, these were; *Azahdracta indica*, *Cedrela odorata*, *Cipadessabaccifera*, and *Firmiana simplex*, *Bombax ceiba*, and *Ceiba speciosa*respectively. In the families of *Anacardiaceae* and *Bignoniaceae* two different species were identified.

Table1: Gamma Species of the Study Area

Family	No. Spp.	Common name	Scientific name	No. Occurrence	R.A	R.D(%)	Status
Moraceae	04	*Sacred fig*	*Ficus religiosa*	38	0.19	19.39	Abundant
		Chenese Bayan	*Ficus macrocarpa*	06	0.03	3.06	Occasional
		White fig	*Ficus virens*	02	0.01	1.02	Rare
		Weeping fig	*Ficus benjammna*	01	0.01	0.51	Threatened/ Endangered
Meliaceae	*03*	*Neem*	*Azahdracta indica*	24	0.12	12.24	Abundant
		Spanish cedar	*Cedrela odorata*	03	0.02	1.53	Rare
		Rana bili	*Cipadessabaccifera*	01	0.01	0.51	Threatened/ Endangered
Malvaceae	*03*	Chinese parasol	*Firmiana simplex*	04	0.02	2.04	Rare
		Red silk cotton	*Bombax ceiba*	01	0.01	0.51	Threatened/ Endangered
		Silk floss	*Ceiba speciosa*	01	0.01	0.51	Threatened/ Endangered
Anacardiaceae	*02*	Mango	*Mangifera indica*	48	0.24	24.49	Abundant
		Cashew nut	*Anacardium occidental*	09	0.05	4.59	Frequent
Bignoniaceae	02	Boundary tree	*Newbouldialeavis*	34	0.17	17.35	Abundant
		Pink trumpet	*Handroanthusimpetiginosus*	05	0.03	2.55	Rare
Combretaceae	01	Tropical almond	*Terminalia catappa*	01	0.01	0.51	Threatened/ Endangered
Euphorbiaceae	01	Sand box tree	*Hura crepitans*	02	0.01	1.02	Rare
Sapindaceae	01	Soap berry	*Sapindussaponaria*	10	0.05	5.10	Abundant
Burseraceae	01	Gumbo lumbo	*Bursera simaruba*	05	0.03	2.55	Rare
Laminaceae	*01*	Beechwood	*Gmelina arborea*	01	0.01	0.51	Threatened/ Endangered

They were *Mangifera indica* and *Anacardium occidental, and Newbouldialeavis* and *Handroanthusimpetiginosus* respectively. The families with least tree s species (one) for each were *Combretaceae* (*Terminalia catappa)*, *Euphorbiaceae* (*Hura crepitans*), *Sapindaceae* (*Sapindussaponaria*), *Burseraceae* (*Bursera simaruba*), and *Laminaceae (Gmelina arborea).* The result of status of trees species in the study area indicated that out of 19 species that were identified, only five (05) species were abundant, one (01) species was occasional, one (01) was frequent, six (06) species were rare, and six (06) were threaten or endanger. Soba *et al.*, (2023) reported higher number of families and trees species in in Lafia, which is the nearest local government from the study site. It is evidence from the result that many know indigenous trees species especially those of family Fabaceae that are basically found in the savannah region were not represented completely. The family *Moraceae* which is represented by the highest species could be attributed to its broad leave which provided total shading for the traders and external root formation for seating and displayed of product by the traders.

Table2: Alpha Species of Obi and DaddareMarkets

Family	No Spp	Common names	Scientific name	No. Occurrences	R.A	R.D(%)	Status
Moraceae	*02*	Weeping fig	*Ficus benjammna*	*01*	0.019	1.89	Rare
		Chinese banyan	*Ficus microcarpa*	*06*	0.11	11.32	*Abundant*
Anacardiaceae	*02*	Mango	*Mangifera indica*	*23*	0.43	43.39	*Abundant*
		Cashew nut	*Annacardium occidental*	*09*	0.17	16.98	*Abundant*
Meliaceae	*02*	Neem	*Azahdracta indica*	*10*	0.19	18.87	*Abundant*
		Rana bill	*Cipadessabaccifera*	*01*	0.02	1.89	*Rare*
Euphorbiaceae	*01*	Sandbox tree	*Hura crepitans*	*02*	0.04	3.77	*Occasional*
Combretaceae	*01*	Tropical almond	*Terminalia catappa*	*01*	0.02	1.89	*Rare*
Alpha Species		of	Daddare	Market			
Moraceae	02	Sacred fig	*Ficus religiosa*	10	0.19	19.61	Abundant
		White fig	*Ficus exasperata*	01	0.02	1.96	Rare
Malvaceae	02	Chinese parasol	*Firmiana simplex*	04	0.08	7.84	Abundant
		Silk floss	*Ceiba speciosa*	01	0.02	1.96	Rare
Anacardiaceae	01	Mango	*Mangifera indica*	16	0.31	31.37	Abundant
Meliaceae	01	Neem	*Azahdracta indica*	05	0.09	9.80	Abundant
Sapindaceae	01	Soap berry	*Sapindussaponaria*	09	0.18	17.65	Abundant
Burseraceae	01	Gambo limbo	*Bursera simaruba*	05	0.09	9.80	Abundant

The Alpha trees species in Obi market is presented as shown Table 2. It revealed a total of eight (08) tree species belonging to five (05) families identified. The family *Moraceae (*Ficus benjammna and Ficus macrocarpa), *Anacardiaceae (*Mangifera indica and Annacardium occidental) *and Meliaceae (Azahdracta indica* and *Cipadessabaccifera*)had the highest number of tree species (02).The families with least tree species (one) for each were *Combretaceae*(*Terminalia catappa), Euphorbiaceae* (*Hura crepitans*), The result of the status of tree species in Obi indicated that, out of 08 species that were identified, only four (04) species were abundant, one (01) species was occasional, and three (03) species were rare. Akosim*et al*., (2016), noted that the size of the sample can influence the level of precision in a given research. The presence of few trees species in Obi town showed that market traders does not spare trees life ,instead they prepared clearing them for shop construction. The number recorded is far below the report of Adeniji *et al.*, (2021) in his study in New Bussa were he reported 41 species in 18 families. Similarly, Abdullahi and Abba (2021) in Kumo reported 27 tree species in 12 families which is by far higher than the report of this study.

The Alpha trees species of Daddare market (Table 2) showed a total of 8 tree species belonging to 06 families identified. The family *Moraceae had two species Ficus religiosa*, and*Ficus* exasperate. The family *Malvaceae* had two, these were; *Firmiana simplex*and *Ceiba speciosa*. In the families of *Anacardiaceae (Mangifera indica) Meliaceae* (Azahdracta indica), *Sapindaceae* (*SapindusSaponaria*), and *Burseraceae* (*Burserasimaruba*). The result of the status of tree species in the study area indicated that, out of 08 species that were identified, six (06) species were abundant, and two (02) species were rare. The study is not in conformity to the finding of Abba (2014) who reported 25 tree species in 14 families Kanawa forest reserve. Similarly, the result is not in lined with the findings ofIkyaaba*et al* (2015)noted 52 trees species in 22 families in Uni-Agric Markurdi.Family that had two species were the highest in Daddare market which implies that anthropogenic activities in the form of markets has the potentials to declined tree species population especially the native base species as noted by Soba *et al.*, (2023).

Table3: Alpha Species of Adudu, Agyeragu and TudunAdabuMarkets

Family	No Spp	Common names	Scientific name	No. Occurrences	R.A	R.D (%)	Status
Moraceae	02	Sacred fig	*Ficus religiosa*	09	0.47	47.37	Abundant
		White fig	*Ficus exasperata*	01	0.05	5.26	Abundant
Meliaceae	01	Neem	*Azahdracta indica*	02	0.11	10.53	Abundant
Malvaceae	01	Red silk cotton	*Bombax ceiba*	01	0.053	5.26	Abundant
Lamiaceae	01	Beechwood	*Gmelina arborea*	01	0.053	5.26	Abundant
Anacardiaceae	01	Mango		05	0.26	26.32	Abundant
Alpha		Species of	Agyeragu	Market			
Bignoniaceae	02	Pink trumpet	*Handroanthusimpetiginosus*	05	0.08	7.81	Abundant
		Boundary tree	*Newbouldia leavy*	33	0.52	51.56	Abundant
Moraceae	01	Sacred fig	*Ficus religiosa*	15	0.23	23.44	Abundant
Meliaceae	01	Neem	*Azahdracta indica*	06	0.09	9.38	Abundant
Sapindaceae	01	Soap berries	*Sapindussaponaria*	01	0.02	1.56	Rare
Anacardiaceae	01	Mango	*Mangifera indica*	04	0.06	6.25	Abundant
Alpha	Specie	ofTudun	Adabu	Market			
Meliaceae	02	Spanish cedar	*Cedrela odorata*	03	0.33	33.33	Abundant
		Neem	*Azahdracta indica*	01	0.11	11.11	Abundant
Moraceae	01	Sacred fig	*Ficus religiosa*	04	0.44	44.44	Abundant
Bignoniaceae	01	Boundary tree	*Newbouldia leavy*	01	0.11	11.11	Abundant

The alpha tree species of Adudu market is shown (Table 3).Total of 06 tree species belonging to 05 families identified. The family *Moraceae had two species Ficus religiosa* and *Ficus* exasperate. The family of *Meliaceae* (*Azahdractaindica*), *Malvaceae* (*Bombaxceiba*), *Lamiaceae* (*Gmelina arborea*) and *Anacardiaceae* (*Mangifer aindica*).The result of status of trees species in the study area indicated that out of 06 species that were identified, all were abundant. The tree species of Agyeragu market is presented in (Table 3). Six (06) trees species belonging to 05 families were identified. The family *Bignoniaceae had two species Handroanthusimpetiginosus* and *Newbouldia leavy*. The family of *Meliaceae* (*Azahdracta indica*), *Moraceae* (*Ficusreligiosa*), *Sapindaceae* (*Sapindussaponaria*) and *Anacardiaceae* (*Mangifera indica*). The result of the status of tree species in the study area indicated that, out of 06 species that were identified, five were abundant with one rare. The alpha trees species of Tudun-Adabu market revealed a total of 04 tree species belonging to 03 families identified. The family *Meliaceae* had two species *Cedrela* odorata and *Azahdracta indica.* The family of *Moraceae* (*Ficusreligiosa*), and *Bignoniaceae* (*Newbouldia leavy*). The result of the status of tree species in the study area indicated that, out of 04 species that were identified, all of them were abundant. The result of this study was contrary to finding of Shuaibu (2015) study of trees status and diversity in different forest of Idah in Kogi State where report almost the same trees species number and diversity across different forest of the same local government area. The differences observed in regards to number of tree species between these market places could be attributed the difference in infrastructural development, this is so because structural development always comes with a lot of unfavorable impacts on the forest trees species.

Table 4: Shannon-Weiner index (H) and Margalef species richness index (D)

Location	**H'**	**D**	**No. Family**	**No. Species**	**Total Observation**
Gamma Species of the study area	2.21	3.41	10	19	196
Obi Market	1.57	1.76	05	08	53
Daddare Market	1.79	1.78	06	08	51
Adudu Market	1.41	1.69	05	06	19
Agyeragu Market	1.34	1.20	05	06	64
TudunAdabu Market	1.21	1.37	03	04	9

The results of the species diversity and richness in selected markets is shown in Table 4. The species diversity indices (H') computed were; total site = 2.21, Obi Market =1.57, Daddare Market =1.79, Adudu market =1.41, Agyeragu Market = 1.34 and TudunAdabu Market 1.21. The results indicated that total site has higher tree species diversity, which was followed by Obi, Daddare and other communities with slightly variation. The 2.21 diversity value could be attributed to the increased in sample size as reported by Akosim*et al.*, (2016). The result indicated low species diversity value compared to the report of Soba *et al*., (2023) on ecological assessment of trees species diversity, richness and status in Shabu- Lafia Nasarawa State suggesting that marketers and traders careless in terms of trees conservation. Similarly, Abdullahi and Abba (2021), reported higher diversity values in a study of floristic composition and diversity of trees species in Kumo town and its environs.

CONCLUSION AND RECOMMENDATIONS

It can be concluded that the market places of Obi Local government area are dominated with trees species of family *Moraceae*, *Meliaceae,* and*Malvaceae.* Among the 19 tree species recorded *Azahdracta indica* was the only trees species that cut across all the markets and found in abundance. The trees species diversity and richness values were relative low compared to other studies conducted within the same agro-ecological zone. The finding of this investigation recommends that policies should be made to make its mandatory for all the traders in markets places of Obi Local Government to plant at least a trees species within a particular market environ to help in promoting afforestation .

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Social and Environmental Impact Assessment of Bodija Plank Market, Southwest Nigeria

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ABSTRACT

This study investigated the social and environmental impact of Bodija plank market on the immediate environment. The study area comprises nine (9) zones; five (5) zones were selected randomly, and ten (10) respondents were selected randomly in each zone, making a total of fifty (50) respondents for the study. A well-structured questionnaire was administered for primary data collection from the respondents. Secondary data were obtained from existing literature. 90.0% of the respondents were male and were within the age bracket of 41-50 years (50.0%). 76.0% of the respondents were married, were of Yoruba origin (96.0%), and earned between ₦10,000 and ₦60,000 monthly (58.0%). 42.0% had secondary education, and 44.0% had been in the business for 6-10 years. Most of the respondents (70.0%) agreed that the forest and wildlife resources of the study area were rich in its early days, while 60.0% stated the presence of rare/endangered species peculiar to the area during that time. Additionally, 76.0% stated that deforestation activities occurred during the process of plank market establishment, and 72.0% noted the absence of Environmental Impact Assessment before establishing the study area. 60.0% of the respondents agreed that the mill has positive impacts on community development, while 64.0% disagreed that the mill's establishment negatively impacts community development. The study identified continued sourcing for raw materials, loss of biodiversity, noise pollution, atmospheric pollution, water pollution, soil pollution, and improper waste disposal as the major negative impacts of the study area and highlighted different mitigation measures for the negative impacts identified.

INTRODUCTION

The forestry sector contributes significantly to the Nigerian economy (Idumah *et al*., 2016; Idumah and Awe, 2017; Ibrahim *et al*., 2020). According to Uzuegbu (2022), forestry sector amassed about ₦52.02 billion in the fourth quarter of 2021, a 10.6% increase from the third quarter of 2021. Forest ecosystem provides ecosystem services for man in the form of provision (e.g., fuel wood, food, and genetic resources), regulation (e.g. seed dispersal, water purification and climate regulation), support (e.g. primary production, nutrient cycling, and water cycling), and cultural (e.g. spiritual values, recreation, and aesthetic values) (Millenium Ecosystem Assessment (MEA, 2005).

The rapid pace of urbanisation and economic development in Nigeria has led to significant transformations in its socioeconomic landscape, accompanied by positive developments and substantial environmental challenges (Jiboye and Ogunshakin, 2011; Abubakar and Dano, 2018). Among the urban spaces grappling with the complexities of development and sustainability is the Bodija plank market. Bodija plank market serves as a vital economic hub where timber merchants and sawn-wood marketers engage in trade activities, and it plays a significant role in generating income and enhancing the livelihoods of several groups of people (Ajewole and Fasoro, 2013).

Establishing plank markets involves activities that directly and indirectly impact the workers, residents, and immediate environment. These impacts are usually social or environmental (Azeez *et al*., 2022). The social impact could be in the form of employment generation, livelihood improvement, and improved infrastructure, among others, while the environmental impacts could be in the form of air pollution, noise pollution, and improper waste disposal. Environmental and Social Impact Assessment plays a crucial role in sustainable development by identifying impacts, informing decision-making, promoting stakeholder engagement, and ensuring the integration of environmental and social considerations of a project (Barasa, 2017; Ulibarri *et al*., 2019).

Several studies have been conducted in Bodija plank market. For instance, Ajewole and Fasoro (2013) assessed the market and marketing information, Aremu *et al*. (2015) assessed the socioeconomic characteristics of the market, Oladejo *et al*. (2020) studied the effect of air pollution from pedestrian traffic in the market and Bolarinwa (2018) and Sridhar and Omokhodion (2017) studied the noise level in the market. However, there is a dearth of information on the social and environmental impact of the market on the immediate environment, especially individuals who are directly involved in marketing activities. The necessity to assess the Social and Environmental Impact Assessment (SEIA) of Bodija plank market arises from recognising its multifaceted interactions with the human and natural environments. As urbanisation intensifies and demand for timber products escalates, the market's operations significantly stress local ecosystems, socio-cultural dynamics, and economic structures. Therefore, this study assessed the social and environmental impact of Bodija plank market to proffer sustainable mitigation measures for the identified impacts.

MATERIALS AND METHODS

Study Area

The study was conducted in Bodija plank market (established in 1970) in Ibadan North Local Government Area of Oyo State. It is geographically situated on Longitude $3^0$54'56" E and $3^0$55'12" E and Latitude $7^0$26'2" N and $7^0$26'16" N (Figure 1) and covers about 0.12 km^2 of land (Ajewole and Fasoro, 2013). It is divided into nine zones, with 144 sheds in each zone (Aremu *et al*., 2015). Ibadan has an average rainfall of about 1150-1250 mm with two notable seasons (wet and dry), an average daily temperature of about 25-35℃ and relative humidity of about 25% almost throughout the year (Aremu *et al*., 2015; Ugege *et al*., 2020; Salami *et al*., 2021).

Data Collection and Analysis

Primary data were collected using a structured questionnaire administered to plank marketers in Bodija plank market. Five (5) zones were selected randomly out of the nine (9) zones that make up the area (Ajewole and Fasoro, 2013), ten (10) respondents were randomly selected in each zone. Thus, fifty questionnaires were administered. Secondary data were obtained from existing literature, such as peer-reviewed articles and reports. Data were analysed and summarised using descriptive statistics (percentages and charts).

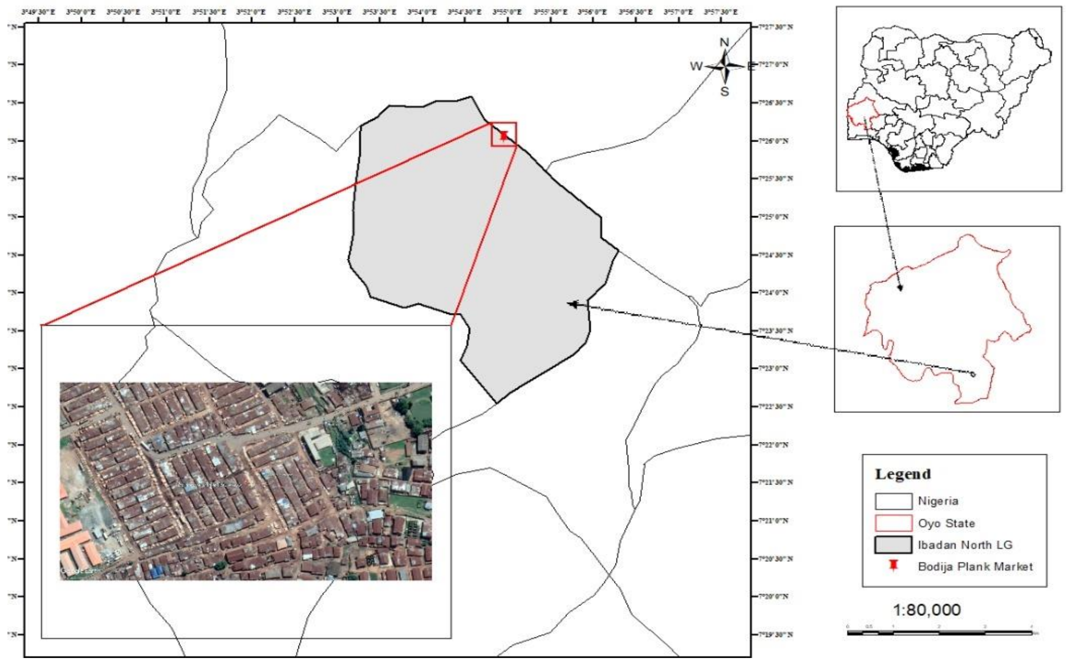

Figure 1: Map of Bodija plank market (inset: map of Nigeria and map of Oyo State)

RESULTS AND DISCUSSION

Socioeconomic Characteristics of the Respondents

The socioeconomic characteristics of the respondents are presented in Table 1. Majority (90.0%) of the respondents were male, while just 10.0% were female. Most of the respondents (50.0%) were within the age bracket 41-50 years, 22.0% were within 31-40 years, 20.0% were within 20-30 years, while age bracket <20 and >50 years accounted for 4.0% each of the respondents. 76.0% of the respondents were married, while 14.0% were single, and 6.0% and 4.0% were widowed and divorced, respectively. The dominant religion was Islam, which accounted for 56.0% of the respondents. 36.0% practise Christianity, 6.0% practise African Traditional Religion (ATR), and 2.0% practise other religion(s). As for the household sizes of the respondents, 1-3 persons, 4- 6 persons, 7-9 persons and > 9 persons recorded 24.0%, 20.0%, 38.0% and 18.0% respectively. 96.0% were Yorubas, while just 4.0% were Igbos. Furthermore, 18.0% of the respondents had no formal education, 36.0% had primary school education, 42.0% had secondary education,and 4.0% studied up to the tertiary level. Also, 20.0% of the respondents have been in the sawing business for 1-5 years, 44.0% for 6-10 years, 24.0% for 11-20 years, and 12.0% of them have been in the business for over 20 years.

Table 1: Socioeconomic characteristics of respondents at Bodija plank market

Demographic Characteristics	Frequency (n=50)	Percentage (%)
Sex		
Male	45	90.0
Female	5	10.0
Age		
<20 years	2	4.0
20 – 30 years	10	20.0
31 – 40 years	11	22.0
41 – 50 years	25	50.0
> 50 years	2	4.0
Marital Status		
Single	7	14.0
Married	38	76.0
Widowed	3	6.0
Divorced	2	4.0
Religion		
Islam	28	56.0
Christianity	18	36.0
ATR	3	6.0
Others	1	2.0
Household Size		
1-3 persons	12	24.0
4-6 persons	10	20.0
7-9 persons	19	38.0
> 9	9	18.0
Mother Tongue		
Yoruba	48	96.0
Igbo	2	4.0
Level of		
Education	9	18.0
No formal	18	36.0
education	21	42.0
Primary education	2	4.0
Secondary		
education	10	20.0
Tertiary education	22	44.0
Number of Years	12	24.0
in the Business	6	12.0
1-5		
6-10		
11-20		
>20		

Respondents response on Background Information of the study area

The respondents were asked to react to some statements to ascertain the study area's previous state before the plank market's establishment (Table 2). 70.0% of the respondents agreed that the forest resources of the study area were rich in its early days, while 30.0% were undecided. 70.0% and 30.0% agreed and were undecided respectively that the study area's wildlife resources were rich in its early days. When asked if rare/endangered species were peculiar to the area in its early days, 60.0% agreed, while 40.0% were undecided. 56.0% agreed that the area's climate before the sawmill establishment was normal, while 44.0% were undecided. 10.0% disagreed, 44.0% agreed, and 46.0% were undecided on if the nature of water bodies before plank market establishment was undisturbed. 76.0% and 24.0% agreed and were undecided that deforestation occurred during the plank market establishment. The respondents were asked the types of animals and tree speciesfound in this area before its establishment. The animals mentioned were monkeys, giant rats, cane rats, snakes, and squirrels while the tree species were *Ficus exasperata*, *Terminalia ivorensis*, *Accacia* spp, *Ceiba pentandra*, *Treculia africana*, *Parkia biglobosa*, *Daniella oliveri*, *Vitellaria paradoxa* and *Azadirachta indica*.

Table 2: Response of respondents to some background statements regarding Bodija plank market

Statements	D (%)	UN (%)	A (%)
Forest resources of this community were rich in its early days	0(0.0)	15(30.0)	35(70.0)
Wildlife resources of this community were rich in its early days	0(0.0)	15(30.0)	35(70.0)
There were rare/endangered species peculiar to this area in its early days	0(0.0)	20(40.0)	30(60.0)
Climate nature of the area before the sawmill establishment is normal	0(0.0)	22(44.0)	28(56.0)
Nature of water bodies before sawmill establishment is undisturbed	5(10.0)	23(46.0)	22(44.0)
Deforestation activities took place in the process of sawmill establishment	0(0.0)	12(24.0)	38(76.0)

Note: D = Disagree; UN = Undecided; A = Agreed

Positive Impacts Identified

Employment Creation and Income Generation

The presence of the plank market in Bodija has generated a source of employment for hundreds of individuals directly or indirectly. The running of a plank market requires labour, usually provided by individuals living within the town. The buying and selling activities of plank and wood wastes have become a source of income for many. According to Alawode and Jimoh (2021), 58% of the respondents reported monthly earnings ranging from ₦10,000 to ₦60,000. Additionally, 31% indicated earnings between ₦60,001 and ₦110,000, while 7% reported incomes falling between ₦110,001 and ₦160,000. Only 4% of all respondents reported earnings above ₦160,000 monthly. The lowest monthly income recorded from sawn wood sales was ₦10,000, while some participants earned as much as ₦300,000, with the average income calculated at ₦69,830.

Socioeconomic Development

The plank market has paved the way for improved infrastructural development around Bodija area. Electricity, road network, schools, health centres and other infrastructures have improved. Olatunji *et al*. (2021) identified Bodija as one of the localities with the most facilities in Ibadan metropolis. Respondents' perception of the socioeconomic impact of the area is shown in Figure 2.

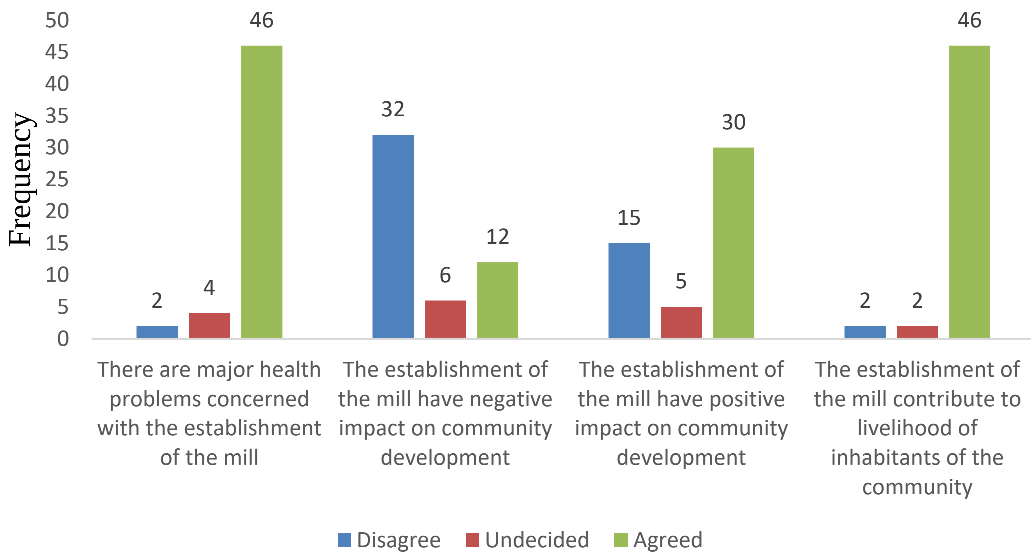

Figure 2: Respondents perception on the socioeconomic impacts of the market on the community

Provision of Market for Supply of Building Materials

The presence of Bodija plank market has made it possible to regularly supply large quantities of logs sourced locally within Ibadan metropolis. It is one of the biggest plank markets in Southwestern Nigeria. Aremu *et al*. (2015) noted that African teak (Milicia excelsa) is the major sawn wood sold in Bodija market. This was followed by white Afara (Terminalia superba). This implies that Bodija market is a complete sawn wood market where sawn wood buyers can get different types of sawn wood of several species they may want.

Livelihood Improvement

The presence of the plank mark*et al*lows for the improvement of the livelihoods of those generating income. A regular source of income helps them to have a better life. 24.0% of the respondents in this study had a household size of 1-3 persons, 20.0% had 4-6 persons, 38.0% had 7-9 persons, and 18.0% had above nine (9) persons. This implies that the business activities at Bodija plank market serve as an essential means of meeting family needs. This result conforms with the observation of Sekumade and Oluwatayo (2011), who noted that the wood-based industries have contributed to the economy of Nigeria and, by extension, the livelihood of many people.

Negative Impacts Identified

Continued Source of Raw Materials

The presence of the plank market implies the continuous exploitation of the forests within and outside Oyo State. The indiscriminate removal of trees from the environment has catastrophic consequences. The findings of Aremu *et al*. (2015) revealed that the six southwestern states of Nigeria are the major wood sources. This may be because of the abundance of rainfall and heavy forests throughout the year in all six states.

Loss of Biodiversity

Flora and fauna were lost during the study area's establishment. The existence of a plank market will automatically threaten the existence of many tree species. The respondents confirmed that deforestation occurred when the area was to be established and noted the presence of some flora and fauna species before establishing the area (Table 2). The results highlight significant environmental concerns associated with urban development and commercial activities. Several authors have mentioned that urban development is usually at the expense of environmental well-being (Antharvedi, 2007; Matlock and Lipsman, 2020; Tyagi *et al*., 2023).

Noise Pollution

The running of heavy machines and generators generates noise, which constitutes noise pollution. Sridhar and Omokhodion (2017) examined the noise levels in markets situated in Ibadan. They found that the plank section of Bodija market (the study area), the largest market in the city, exhibited the highest noise levels recorded at 88.13 dB. Additionally, the study noted that these noise levels surpassed the acceptable limits. The respondent's perception of the noise level in the study area is shown in Figure 3. All the respondents agreed that the plank market establishment contributes to the environment's internal and external noise levels. The majority also agreed that vibrations from the mill affect humans in the environment and disagreed that the noise from the sawmill is pleasing to the ear.

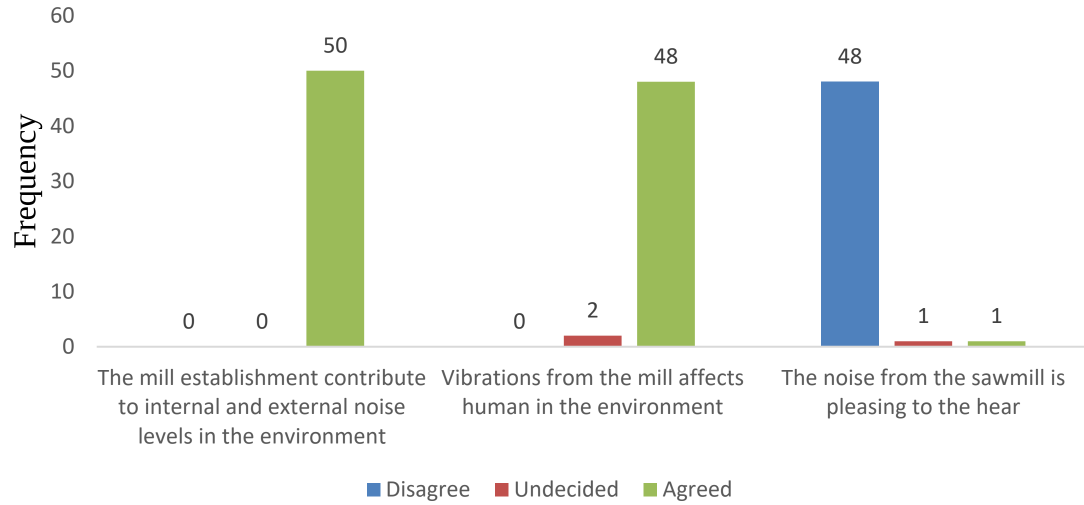

Figure 3: Respondents perception on the noise level in the study area

Atmospheric Pollution

The release of harmful gases like carbon monoxide from machinery exhaust contributes to air pollution, leading to a decline in air quality in the vicinity. According to a study by Oladejo *et al*. (2020) on air quality in Bodija, variations in PM2.5 levels between dry and wet seasons were noted. During the dry season, PM2.5 concentrations exceeded World Health Organization (WHO) and National Ambient Air Quality Standards (NAAQS) standards, ranging from 47.9μg/m^3 to 231.88μg/m^3 in the morning and 65.17μg/m^3 to 1806.33μg/m^3 in the afternoon. Elevated PM2.5 levels observed in the market area adversely affect the health of workers and pedestrians, causing symptoms like sneezing, eye and throat irritation, headaches, and potential internal organ damage from prolonged exposure. Figure 4 illustrates respondents' perceptions of atmospheric pollution.

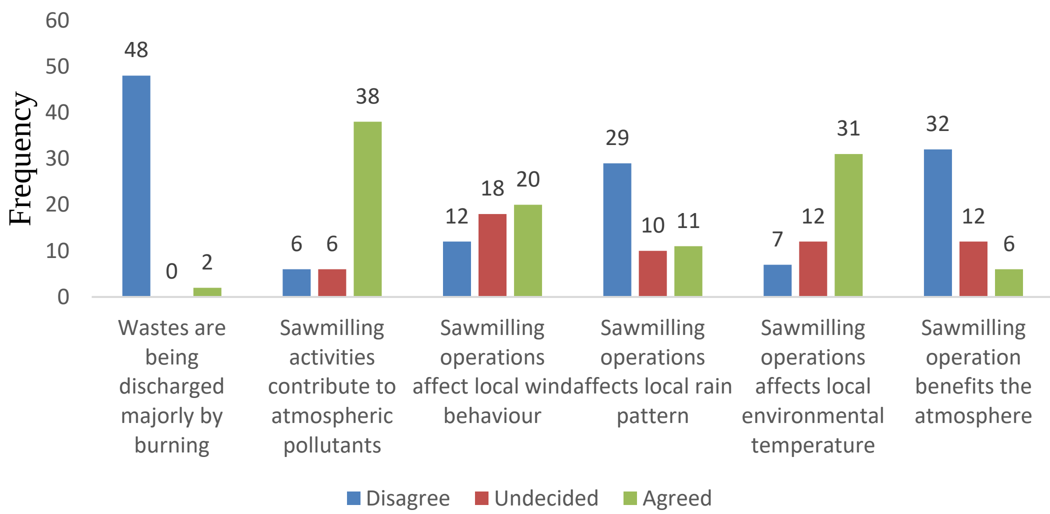

Figure 4: Respondents' perception of atmospheric pollution in the study area

Water Pollution

In the study area, liquid and solid waste are being disposed into nearby water channels. Figure 5 shows the respondents' perception of water pollution in the study area. The majority agreed that wastes are being discharged into water bodies, the structure and its operation affect the quality and quantity of water bodies, and the structure and operation affect the existing water surface. In contrast, the majority disagreed that structure and operation contribute positively to water bodies. This shows significant environmental concerns and potential health hazards for the community and ecosystem. Respondents' perception underscores a general awareness of the adverse effects of waste disposal on water quality and quantity. Such pollution can lead to the contamination of water sources, affecting aquatic life and endangering the health of individuals who rely on these resources for drinking, cooking, and other daily activities (Pandey, 2006; Bashir *et al*., 2020).

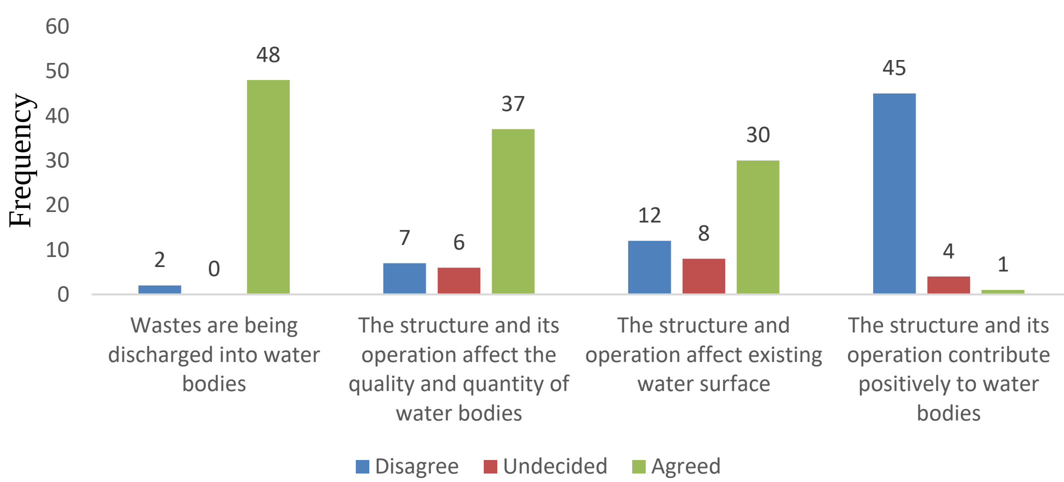

Figure 5: Respondents' perception of water pollution in the study area

Soil Pollution

The infiltration of heavy chemicals from machinery into the soil constitutes a significant source of soil pollution in the study area. The respondents' view on soil impact in the study area is shown in Figure 6. The findings highlight the urgent need for effective soil management practices to mitigate pollution and safeguard environmental and human health. Soil pollution can have far-reaching consequences, including contamination of groundwater resources and adverse effects on biodiversity (Gupta *et al*., 2019). Most respondents' recognition of soil pollution highlights the importance of integrating environmental education and awareness campaigns into local initiatives to promote sustainable development. Empowering community members with knowledge about the sources and impacts of soil pollution can foster a sense of responsibility and encourage participation in efforts to address environmental challenges. Contaminated soil risks public health by accumulating toxins in food crops and residents' potential exposure to harmful substances (Okoronkwo *et al*., 2011).

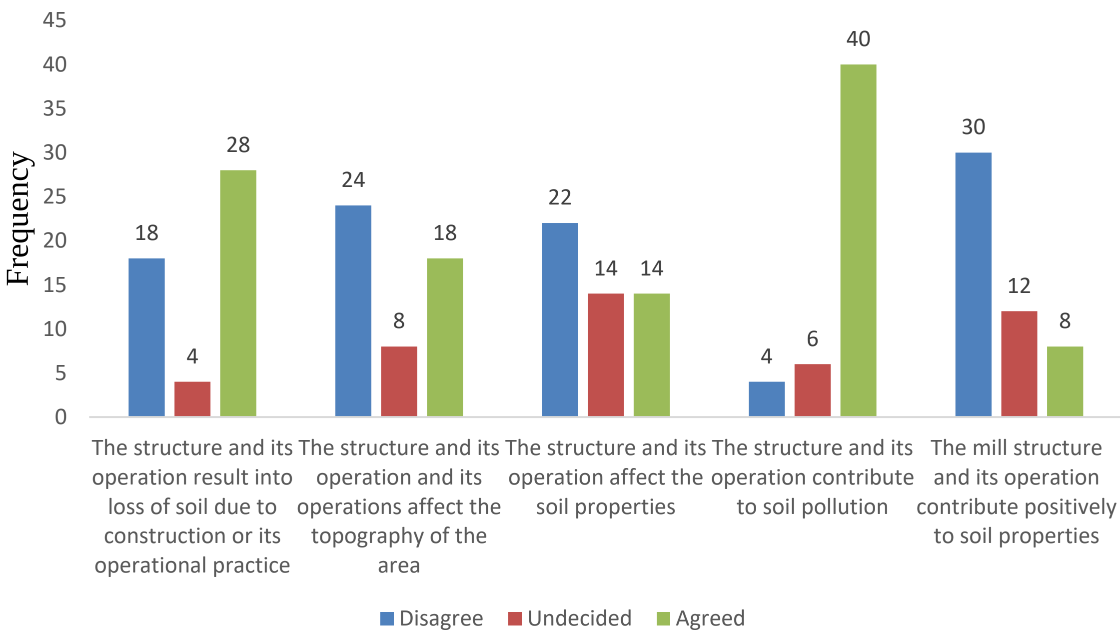

Figure 6: Respondents' perception of soil impacts in the study area

Improper Waste Disposal

Solid and liquid wastes are not properly disposed of in the study area. However, there have been improvements in the method of waste disposal. In the past, sawdust used to be burnt, which constituted severe atmospheric pollution. A nearby primary school petitioned the Oyo State Ministry of Environment, eventually banning the study area from burning sawdust. Sawdust is now being sold, but some are still disposed of improperly. Improper disposal pollutes water sources and contributes to soil contamination and the proliferation of disease vectors (Pedley and Howard, 1997). A report by the World Health Organization (WHO, 2018) highlights the adverse effects of improper waste management on public health, citing increased risks of waterborne diseases, respiratory ailments, and exposure to hazardous chemicals. The accumulation of organic and inorganic waste materials in the market area degrades environmental quality and poses occupational hazards to market vendors and residents.

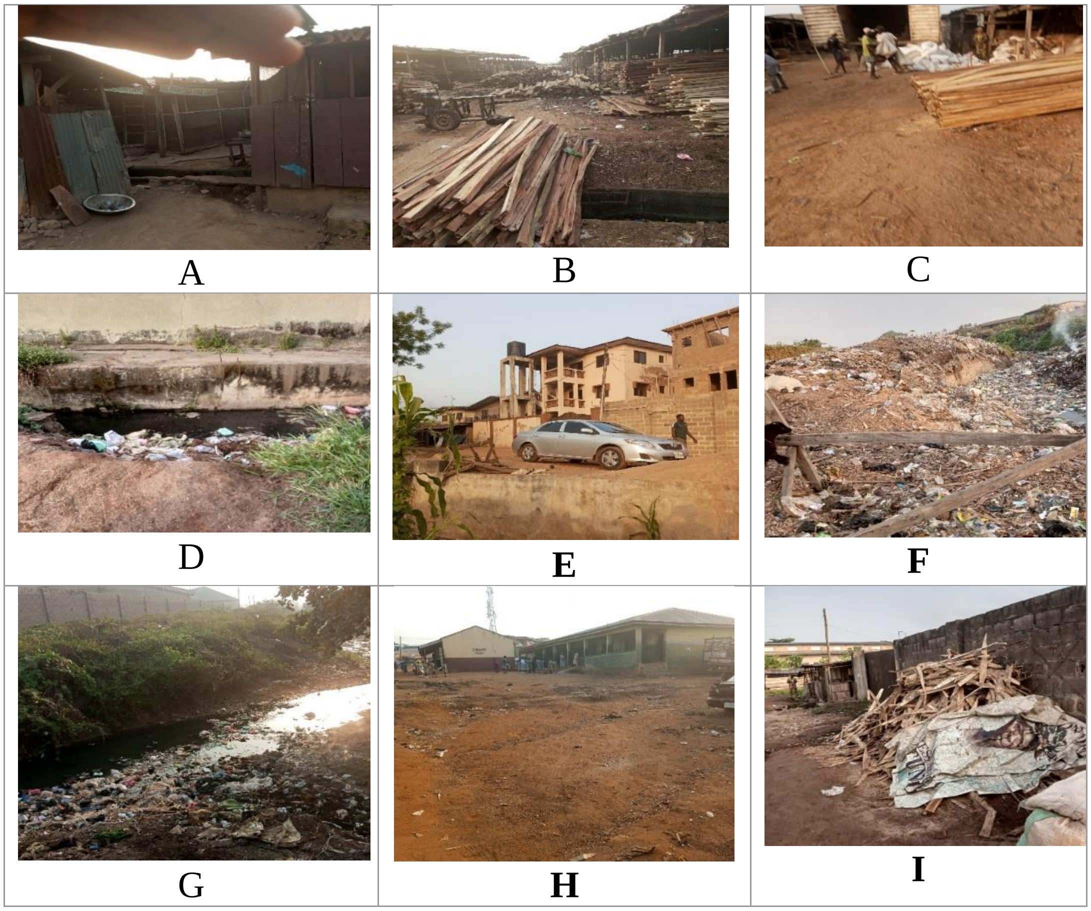

Plate 1: A – a food canteen at Bodija plank market; B – planks of different dimensions at Bodija plank market; C – bagged sawdust for sale/disposal at Bodija plank market; D - stagnant and contaminated water at Bodija plank market; E – residential buildings close to Bodija plank market; F – improper waste disposal at Bodija plank market; G – a contaminated water channel near Bodija plank market; H – a primary/basic school near Bodija plank market; I – wood offcuts for sale/disposal at Bodija plank market.

Mitigation Measures to the Negative Impacts

Mitigative measures refer to the strategic process of identifying, assessing, and addressing the negative effects of a project, activity, or development on social and environmental aspects (Marshal, 2001). In other words, mitigative measures are essential to sustainable development, emphasising the need to balance economic growth, social equity, and environmental conservation (Sathaye *et al*., 2007). In the Bodija plank market context, mitigative measures aim to preserve the community's well-being while safeguarding the environment against detrimental effects from plank market operations. The following mitigation measures for the identified negative impacts are thus provided:

Continued Source of Raw Materials

The impacts of continued source of raw materials associated with Bodija plank market can be mitigated in the following ways:

- Promoting sustainable forestry practices and responsible sourcing of timber is paramount.
- Implementing strict regulations and monitoring mechanisms to ensure that timber comes from sustainably managed forests can help reduce the market's ecological footprint.

- Encouraging the adoption of alternative materials such as bamboo or recycled wood products can diversify sourcing options and lessen dependence on traditional timber.
- Investing in community-based forestry initiatives and agroforestry programmes can provide alternative livelihoods while conserving forest resources.

Loss of Biodiversity

The impacts of biodiversity loss associated with Bodija plank market can be mitigated in the following ways:

- Promoting habitat conservation and restoration efforts in collaboration with local communities and conservation organisations to help restore degraded areas and create wildlife corridors.
- Implementing strict regulations against illegal logging and unsustainable harvesting practices is crucial to prevent further habitat destruction.
- Encouraging the use of certified sustainable timber and promoting the adoption of alternative materials can reduce pressure on natural habitats.
- Raising awareness among market stakeholders about the importance of biodiversity conservation and their role in preserving ecosystems is essential.

Noise Pollution

To mitigate the effects of noise pollution in Bodija plank market, the following strategies can be implemented:

- Installing sound barriers or acoustic panels around the market perimeter can help contain noise within the premises and minimise its propagation to surrounding areas.
- Implementing regulations restricting noisy activities during certain hours or designing specific zones for loud machinery can help mitigate noise disturbances.
- Investing in noise-reducing technologies for machinery and equipment used within the market can significantly lower overall noise levels.
- Encouraging traders to use quieter equipment and providing incentives for adopting noise mitigation measures can promote voluntary compliance.
- Raising awareness among market stakeholders about the harmful effects of noise pollution and the importance of sound management practices is essential.
- Establishing a mechanism for regular monitoring and enforcement of noise regulations can ensure compliance and effectiveness of mitigation measures.

Atmospheric Pollution

The effects of atmospheric pollution in Bodija plank market can be mitigated in the following ways:

- Implementing emission control technologies on machinery such as particulate filters and catalytic converters can significantly reduce pollutant emissions.
- Promoting cleaner-burning fuels or alternative energy sources, such as natural gas or solar power, for powering machinery and equipment can further mitigate atmospheric pollution.
- Enforcing regulations to limit the use of high-polluting equipment and incentivising adoption of environmentally friendly practices can also contribute to pollution reduction efforts.
- Conducting regular maintenance and tuning of machinery to optimise performance and minimise emissions is essential.
- Implementing monitoring systems to track air quality levels within and around the market can provide valuable data for assessing mitigation measures' effectiveness and identifying improvement areas.

- Educating market stakeholders about the health impacts of atmospheric pollution and the importance of pollution control measures is crucial for fostering a culture of environmental responsibility.
- Engaging with local authorities and environmental agencies to develop and enforce air quality standards can ensure compliance and accountability.

Water Pollution

To mitigate the effects of water pollution in Bodija plank market, the following strategies can be adopted:

- Implementing proper waste management practices within the market can help capture pollutants before they enter waterways.
- Enforcing regulations to prevent the direct disposal of waste materials into drains or water bodies and promoting proper waste disposals techniques, such as recycling and adequate landfilling, can significantly reduce the risk of water contamination.
- Promoting eco-friendly alternatives to hazardous chemicals and adopting best management practices among market vendors can minimise the risk of water pollution.
- Educating market stakeholders about the importance of protecting water resources and the potential consequences of water pollution is essential for fostering a culture of environmental stewardship.
- Collaborating with local authorities, environmental agencies, and community organisations to develop and implement water quality management plans can ensure a coordinated approach to pollution prevention and response.

Soil Pollution

To mitigate soil pollution, the following proactive measures can be adopted:

- Implementing proper waste management practices within the market, including segregating waste streams and establishing designated disposal areas, can help prevent soil contamination.
- Enforcing regulations to prevent the indiscriminate dumping of waste materials and promoting the use of environmentally friendly packaging materials can minimise soil pollution risk.
- Promoting the use of organic waste composting and recycling programmes within the market can help reduce the generation of waste materials and prevent the accumulation of organic matter in the soil.
- Educating market stakeholders about the importance of soil conservation and the potential consequences of soil pollution is essential for fostering a culture of environmental responsibility.

Improper Waste Disposal

To mitigate improper waste disposal, the following measures are essential:

- Implementing waste segregation at the source within the market premises can facilitate the separation of recyclable materials, organic waste, and hazardous substances from general waste streams.
- Providing adequate waste collection infrastructure, including bins for different waste categories and regular collection services, can help ensure proper disposal and prevent littering within the market area. Educating market vendors and patrons about the potential environmental and health impacts of responsible waste management practices and improper disposal is crucial for fostering behaviour change.
- Establishing partnerships with local waste management authorities or private waste collection services to facilitate proper disposal and recycling of waste materials can help improve overall waste management efficiency.

- Implementing penalties or fines for littering and improper waste disposal can deter and encourage compliance with waste management regulations.

CONCLUSION

The study area has impacted the environment positively and negatively. It has impacted the environment from both the ecological and socioeconomic points of view. The activities in the study area significantly impact the area's socioeconomic development and the people's livelihoods. On the other hand, it has led to noise, air, water, and soil pollution, among others. If the mitigation measures are implemented, the study area's negative impact will be drastically reduced.

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Digital Innovations for Sustainable Forest Management: A Review of Strategies and Applications in the Nigerian Context

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Digital Technologies, Environmental Management, Forestry Management, Sustainable Forest

ABSTRACT

The sustainable management of forest resources is imperative for environmental preservation and societal well-being, particularly, for countries like Nigeria facing significant challenges in resource governance. Traditional approaches have proven inadequate in addressing issues such as deforestation, illegal logging, and insufficient monitoring and enforcement. In response, the integration of digital tools present promising solutions to enhance forest resource management in Nigeria. Digital technologies, including satellite monitoring, remote sensing, GIS, and big data analytics offer opportunities for real-time data driven decision-making and improved governance. By adopting digital strategies, Nigeria can address forest-related challenges, combat illegal activities, and promote large-scale forest restoration and reforestation initiatives. Thus, integrated land use planning, supported by digital tools, fosters sustainable development by balancing conservation objectives with economic growth.

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INTRODUCTION

The importance of forest resources cannot be overstated, as numerous nations rely on them to meet various daily needs (Sambe *et al.,* 2020; Kibon *et al*., 2020; Fekadu *et al.,* 2021). Consequently, the sustainable management of forests is a global priority due to their crucial role in environmental preservation and the promotion of a healthy society. In developing nations like Nigeria, inadequate forest resource management poses a critical threat, endangering land and other natural assets. Nigeria, as a country endowed with abundant natural resources, faces the critical challenge of effectively managing these resources to ensure sustainability, economic development, and environmental conservation (Okeri *et al.,* 2016; Akinsorotan, 2021; Abdulkadir, 2021).

The nation's diverse resource base includes vast forest reserves, rich biodiversity, extensive mineral deposits, and significant agricultural potential. However, the management of these resources has been marred by various issues such as deforestation, illegal mining activities, biodiversity loss, and unsustainable exploitation (Okeri *et al.,* 2016). Additionally, the impact of climate change further complicates the task of resource management in Nigeria, posing significant threats to the country's ecosystems and livelihoods (Olaniyi *et al.*, 2013; Ebele and Emodi, 2016; Wakdok and Bleischwitz, 2021). Thus, there is an urgent need for comprehensive and sustainable resource management strategies that integrate modern technologies, community engagement, and effective governance to address these multifaceted challenges and unlock the full potential of Nigeria's natural resources for the benefit of the present and future generations.

The conventional approach has often relied on manual data collection methods, limited spatial analysis capabilities, and a lack of digital technologies for monitoring and assessing forest dynamics (Oke and Akindele, 2022). This has hindered the ability to gather comprehensive real-time information and make informed, data-driven decisions for sustainable forest management. Furthermore, the static nature of traditional approaches to forest management has limited their capacity to adapt to evolving environmental, social, and economic dynamics. These approaches have struggled to address emerging challenges such as the impacts of climate change, shifting land use patterns, and the increasing demand for forest products, gradually eroding the resilience of forest ecosystems.

Digitalization entails employing digital technologies to augment the daily lives of individuals (Bespalova *et al.,* 2021). The advent of digitalization disrupts conventional practices in the forest-based industry; traditional regulations, tailored for non-digital economies are challenged by digital transformation (Watanabe and Naveed, 2019). In recent years, the application of digital solutions has emerged as a transformative force in the realm of forest resources management, offering innovative solutions to age-old challenges (Rohmy and Nihayaty, 2023; Nitoslawski *et al.,* 2021). Presently, a number of tools and technologies exist, enhancing the efficiency of information collection and exchange (Nitoslawski *et al.,* 2021). Adopting a spectrum of technologies including geographic information systems (GIS), remote sensing, big data analytics, and mobile applications, digital solutions have revolutionized the way forest resources are monitored, preserved, and sustainably utilized (Nitoslawski *et al.,* 2021). These technologies provide unprecedented capabilities to collect real-time data, map forest cover changes, monitor wildlife activities, and engage with local communities, thereby enabling more informed decision-making and proactive conservation efforts. The integration of digital strategies not only enhances the efficiency and accuracy of forest management practices but also facilitates the empowerment of local stakeholders and the preservation of invaluable ecosystems. As such, the role of digital solutions in forest resources management extends beyond mere technological advancement, serving as a catalyst for achieving long-term ecological balance, economic prosperity, and social equity within forest-dependent regions (Gavilanes Montoya *et al.,* 2023). In the proceeding sections, we examine digital strategies for forest management and how innovative technologies reshape traditional practices, offering new avenues for sustainable conservation.

Challenges in Forest Resources Management in Nigeria

Nigeria grapples with a multitude of challenges in managing its forest resources, spanning from deforestation and illicit activities to governance deficiencies and insufficient community engagement (Mfon *et al.,* 2014; Ahmed and Olaitan, 2023). The traditional forest management approaches have proven inadequate in addressing these challenges due to their limited technological integration, insufficient community involvement, and lack of adaptive capacity. This section highlights the challenges facing forest resource management in Nigeria while advocating for the adoption of innovative digital strategies and the incorporation of a more inclusive, adaptive approach to forest management. Such measures can help surmount these limitations and foster more effective, sustainable stewardship of Nigeria's invaluable forest resources.

Deforestation and Degradation

Nigeria contends with substantial rates of deforestation and forest degradation, propelled by agricultural expansion, logging, infrastructural development, and urbanization (Ahmed and Olaitan, 2023). These activities result in the depletion of valuable forest cover, disruption of ecosystems, and a reduction in biodiversity, presenting significant environmental and socio-economic challenges.

Illegal Logging and Land Encroachment

The widespread occurrence of illegal logging, unregulated land encroachment, and unsustainable resource extraction practices has compromised the integrity of Nigeria's forest ecosystems (Sambe *et al.,* 2020; Chigonu *et al.,* 2022). These activities contribute to habitat destruction, soil erosion, and the depletion of crucial forest resources, heightening the vulnerability of forest-dependent communities and indigenous populations.

Inadequate Monitoring and Enforcement

The effectiveness of forest resource governance in Nigeria is hindered by a constrained capacity for monitoring and law enforcement (Chigonu *et al.*, 2022). The absence of robust monitoring systems, including surveillance technologies and real-time data collection methods, complicates the detection and prevention of illegal activities, allowing for the unchecked exploitation of forests and their resources.

Digital Technologies in Forest Resource Management

The effective management of forest resources is crucial for maintaining ecological balance, preserving biodiversity, and sustaining livelihoods (Ikemeh, 2013; Ojomah and Fasoro, 2023). In the contemporary era, the integration of digital tools and technologies has revolutionized the way forest resources are monitored, conserved, and utilized. Here, the exploration delved into the diverse array of digital solutions and technologies that have proven instrumental in enhancing forest resources management, offering innovative solutions to complex challenges, and empowering stakeholders to make informed decisions.

Geographic Information System (GIS)

Geospatial tools encompass a range of technologies and software utilized for collecting, analysing, and visualizing spatial data related to forests, including Geographic Information Systems (GIS) and Global Positioning Systems (GPS). These tools empower forest managers to map forest resources, monitor changes in land use, and assess biodiversity. They have also been employed as a tool for wildlife management (Burger and Burger, 2006).

GIS serves as a critical tool by addressing inquiries regarding location, condition, trends, patterns, and modelling techniques essential for effective forest management activities (Creutzburg *et al.,* 2017; Kibon *et al.*, 2020). With GIS, foresters can generate comprehensive maps, pinpoint deforestation hotspots, and evaluate the impact of land use changes on forest ecosystems. Numerous studies in Nigeria (Kibon *et al.*, 2020; Ahuchaogu *et al.*, 2020; Akinola and Akindele, 2020) have highlighted the effectiveness of GIS technology in monitoring and managing forests. However, there remains untapped potential for exploiting its benefits in the management of public forests (Oke and Akindele, 2022). Additionally, GIS enables the integration of diverse datasets, such as satellite imagery and field observations, to support informed decision-making and effective conservation strategies.

Remote Sensing

The emergence of remote sensing technologies, including satellite imagery and aerial drones, has revolutionized the monitoring and assessment of forest resources on a large scale. This discipline involves acquiring information about a phenomenon, object, or surface feature from distant platforms, typically satellites or airborne sensors, without direct physical contact (Sonti, 2015; Lwin, 2018). Satellite remote sensing ensures continuous observation of forest cover dynamics, identification of illegal logging activities, and detection of disturbances caused by natural disasters or human interventions. Similarly, unmanned aerial vehicles, commonly known as drones, equipped with high-resolution cameras and LiDAR sensors (Sofia *et al.,* 2022), facilitate detailed, real-time monitoring of forested areas, providing invaluable insights for forest inventory, biodiversity assessment, and habitat mapping.

This technology aids in monitoring forest conditions, detecting disturbances like wildfires, and assessing the effectiveness of conservation efforts. Both geospatial tools and remote sensing are integral in modern forest management, offering valuable data and insights for decision-making, monitoring, and planning. Together, they contribute significantly to the sustainable use and conservation of forest resources by facilitating efficient and informed management practices. GIS softwares have been used by researchers at the Forestry Research Institute of Nigeria to analyse forest cover loss and gain from Google Earth platform data in addition to the various applications of remote sensing techniques in Nigerian forestry (Akindele *et al.*, 2022).

Big Data Analytics

The advent of big data analytics has revolutionized the processing and analysis of large volumes of forest-related information. By exploiting powerful algorithms and machine learning techniques, big data analytics can derive meaningful patterns and trends from complex datasets, facilitating predictive modelling of forest dynamics, species distributions, and ecosystem services (Adewoye *et al.*, 2022). Moreover, big data analytics enables the integration of socio-economic data with ecological indicators providing a holistic understanding of the interdependencies between forest resources and human well-being.

Mobile Applications

Mobile applications and tracking software play a crucial role in monitoring the flow of forest products from the forest to the end consumer (He and Turner, 2021). The widespread availability of mobile applications designed for forest resources management has democratized processes such as data collection, stakeholder engagement, and decision support. Numerous open-source digital tools are accessible for data collection on various mobile operating systems, including Android and iOS (Adewoye *et al.*, 2022). These applications empower local communities, forest rangers, and conservation practitioners to report forest-related incidents, document wildlife sightings, and participate in citizen science initiatives. Moreover, mobile applications facilitate the dissemination of conservation guidelines, educational materials, and market information, fostering a culture of environmental stewardship and promoting sustainable forest use among diverse user groups.

Benefits of Integrating Digital Strategies in Nigerian Forest Resources Management

While digital initiatives hold promise for enhancing forest management, there is a need to ensure the integration of traditional ecological knowledge and meaningful community participation in these efforts. Embracing a participatory approach that acknowledges local expertise and engages forest-dependent communities is crucial for the success and sustainability of digital projects. The potential benefits of integrating digital strategies in Nigerian forest resources management are significant, offering opportunities to address specific challenges in the Nigerian context. Some of the benefits and opportunities include and not limited to:

Enhanced Monitoring and Surveillance: Digital strategies such as satellite monitoring, remote sensing and GIS can enable real-time monitoring of forest cover changes, illegal activities, and ecosystem health. These technologies offer opportunities to strengthen surveillance efforts, detect deforestation and degradation, and facilitate prompt intervention to mitigate forest threats.

Data-Driven Decision Making: Digital tools provide the opportunity to collect, analyse and visualize extensive datasets related to forest resources. By leveraging on these technologies, decision makers can access comprehensive, evidence-based information to inform policy formulation, land use planning, and conservation strategies. This data-driven approach enhances the precision and effectiveness of forest management interventions.

Community Engagement and Empowerment: Digital strategies offer opportunities to engage local communities and indigenous groups in forest resources management. Platforms for participatory mapping, citizen science initiatives, and mobile-based reporting systems can empower communities to contribute their knowledge, monitor forest activities, and collaborate with authorities in safeguarding forest resources.

Improved Governance and Transparency: Digital platforms can enhance transparency and accountability in forest management by facilitating the open sharing of data, promoting stakeholder participation, and increasing public access to information. This can lead to more transparent governance practices, reduced corruption, and enhanced public oversight of forest management activities.

Efficient Resource Allocation: Through the integration of digital technologies, forest agencies can optimize resource allocation, prioritize conservation areas, and streamline operational planning. Advanced modelling and simulation tools can help forecast the impacts of different management scenarios, enabling more efficient and strategic allocation of resources.

Climate Change Mitigation and Adaptation: Digital strategies can support Nigeria’s efforts to mitigate and adapt to climate change impacts on forest resources. By using predictive modelling, remote sensing for carbon monitoring, and climate data integration, technology can assist in developing resilient forest management strategies th*at al*ign with climate change goals.

Adopting digital strategies in Nigeria presents multifaceted opportunities to address forest-related challenges through enhanced law enforcement and surveillance technologies like satellite imagery and geospatial analysis. These tools will strengthen efforts to combat forest-related crimes while supporting large-scale forest restoration and reforestation initiatives. Integrated land use planning, facilitated by digital tools, fosters sustainable development by balancing conservation goals with economic growth, optimizing land use decisions, and minimizing deforestation for agricultural expansion.

CONCLUSION

In summary, the review underscores the potential of adopting digital strategies in forest resource management in Nigeria, emphasizing the necessity for a comprehensive policy framework and governance structure. The integration of digital tools offers opportunities to address specific challenges such as illegal logging, community empowerment, forest restoration, and sustainable land use planning. A robust policy framework is crucial to establish clear guidelines, promote stakeholder engagement, address data governance, build capacity, regulate technology adoption, and foster cross-sectoral collaboration. By creating an enabling environment for the effective implementation of digital strategies, Nigeria can enhance sustainable management of its invaluable forest resources, contributing to environmental conservation, economic development, and social well-being. As we harness the potential of these digital solutions, prioritizing equitable access, capacity building, and ethical considerations is vital to optimize their positive impact on forest ecosystems and the communities dependent on them.

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Preliminary Assessment of Bird Species Diversity in Chukwuemeka Odumegwu Ojukwu University, Igbariam, Nigeria

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ABSTRACT

Birds are excellent bio indicators of health of biodiversity. Urbanization has been identified as one of the causes for bird decline. This study aimed at assessing bird diversity and distribution within Chukwuemeka Odumegwu University (COOU), Igbariam campus, Anambra State, Nigeria with a view to providing baseline information for ecological management. The study area was stratified into forested and open spaces; hence, 5 plots of 100 m × 100 m size were systematically laid in each stratum. Bird activities were recorded from line transects with stating points systematically determined in each plot for one (1) month. Birds were identified to species level. The species compositions were analyzed using Shannon Wiener (H') diversity and Pielou's richness (E) indices. A total of 1984 birds distributed in birds consisting of 73 species distributed among 28 families were recorded COOU. Cisticolidae and Estrildidae were the most dominate family. Streptopelia semitorquata (Red-eyed dove) had the highest Relative density (RD) of 13.58% in the open space and 21.30% in the forested habitats. The result showed that COOU had H' and E had values of 3.20 and 0.461 for the forested area and 3.18 and 0.463 for the open area, respectively. The study concluded that COOU Igbariam campus has high bird species diversity. Furthermore, the design of programmes that encourage nature conservation were recommended.

INTRODUCTION

Birds are feathered, winged, egg–laying vertebrates which are often termed as avifauna. Birds belong to the Kingdom "Animalia," Phylum "Chordata" and Class "Aves", they have a worldwide distribution, living in and around rural and urban, forested and residential areas and are the most noticeable group in the animal kingdom (Zedler, 2003). The bright colours, distinct songs and calls, and showy displays of birds add fun to human life. Birds live and breed in most terrestrial habitats and on all countries including Nigeria which have diverse bird species of birds in all its ecological regions (Labe *et al*., 2018).

The increased disappearance of avifauna species over the years especially as a result of the anthropogenic activities is a great challenge to conservation. The United Nations (UN) estimates 55% of the world's population lives in urban areas, with the proportion expected to increase to 68% by 2050 (UN, 2918). Increase in world's population is positively correlated with deforestation (Carr, 2004), leading to loss of biodiversity. In Nigeria, the destruction of natural habitats continues rapidly, resulting in the depletion of the country's bird biodiversity and distribution (Oladeji *et al*., 2012).

Diverse urban forests can also function as wildlife habitats for a wide range of organisms especially wild birds (Jaman *et al*., 2021). University campuses are among urban structures that usually have more trees and can provide various ecosystem services (Wang *et al*., 2021).Various campuses in higher institutions represent a fundamental component of biodiversity in many parts of the world (Hernandez *et al*., 2018). Irrespective of the fact that institutional campuses have been linked to positive health and well-being (Holt *et al*., 2019), and they are primarily designed to provide a picturesque environment for learning and leisure, these campuses have the capacity to support high avifauna diversity due to their vegetation complexity (Carb´o-Ramírez *et al*., 2010; Lessi *et al*., 2016). High institutional campuses have been reported to serve as important habitats with the capacity to host a wide variety of fauna and flora (Colding and Barthel, 2017). For example, the Pune City University Campus, in the Western Indian state of Maharashtra, even though covers about 5% of the city's total landmass, is said to harbor half of the city's birds, butterfly and plant species. Surprisingly, a quarter of these taxa were found nowhere else order than the university campus (Kulkarni *et al*., 2001).

Successful conservation requires the urban habitat matrix to provide enough resources and connectivity for local species, in addition to habitat preservation (Shoffner *et al*., 2018). Thus, acting to alter urban vegetation communities can positively impact bird species diversity and how the birds are distributed in the area (Threlfall *et al*., 2016). While birds are seemingly ubiquitous throughout Nigeria, their ecologies in the urban ecosystems remain poorly understood. Thus, this study assessed bird diversity and distribution within Chukwuemeka Odumegwu Ojukwu University, Igbariam campus, Nigeria.

MATERIAL AND METHOD

Study area

The study was conducted in Chukwuemeka Odumegwu University (COOU) Igbariam Campus Anambra State, Nigeria. The University covers an area of about 714 hectares and located between longitude 6.94869° to 6.98174° E and latitude 6.27321° to 6.31003° N (Fig. 1) on elevation of 76 m above sea level. The climate is dominated with distinct dry and wet seasons with a temperature range of 24 – 36°C and annual rainfall of 1520-2020 mm. The vegetation in this area is half cleared dominated by farmlands with a wide expanse of palm tree (*Elaeis guineensis*) plantation. It has a table to gentle sloppy terrain with streams some of which dries up at the peak of dry season (Ibeh and Nworji, 2022).

Instrument Used

The Vortex 8×42 Binoculars was used for sighting of the birds from a distance, features such as feather shape and colors, beak, eye colors, legs and body size, and bird in flight were used to identify individual bird species and confirmed using HELM Field Guide (Birds of Western Africa by Borrow and Demey, 2014). A Sound recorder from mobile device was used to record the birds heard, this was later sent to an Ornithologist Expert for a second verification to reduce errors. Birdlasser mobile application was used to note the birds seen and heard, which formulate the data into a CSV file. For safety, a pair of Safety Boots, Rain coat, Water-proof back pack and Forestry overall was used. To map out transects, Global Positioning System (GPS) Map was used to measure the distance of transects and to take coordinates of the area which the study was carried out, Cutlass, Distance tape to measure the area.

Data Collection and Analysis

The areas inside the campus were stratified into forested and open spaces (Bibby *et. al.*, 2000; Sutherland, 2006) depending on the activity and position of birds (Bibby *et. al.*, 2000), a systematic selection was used to select five (5) plots of 100 m × 100 m for the forested areas (PLT 1 – 5) and also for the open areas (PLT 6 – 10), which gave a total of ten (10) plots. To ensure the independence of each plots, were laid 50 m apart from each other from 7h30 to 11h00 (Morning) and from 3h00 to 6h30 (Evening). All the selected plots were shuffled into all the designated time of the day to ensure no bird relating to time was missed out.

Within each plot, line transects were laid, starting points each line transects were systematically selected for each day to eliminate some areas being left out and five (5) plots data was collected morning and evening for five (5) days in a week, for four (4) weeks. The time ration was also systematically spread out to each transect. This is to ensure bird activities were properly collected with respect to time.

The data collected for this project was subjected to descriptive and correlation analysis. Shannon – wiener's diversity (Shannon and Weaver, 1949) and Pielou's evenness (Adekunle *et al.,* 2013) indices were also computed. The mathematical expressions are as:

$$H' = -\sum_{i=1}^{s} P_i \ln P_i \qquad (Equation\ 1)$$

$$E = \frac{H'}{H_{max}} = \frac{\sum_{i=1}^{s} P_i \ln P_i}{\ln(s)} \qquad (Equation\ 2)$$

Where,

H= Shannon-Weiner index
Pi= Relative abundance (RD) of the ith species,
S = the total number of species in the community
ln= natural log
i= 1, 2, . . ., n.

This analysis was implemented using Microsoft Excel 2010.

RESULTS

This study enumerated a total of 1984 birds consisting of 73 species distributed among 28 families. The family Cisticolidae and Estrildidae were the most dominate family of the bird population in this study area with the largest number of bird species representing 10.00% each of the total number of bird species in the population (Table 1). The bird species with the highest frequency was *Streptopelia semitorquata* (Red-eyed dove) with Relative density (RD) of13.58% in the open and 21.30% in the forested habitats. This was followed by *Lonchura cucullata* (Bronze Mannikin) with RD= 11.19% in the forested habitat and *Milvusa egyptius* (Yellow-billed Kite) with RD= 6.63% in the open habitat.

Bird species diversity and evenness in COOU are presented in Table 2. Shannon-Weiner index of diversity (H') and Pielou's evenness index (E) had a value of 3.20 and 0.461 respectively for the forested area, 3.18 and 0.463 respectively for the open area, and 3.19 and 0.46 respectively for the study area (pooled data) (Table 2).

Table 1: Distribution of bird species and frequency within each bird family in the study area

FAMILY	RD	SPECIES	SN	OPEN			SN	FORESTED		
				Scientific Name	F	RD %		Scientific Name	F	RD %
Accipitridae	7.14	African Goshawk	*1*	*Accipiter tachiro*	2	0.21				
		Black-winged Kite	*2*	*Elanus caeruleus*	2	0.21				
		Lizard Buzzard	*3*	*Kaupifalco monogrammicus*	5	0.52	*1*	*Kaupifalco monogrammicus*	6	0.59
		Yellow-billed Kite	4	*Milvus aegyptius*	64	6.63	*2*	*Milvus aegyptius*	53	5.20
		African Harrier-Hawk					*3*	*Polyboroides typus*	7	0.69
Alcedinidae	1.43	Woodland Kingfisher	*5*	*Halcyon senegalensis*	11	1.14	4	*Halcyon senegalensis*	10	0.98
Apodidae	1.43	African Palm Swift	*6*	*Cypsiurus parvus*	1	0.10	*5*	*Cypsiurus parvus*	8	0.79
Ardeidae	4.29	Black-headed Heron	*7*	*Ardea melanocephala*	35	3.63	*6*	*Ardea melanocephala*	3	0.29
		Little Egret	*9*	*Egretta garzetta*	43	4.46	*7*	*Egretta garzetta*	57	5.59
		Western Cattle Egret	*10*	*Bubulcus ibis*	26	2.69	*8*	*Bubulcus ibis*	50	4.91
Bucerotidae	2.86	African Grey Hornbill	*11*	*Lophoceros nasutus*	19	1.97	*9*	*Lophoceros nasutus*	13	1.28

		African Pied Hornbill	*12*	*Lophoceros fasciatus*	5	0.52				
Burhinidae	1.43	Senegal Thick-knee	*13*	*Burhinus senegalensis*	2	0.21				
Cisticolidae	10.00	Croaking Cisticola	*14*	*Cisticola natalensis*	3	0.31	*10*	*Cisticola natalensis*	1	0.10
		Grey-backed Camaroptera	*15*	*Camaroptera brevicaudata*	2	0.21	*11*	*Camaroptera brevicaudata*	3	0.29
		Short-winged Cisticola					*12*	*Cisticola brachypterus*	1	0.10
		Singing Cisticola					*13*	*Cisticola cantans*	7	0.69
		Red-faced Cisticola	*16*	*Cisticola erythrops*	13	1.35	*14*	*Cisticola erythrops*	29	2.85
		Tawny-flanked Prinia	*17*	*Prinia subflava*	6	0.62	*15*	*Prinia subflava*	9	0.88
		Winding Cisticola	*18*	*Cisticola marginatus*	10	1.04	*16*	*Cisticola marginatus*	2	0.20
Columbidae	7.14	Blue-spotted Wood Dove	*19*	*Turtur afer*	20	2.08	*17*	*Turtur afer*	19	1.87
		Laughing Dove	*20*	*Spilopelia senegalensis*	36	3.73	*18*	*Spilopelia senegalensis*	15	1.47
		Red-eyed Dove	*21*	*Streptopelia semitorquata*	131	13.58	*19*	*Streptopelia semitorquata*	217	21.30
		Tambourine Dove	*22*	*Turtur tympanistria*	1	0.10				
		Vinaceous Dove	*23*	*Streptopelia vinacea*	2	0.21	*20*	*Streptopelia vinacea*	22	2.16
Coraciidae	1.43	Blue-bellied Roller					*21*	*Coracias cyanogaster*	11	1.08
Corvidae	1.43	Pied Crow	*24*	*Corvus albus*	45	4.66	*22*	*Corvus albus*	18	1.77
Cuculidae	5.71	Jacobin Cuckoo	*25*	*Clamator jacobinus*	1	0.10	*23*	*Clamator jacobinus*	1	0.10
		Senegal Coucal	*26*	*Centropus senegalensis*	13	1.35	*24*	*Centropus senegalensis*	13	1.28
		Diederik Cuckoo					*25*	*Chrysococcyx caprius*	1	0.10
		Klaas's Cuckoo					*26*	*Chrysococcyx klaas*	2	0.20
Estrildidae	10.0	Bar-breasted Firefinch	*27*	*Lagonosticta rufopicta*	2	0.21	*27*	*Lagonosticta rufopicta*	7	0.69
		Black-and-white Mannikin	*28*	*Lonchura bicolor*	1	0.10	*28*	*Lonchura bicolor*	34	
		Black-bellied Firefinch					*29*	*Lagonosticta rara*	2	0.20
		Bronze Mannikin	*29*	*Lonchura cucullata*	55	5.70	*30*	*Lonchura cucullata*	114	11.19
		Grey-headed Nigrita	*30*	*Nigrita canicapillus*	1	0.10	*31*	*Nigrita canicapillus*	2	0.20
		Orange-cheeked Waxbill	*31*	*Estrilda melpoda*	6	0.62	*32*	*Estrilda melpoda*	2	0.20
		Red-billed Firefinch	*32*	*Lagonosticta senegala*	4	0.41	*33*	*Lagonosticta senegala*	9	0.88
Falconidae	2.86	African Hobby					*34*	*Falco cuvierii*	1	0.10
		Common Kestrel	*33*	*Falco tinnunculus*	8	0.83	*35*	*Falco tinnunculus*	2	0.20
Fringillidae	1.43	Yellow-fronted Canary					*36*	*Crithagra mozambica*	15	1.47

Hirundinidae	1.43	Ethiopian Swallow	*34*	*Hirundo aethiopica*	1	0.10				
Malaconotidae	1.43	Black-crowned Tchagra	*35*	*Tchagra senegalus*	3	0.31	*37*	*Tchagra senegalus*	11	1.08
Meropidae	1.43	White-throated Bee-eater	*36*	*Merops albicollis*	24	2.49				
Motacillidae	1.43	Yellow-throated Longclaw	*37*	*Macronyx croceus*	5	0.52	*38*	*Macronyx croceus*	5	0.49
Musophagidae	1.43	Western Plantain-eater	*38*	*Crinifer piscator*	17	1.76	*39*	*Crinifer piscator*	17	1.67
Nectariniidae	5.71	Copper Sunbird	*39*	*Cinnyris cupreus*	7	0.73	*40*	*Cinnyris cupreus*	28	
		Olive Sunbird	*40*	*Cyanomitra olivacea*	1	0.10	*41*	*Cyanomitra olivacea*	1	0.10
		Splendid Sunbird					*42*	*Cinnyris coccinigastrus*	21	2.06
		Variable Sunbird	*41*	*Cinnyris venustus*	16	1.66	43	*Cinnyris venustus*	27	2.65
Passeridae	2.86	Bush Petronia					*44*	*Gymnoris dentata*	3	0.29
		Northern Grey-headed Sparrow	42	*Passer griseus*	149	15.44	*45*	*Passer griseus*	33	3.24
Phasianidae	4.29	Common Quail					*46*	*Coturnix coturnix*	1	0.10
		Double-spurred Francolin	*43*	*Pternistis bicalcaratus*	13	1.35	*47*	*Pternistis bicalcaratus*	16	1.57
		Helmeted Guineafowl	*44*	*Numida meleagris*	1	0.10				
Platysteiridae	1.43	Brown-throated Wattle-eye	*45*	*Platysteira cyanea*	10	1.04	*48*	*Platysteira cyanea*	7	0.69
Ploceidae	8.57	Black-necked Weaver	*46*	*Ploceus nigricollis*	15	1.55	*49*	*Ploceus nigricollis*	15	1.47
		Chestnut-crowned Sparrow-Weaver	*47*	*Plocepasser superciliosus*	5	0.52				
		Heuglin's Masked Weaver	*48*	*Ploceus heuglini*	15	1.55				
		Northern Red Bishop	*49*	*Euplectes franciscanus*	13	1.35				
		Vieillot's Black Weaver					*50*	*Ploceus nigerrimus*	11	1.08
		Yellow-mantled Widowbird	*50*	*Euplectes macroura*	67	6.94				
Pycnonotidae	5.71	Common Bulbul	*51*	*Pycnonotus barbatus*	22	2.28	*51*	*Pycnonotus barbatus*	43	4.22
		Red-tailed Leaflove	*52*	*Phyllastrephus scandens*	3	0.31	*52*	*Phyllastrephus scandens*	3	0.29
		Simple Greenbul	*53*	*Chlorocichla simplex*	2	0.21				
		Yellow-whiskered Greenbul					*53*	*Eurillas latirostris*	1	0.10
Scopidae	1.43	Hamerkop					*54*	*Scopus umbretta*	1	0.10
Turdidae	1.43	African Thrush					*55*	*Turdus pelios*	4	0.39
Viduidae	2.86	Pin-tailed Whydah	*54*	*Vidua macroura*	1	0.10	*56*	*Vidua macroura*	4	0.39
		Village Indigobird					*57*	*Vidua chalybeata*	1	0.10
SUMMARY	**100**			***H'*=3.18**	**965**	**100**		***H'*=3.20**	**1019**	**100**

DISCUSSION

This study shows the diversity and distribution of birds in COOU Igbariam campus. In the Campus, the families: Cisticolidae andEstrildidae were the most dominate family in the study area. This result was similar to Nsor*et al.* (2018) the most diverse avian family in the Federal College of Education (Technical) Gombe, Nigeria was the Estrildidae family. This was not similar to Ogunyemi (2020) who reported that Nectarinidae, Columbidae and Pycnontidae as the most dominant families of birds in Ekiti State University, Ado - Ekiti, Nigeria. This was also in disagreement with Eveso *et al.* (2022) that reported Ploceidae as the most dominant family in Federal University Gashua, North-East Nigeria; the differences might be as a result of the difference in the ecology of the study areas.

Streptopelia semitorquata (Red-eyed Dove) and *Lonchura cucullata*(Bronze Mannikin) were the dominant bird species in the study area. From the study, it is evident that the open and forested strata in the Campus share similar and dissimilar bird species and the frequency of each species are almost the same number. The Shannon's diversity index of COOU had a value of 3.20 and 3.18 respectively for the Forested and Open Area, this indicates a fairly higher diversity in the Forested strata (H>3.0). This result agrees with Magurran (2004) who stated that a low H' value generally suggests a study area with few species and a few dominant species, while a high H' value suggests considerably more dominant species. These values were greater than 2.85 Ekiti State University, Ado- Ekiti (Ogunyemi, 2020) and less than 4.218 for Covenant University Ota (Okosodo *et al.,* 2016) both in Southwestern Nigeria. Pielou's evenness for the bird species in the open strata of 0.461 was also slightly higher than that of the open strata with a 0.002 difference. This also implies that the species in Open strata are more evenly distributed than the forested strata, though the forested strata have more diversity. The active disturbance of the open area might have also a contributed factor, due to the fact that the area is characterized with active farms, roads side, classrooms and construction sites. Farming activities such as Rice and Cassava farming are very popular on the campus, including cattle grazing.

The disparities in bird species diversity and abundance among the various land use types may be due to variations in land use and forest heterogeneity, which affect food, cover, predation danger, and microclimatic fluctuation (Okosodo *et al.,* 2016).

CONCLUSION

This study shows the diversity and distribution of birds in the Chukwuemeka Odumegu Ojukwu University, Igbariam campus, Nigeria. Bird species diversity was higher in the forest area than open area within the campus. *Streptopelia semitorquata* (Red-eyed Dove) and *Lonchura cucullata* (Bronze Mannikin) were the dominant bird species and Cisticolidae and Estrildidae were the most dominate families in the study area. The University management should design programmes to encourage nature conservation.

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Digitalization of Forest Resources Management in Nigeria: A Review of Concept, Status, Challenges and Way Forward

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ABSTRACT

Nigeria prioritizes the revitalization of forestry due to the abundance of forest resources in the nation and the various challenges that the forestry sector faces. Despite the significant proportion of forest cover, Nigeria has high rates of deforestation driven by factors such as urbanization, agricultural expansion, and other challenges including land degradation, illegal logging, and inadequate enforcement and monitoring. Nigeria can tackle long-standing issues with forestry management and advance toward sustainable development goals with the help of digitization. Digitalizing the management of forest resources has become essential for promoting sustainable practices and conservation initiatives. With the use of cutting-edge technologies like Geographic Information Systems (GIS), remote sensing, and data analytics, digitalization has the potential to significantly improve the management of Nigeria's forest resources. These technologies allow for accurate mapping, real-time monitoring, and well-informed decision-making, which promote sustainable practices. Through the application of advanced technologies, forestry professionals can maximize resource use, minimize waste, and encourage sustainable practices. Sustaining a long-term ecological balance relies on this efficiency. Therefore, establishing long-term monitoring tools to track the advancement and efficacy of digitization initiatives over time is critical. Thus, long-term monitoring programs to track the progress and effectiveness of digitalization initiatives over time should be established. Adaptive management strategies that enable feedback loops, iterative improvements based on data monitoring and stakeholder feedback, and continual learning are paramount. Scholars, practitioners, and policymakers can contribute to advancing the understanding, implementation, and impact of digitalized forestry resources management in Nigeria, ultimately promoting sustainable development and environmental conservation efforts.

INTRODUCTION

Digitalization refers to the process of integrating digital technologies, such as Geographic Information Systems (GIS), remote sensing, and data analytics, into traditional forestry management practices to enhance efficiency, effectiveness, and sustainability (Laudon and Laudon, 2020). It involves the digitization of data, automation of processes, and utilization of digital tools for decision-making, monitoring, and analysis in forestry resources management. Digitalization allows for precise mapping and monitoring of forest resources, enabling accurate assessments of tree density, species composition, and ecosystem health (Adeofun *et al.,* 2020). Advanced technologies facilitate real-time monitoring of forestry activities, including logging, land-use changes, and illegal activities. This enables prompt responses and interventions for sustainable management (Olabode *et al.,* 2019).

Digitalization provides comprehensive and up-to-date data, empowering forestry managers to make informed decisions regarding resource allocation, conservation strategies, and land-use planning (Adewale *et al.,* 2021). Through digital tools, forestry practitioners can optimize resource utilization, reducing wastage and promoting sustainable practices. This efficiency is crucial for long-term ecological balance (Akindele *et al.,* 2021). Digital technologies support the development of sophisticated ecosystem models, aiding in predicting and understanding the impact of various factors on forest ecosystems. This is vital for proactive management and conservation efforts (Ogunjemiyo *et al.,* 2018).

In the global context, sustainable practices and conservation efforts are paramount for addressing pressing environmental challenges, including deforestation, biodiversity loss, and climate change. Digitalization plays a crucial role in advancing these objectives by providing innovative tools and techniques for monitoring, managing, and protecting forest resources (FAO, 2020). By providing stakeholders with access to accurate and up-to-date information, digital platforms empower communities, NGOs, and governmental agencies to actively participate in conservation initiatives and advocate for sustainable forestry practices on a global scale.

In Africa, the relevance of sustainable forestry practices and conservation efforts is particularly pronounced due to the continent's rich biodiversity and dependence on forest resources for livelihoods and ecosystem services. Digitalization presents unique opportunities for African countries to address deforestation and promote sustainable land management practices (Asare *et al.,* 2020). Through initiatives like the African Forest Landscape Restoration Initiative (AFR100) and the Central African Forest Initiative (CAFI), African nations are leveraging digital technologies to enhance forest monitoring, restoration, and conservation efforts (World Bank, 2018). By harnessing the power of satellite imagery, drones, and mobile applications, African countries can accurately assess forest cover changes, identify deforestation hotspots, and implement targeted interventions to protect critical ecosystems and biodiversity.

In Nigeria, sustainable forestry practices and conservation efforts are essential for safeguarding the country's diverse ecosystems, supporting rural livelihoods, and mitigating the impacts of climate change. With digitalization, Nigeria has the opportunity to address longstanding challenges in forestry management and accelerate progress towards sustainable development goals (Olabode *et al.,* 2019). Digital technologies offer innovative solutions for monitoring and managing Nigeria's forest resources, from the mangrove forests of the Niger Delta to the savannas of the north. By integrating remote sensing, GIS, and mobile applications, Nigeria can improve forest inventory assessments, land-use planning, and enforcement of forestry regulations (Ajayi *et al.,* 2020). Moreover, digitalization enhances community engagement and participatory decision-making in forestry management, empowering local stakeholders to actively contribute to conservation efforts and benefit from sustainable forest practices (Oyinlola *et al.,* 2018). Through initiatives like the REDD+ program and the National Forest Inventory, Nigeria is leveraging digital platforms to strengthen governance, enhance transparency, and promote inclusive development in the forestry sector (Federal Ministry of Environment, Nigeria).

Current Status of Digitalization in Nigeria

The digital infrastructure in Nigeria's forestry sector has been gradually evolving, with various initiatives aimed at modernizing and enhancing forest management practices. One notable aspect of the existing digital infrastructure is the establishment of the National Forestry Information System (NFIS), which serves as a centralized platform for collecting, storing, and analyzing forestry data (Federal Ministry of Environment, Nigeria). The NFIS facilitates access to information on forest cover, biodiversity, land use, and other relevant parameters, enabling informed decision-making and policy formulation processes. In addition to the NFIS, several ongoing digitalization projects are underway to further strengthen the digital infrastructure in Nigeria's forestry sector. One such project is the integration of remote sensing and Geographic Information Systems (GIS) technologies for forest monitoring and mapping purposes. Through this project, satellite imagery and geospatial data are utilized to assess forest cover change, detect illegal logging activities, and monitor forest health indicators (Oyinlola *et al.,* 2018).

Multiple digitalization projects are ongoing in Nigeria. These ongoing projects include but are not limited to the following;

- Forest Inventory and Monitoring System (FIMS): The Forest Inventory and Monitoring System (FIMS) is a project aimed at developing a comprehensive database of forest resources in Nigeria. Using remote sensing technologies and ground-based surveys, FIMS collects data on forest cover, species composition, biomass, and ecological indicators (Ajayi *et al.*, 2020). The project aims to improve forest management decision-making and facilitate sustainable utilization of forest resources through informed planning and monitoring processes.
- Forest Protection and Monitoring System (FPMS): The Forest Protection and Monitoring System (FPMS) is a project focused on combating illegal logging, encroachment, and other forms of forest degradation through enhanced surveillance and enforcement mechanisms. FPMS utilizes a combination of satellite imagery such as NigeriaSat-1 and Landsat Thematic Mapper, drones, and ground-based sensors to detect and respond to forest-related threats in real time (Federal Ministry of Environment, Nigeria). By strengthening forest protection measures, FPMS aims to safeguard biodiversity, mitigate climate change, and promote sustainable forest management practices.
- Digital Training and Capacity Building Initiatives: Various digital training and capacity building initiatives have been launched to enhance the technical skills and knowledge of forestry professionals, government officials, and local communities. These initiatives utilize online learning platforms, webinars, and workshops to provide training on digital tools, data analysis techniques, and best practices in forest management (Ajayi *et al.*, 2020). By improving human capacity in digital technologies, these initiatives support the effective implementation of digitalization projects and contribute to long-term sustainability.

Another noteworthy initiative is the deployment of mobile-based applications such as locus maps for forest inventory and field data collection, allowing forestry officials and field workers to record and update information on tree species, biomass, and ecosystem services in real-time (Ajayi *et al.*, 2020). Despite these efforts, the level of implementation and effectiveness of digitalization projects in Nigeria's forestry sector varies across different regions and jurisdictions. While some states have made significant progress in adopting digital technologies and integrating them into forestry management practices, others continue to face challenges related to infrastructure limitations, funding constraints, and institutional capacity gaps (Ajani *et al.,* 2021**)**. Moreover, the impact of digitalization projects on improving forest management outcomes, such as conservation effectiveness, sustainable utilization, and community engagement, requires further assessment and evaluation (Olabode *et al.*, 2020). While Nigeria's forestry sector has seen advancements in digital infrastructure and ongoing digitalization projects, there is still room for improvement in terms of implementation and effectiveness.

Challenges

Some notable challenges that are affecting the digitalization of Nigeria's forestry resources management include but are not limited to the following;

1. Challenges in Implementation: Despite the introduction of digitalization projects, challenges such as inadequate technical capacity, limited infrastructure, and funding constraints persist in Nigeria's forestry sector. The successful implementation of digital initiatives is hindered by these challenges; leading to delays, suboptimal outcomes, and limited scalability of projects (Ajani *et al.*, 2021).
2. Infrastructure and Connectivity Challenges: Implementation of digitalization projects in Nigeria's forestry sector is hampered by infrastructure limitations, particularly in remote and rural areas. Limited access to electricity, internet connectivity, and digital devices impedes the deployment and utilization of digital technologies, hindering the effectiveness of projects (Oyinlola *et al.*, 2018).
3. Technological Integration and Interoperability: One of the key challenges in implementing digitalization projects in Nigeria's forestry sector is ensuring the integration and interoperability of diverse digital technologies and platforms. Lack of standardization, compatibility issues, and data silos hinder the seamless exchange of information and coordination among stakeholders, affecting the effectiveness of digital initiatives (Oyinlola *et al.*, 2018).

Some ongoing digitalization projects in Nigeria's forestry sector, such as FIMS and CBFM platforms, demonstrate efforts to modernize forest management practices and enhance stakeholder engagement. However, challenges related to implementation barriers and effectiveness assessments remain. Addressing these challenges requires concerted efforts from government agencies, NGOs, local communities, and other stakeholders to ensure the successful adoption and sustainable use of digital technologies in forestry resource management. Challenges related to technological integration, policy alignment, and institutional support need to be addressed to maximize the effectiveness of these projects. By overcoming these challenges, fostering multi-stakeholder collaboration, addressing existing challenges, and harnessing the potential of digital technologies, Nigeria can enhance its forestry management practices, promote sustainable resource utilization, contribute to biodiversity conservation efforts, and harness the transformative potential of digital technologies to advance its forestry management objectives**.**

Successful Global Practices

Canada has implemented robust forest inventory and monitoring programs that leverage remote sensing, aerial surveys, and ground-based measurements to assess forest health, biodiversity, and ecosystem services (Goodenough *et al.*, 2018). Canada's initiatives include the importance of multi-scale monitoring approaches, adaptive management strategies, and stakeholder engagement in data collection and interpretation processes. Nigeria can adopt Canada's best practices by establishing a comprehensive forest inventory and monitoring framework that integrates remote sensing technologies with ground-based surveys, thereby enhancing the accuracy and reliability of forest data and supporting evidence-based decision-making.

Germany has also developed advanced digital forest management systems that utilize mobile applications, Geographic Information Systems (GIS), and cloud-based platforms to streamline administrative processes, optimize resource allocation, and improve forest planning and operations (Hanewinkel *et al.*, 2018). Germany's experience includes the benefits of digitalizing administrative workflows, automating data collection and analysis tasks, and promoting interoperability and data sharing among stakeholders. Nigeria can draw lessons from Germany's digital forest management systems by embracing digital technologies to enhance administrative efficiency, optimize resource utilization, and strengthen governance frameworks in the forestry sector.

United States Forest Service (USFS) operates the Forest Inventory and Analysis (FIA) program, which conducts comprehensive forest inventories using a combination of field surveys, remote sensing, and geospatial analysis (Bechtold and Patterson, 2005). Lessons learned from the FIA program include the importance of long-term monitoring, standardized data collection protocols, and adaptive management strategies. Nigeria can benefit from implementing a similar nationwide forest inventory program to assess forest resources, monitor changes over time, and inform policy and management decisions. Incorporating these global practices into Nigeria's forestry sector can help address current challenges, enhance management effectiveness, and promote sustainable development. By adopting approaches such as establishing a national forest information system, implementing robust inventory, standardized monitoring protocols, stakeholder engagement strategies, monitoring programs, and leveraging digital technologies for administrative efficiency, Nigeria can overcome challenges, improve the current status of forestry resource management, advance its digital forestry resource management goals and contribute to global efforts towards forest conservation and climate change mitigation.

CONCLUSION

Through an examination of ongoing digitalization initiatives, challenges, and opportunities, several key themes emerge. Firstly, digitalization offers immense potential to enhance forest management practices by providing timely, accurate, and accessible data for informed decision-making. Projects such as the National Forestry Information System (NFIS), remote sensing applications, and community-based forest management platforms demonstrate the transformative power of digital technologies in improving forest monitoring, planning, and conservation efforts. Secondly, while digitalization presents numerous benefits such as revolutionizing traditional practices, and offering a suite of tools and approaches that enhance efficiency, sustainability, and the overall health of the forest ecosystem, its successful implementation in Nigeria's forestry sector requires overcoming various challenges. These include infrastructure limitations, funding constraints, capacity gaps, and policy barriers. Addressing these challenges necessitates concerted efforts from government agencies, research institutions, NGOs, and local communities to build technical capacity, foster collaboration, and create an enabling policy environment.

Lastly, the importance of digitalization for sustainable forestry practices cannot be overstated. By leveraging digital technologies, Nigeria can enhance its forest management capabilities, promote conservation efforts, and support socio-economic development in forest-dependent communities. Digitalization facilitates adaptive management approaches, stakeholder engagement, and data-driven decision-making, leading to more effective and resilient forestry practices. In essence, digitalization serves as a catalyst for transforming

Nigeria's forestry sector towards sustainability. Embracing digital technologies enables the country to overcome traditional constraints, unlock new opportunities, and achieve its conservation and development goals. Therefore, investing in digitalization is not just an option but a necessity for ensuring the long-term health, resilience, and prosperity of Nigeria's forests and the communities that depend on them.

RECOMMENDATIONS

Intense policy analysis studies and research should be carried out to assess the adequacy and effectiveness of existing governance frameworks in supporting digitalization efforts in Nigeria's forestry sector, as well as identify policy gaps, regulatory barriers, and institutional challenges that hinder the adoption and implementation of digital technologies, and propose policy recommendations for improving the enabling environment. There is also a need to evaluate the impact of capacity building and training programs on enhancing the technical skills and knowledge of forestry professionals, government officials, and local communities in utilizing digital tools and technologies. It is also important to investigate opportunities for cross-sectoral collaboration and synergies between forestry, agriculture, environment, and other related sectors in leveraging digital technologies for sustainable development, and also explore integrated approaches and holistic solutions that harness the synergies between different sectors to address complex socio-ecological challenges and achieve shared objectives.

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Land Use Land Cover Dynamics of Ise Forest Reserve, Nigeria

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ABSTRACT

Understanding the dynamics of Land Use Land Cover (LULC) is necessary for generating valuable information for informed decision-making in managing natural resources in the tropics. However, relevant information on these dynamics of forest cover is sparse, especially in Ise Forest Reserve. Therefore, this study aimed to assess the changes in land cover in Ise Forest Reserve between 2000 and 2020. Utilizing imagery from Landsat 7 and 8 acquired from the United States Geological Survey (USGS) database, covering the years 2000, 2010, and 2020, we employed a maximum likelihood algorithm to classify the images. Three LULC classes were identified: Forest, Farmland, and Settlement. Our analysis revealed significant shifts in land cover over the studied period. In 2000, forest coverage accounted for 87.5% of the reserve area in 2000, decreasing to 77.46% in 2020. Conversely, farmland increased from 10.74% in 2000 to 17.24% in 2020, while settlement areas expanded from 1.71% to 5.30% during the same period. These changes indicate the impact of anthropogenic activities in the area. In conclusion, LULC changes in Ise forest reserve revealed a concerning trend of deforestation and land cover change due to human activities. This research contributes valuable insights into the evolving landscape dynamics of the reserve, providing essential information for conservation efforts and sustainable land management practices.

INTRODUCTION

The depletion of natural forests in Nigeria has led to escalating concerns regarding their contribution to climate change, exacerbated by factors such as erosion and deforestation (Iwuchukwu *et al*., 2023). Forests are under significant pressure not only from climate change but also from increasing populations and greater demand for forest resources (Onyeneke *et al 2020).* Among the protected areas grappling with these challenges is the Ise Forest Reserve, situated amidst farmlands and human settlements, facing threats from extensive logging and agricultural encroachment (Ajibola and Ilesanmi, 2017). Despite its status as one of the last remaining forest fragments in southwest Nigeria, the reserve is besieged by intense anthropogenic activities, including farming, logging, and hunting (Ogunjemite *et al.*, 2006) and priority conservation areas for the endangered Nigeria-Cameroun Chimpanzees (*Pantroglodytes ellioti*) in Nigeria with a degrading forest environment (Morgan *et al.*, 2011).

Forests play a multifaceted role in mitigating climate change, acting as crucial carbon sinks and regulating global temperatures (Rajasugunasekar *et al*., 2023). However, projections indicate a worrisome increase in greenhouse gas emissions, exacerbating the global average surface temperature and precipitation levels.

(Allen and Ingram, 2002; Noguer *et al.*, 2001). Additionally, forests provide essential shade to preserve soil biodiversity and regulate evapotranspiration rates, crucial for maintaining ecological balance (Ojekunle 2014). The interplay between rising human populations, climate change, and land use dynamics underscores the interconnectedness of environmental challenges, highlighting the need for holistic approaches to conservation and sustainable land management. (Lambin *et al.* 2003; Lepers *et al.* 2005). Increasing acknowledgment has arisen regarding the significant connections among diverse global environmental concerns, including biodiversity loss, climate change, and alterations in land use (Heistermann, *et al.*, 2006). The 20th century witnessed a significant global shift in land use dynamics, driven by the exploitation of natural resources to meet developmental needs (Ramankutty *et al.*, 2005). Land use patterns reflect complex interactions between biophysical characteristics and human activities, shaping ecosystems and influencing global environmental issues such as biodiversity loss and climate change (Eze *et al.*, 2011).

The global climate system is affected by land-use and land-cover dynamics through bio-geophysical, biogeochemical and energy exchange processes. These in turn affect climate at local, regional and global scales. The terrestrial albedo is often altered by use and this is the reason why climate change has been attributed to land-use. Understanding the dynamics of these changes is necessary for generating valuable information for better decision making in the management of natural resources (Lu *et al.* 2003). This is because changes in land use and land cover have been directly linked to biodiversity loss, climate change, food insecurity, human health, and general environmental degradation (Dunjó *et al.* 2003 and Noguer *et al.* 2006).

Against this backdrop, this study investigates the dynamics of land use and land cover in Ise Forest Reserve from 2000 to 2020, leveraging satellite imagery to show the evolving landscape patterns and assess deforestation and anthropogenic encroachment. Employing advanced remote sensing techniques, we aim to provide comprehensive insights into ecological transformations within the reserve. Our research endeavors to bridge existing knowledge gaps regarding land use changes in Ise Forest Reserve and their implications for biodiversity conservation and ecosystem integrity. Through the comprehensive analysis of spatiotemporal trends in forest cover, farmland expansion, and settlement encroachment, we seek to inform evidence-based conservation strategies and policy interventions. By meticulously interpreting satellite imagery, this study contributes to a deeper understanding of the environmental dynamics shaping Nigeria's forest landscapes, advocating for sustainable management practices to safeguard biodiversity and ecological resilience.

METHODOLOGY

Study Area

The study was carried out in Ise Forest Reserve, Southwest Nigeria. It is located within latitude 7° 20' 22.48" N to 7° 25' 03.47" N, and longitude 5° 19' 59.84"E and 5° 25' 35.33"E. The protected area is about 9km to the southern part of the reserve along Akure-Benin expressway from Uso community in Ondo State (Olaniyi *et al.*, 2016). The annual temperature is between 25 ˚C – 28 ˚C while generally, the minimum temperature is 19 ˚C and the maximum temperature is 33 ˚C. The annual precipitation is between 1200mm. Specifically, Ise Forest Reserve receives 1380mm of rainfall annually (Ikemeh, 2013). The rainfall is steady and spread almost evenly throughout the wet season (April-October). The Ogbese River flows by the western borders of Ise Forest Reserve and a relatively smaller perennial river flows within the reserve close to Eastern edge (Ikemeh, 2013). Ise Forest Reserve is blessed with diverse fauna and flora species (Ogunjemite, 2011).

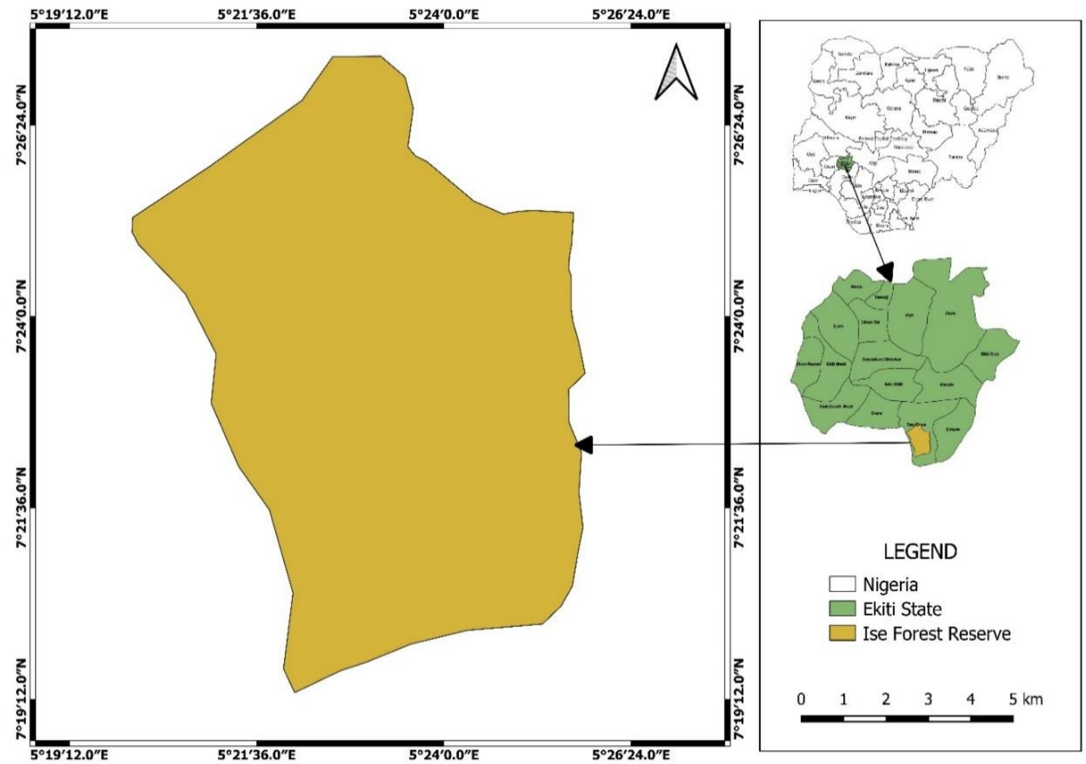

Figure 1: Map of Ise Forest Reserve

Data collection

Raster Data

To conduct this study, satellite data from Landsat 7 and Landsat 8 for the years 2020, 2010, and 2000 were acquired (path and row of 190/055 and 30 m resolution). These datasets were obtained from the United States Geological Survey (USGS) Earth Explorer platform (https://earthexplorer.usgs.gov/). ArcGIS and Quantum GIS (QGIS) software were used to analyze the image classification of the study area.

Data Analysis

Image Classification

Maximum Likelihood Algorithm (MLA) as used by (Alo *et al*., 2022) was utilized for the classification of the study area. MLA which is a supervised classification is the process of using samples of known identity (i.e. pixels already assigned to informational classes) to classify pixels of unknown identity (i.e. to assign unclassified pixels to one of several informational classes).

The classification of the study area was carried out on the imageries in Data Management Tools using ArcMap. A modified version of the Anderson (1976) scheme of land use/ cover classification was adopted: 1. Forested (areas dominated by trees), 2. Farmland (area with agricultural practices) and 3. Settlements (area with houses and other buildings) (Zhao *et al*., 2024).

Accuracy assessment

To assess the precision of the image classification outcomes, we utilized various evaluation methods. We conducted a comparison between the classified images and the reference dataset collected independently. Metrics such as user's accuracy (UA), producer's accuracy (PA), overall accuracy (OA), and kappa coefficient (k) were computed to quantitatively gauge the concordance between the classified results and the reference data. Accuracy Assessment was computed using the following equations:

$$\text{UA} = \frac{Total\ Number\ of\ correctly\ Classified\ Pixels\ in\ each\ category}{Total\ Number\ of\ Classified\ Pixels\ in\ that\ category\ (RowTotal)}\ x\ 100 \quad (1)$$

$$\text{PA} = \frac{Total\ Number\ of\ correctly\ Classified\ Pixels}{Total\ Number\ of\ Rreference\ Pixels\ in\ that\ category}\ x\ 100 \quad (2)$$

$$\text{OA} = \frac{Total\ Number\ of\ correctly\ Classified\ Pixels(Diagonal)}{Total\ Number\ of\ Rreference\ Pixels}\ x\ 100 \quad (3)$$

$$Kappa\ Statistics(k) = \frac{(TS\ x\ TCS) - \sum(Column\ Total\ x\ Row\ Total)}{TS^2 - \sum(Column\ Total\ x\ Row\ Total)}\ x\ 100 \quad (4)$$

Change Detection Analysis

Change detention analysis was carried out to determine the rate of changes over the years in the study area. The percentage change for each year and the rate of change between the years was calculated using the formula below.

Change was computed following: Change $(\Delta) = Y_2 - Y_1$ (5)

Average rate of change (AVR) was computed using: $\text{AVR} = \frac{Y_2 - Y_1}{T_2 - T_1}$ (6)

Percent Change Per Year (%Δ/yr.) was computed using: $\%\Delta/\text{yr.} = \frac{Y_2 - Y_1}{Y_1}$ (7)

Where Δ represents change; Y_2 and Y_1 are the area sizes in the initial year T_1 and final year T_2, respectively.

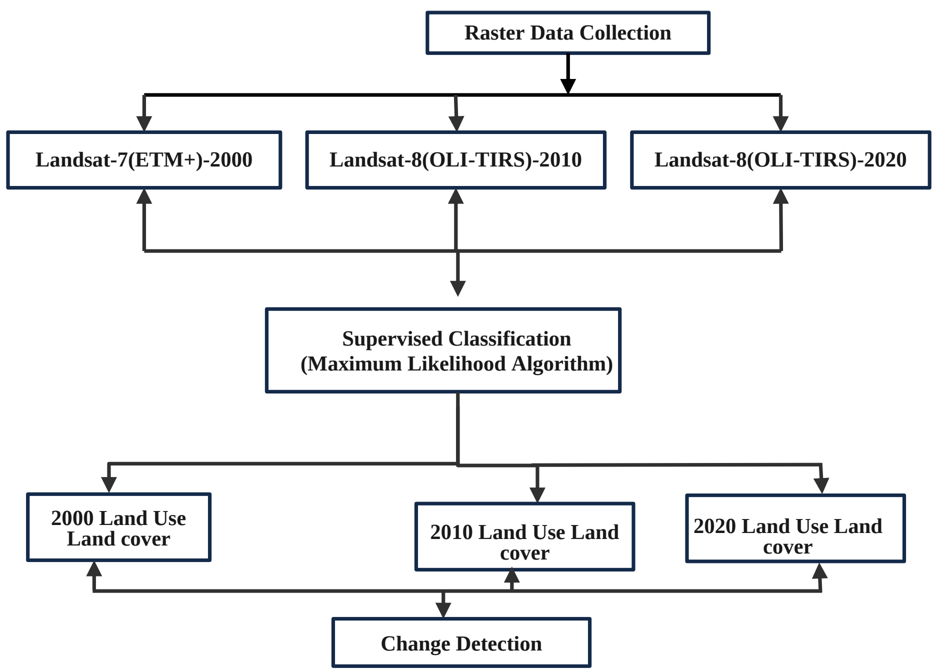

Figure 2: Framework of the methodology

RESULTS AND DISCUSSION

Ise Forest Reserve Land Use Land Cover

Table 1 shows the pattern of LULC of Ise forest reserve, which are Forest, Farmland and settlement for year 2000, 2010 and 2020.Out of the total area (97.16 km^2) the forest area had the largest coverage initially but experienced some fluctuations (Table 1 and Figure 4-6). In 2000, about 85.01 km^2 (87.5%) of the total area were covered with forest (Figure 4), which decreased to 79.68 km^2 (82.01%) in 2010 (Figure 5), and 72.26

km^2 (77.46%) in 2020 (Figure 6). The Farmland covered about 10.74% (10.44 km^2) of the total area in 2000 but increased to 13.62% (13.23 km^2) in 2010 and 17.24% (16.75 km^2) in 2020. However, settlements covered about 1.71km^2 which accounted for the 1.76% of the total area. This increased to 4.25 km^2 (4.37%) in 2010 and 5.15 km^2 (5.30) in 2020.

Table 1: Land cover type in Ise forest reserve from 2000 to 2020

Land cover type	Area in Year 2000		Area in Year 2010		Area in Year 2020	
	km^2	%	km^2	%	km^2	%
Forest	85.01	87.50	79.68	82.01	75.26	77.46
Farmland	10.44	10.74	13.23	13.62	16.75	17.24
Settlements	1.71	1.76	4.25	4.37	5.15	5.30
Total	**97.16**	**100.00**	**97.16**	**100.00**	**97.16**	**100.00**

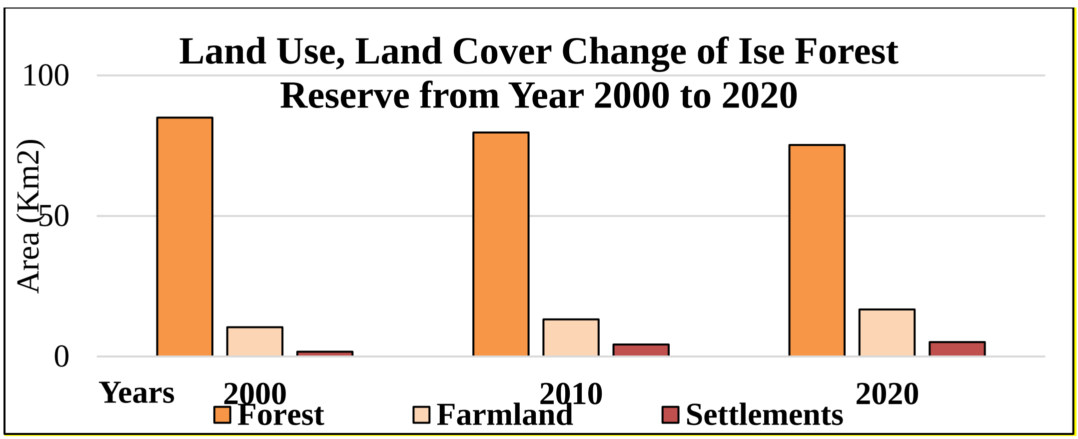

Figure 3: Graph showing the trends of the extent of land cover types in Ise Forest reserve during 2000 to 2020

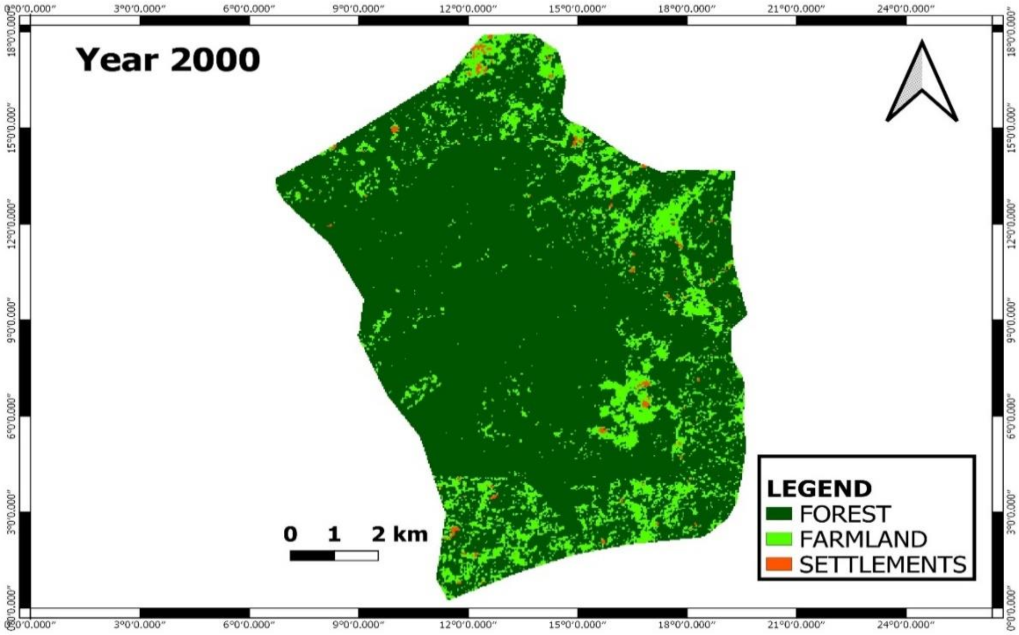

Figure 4: Land use land cover map of Ise forest reserve for year 2000

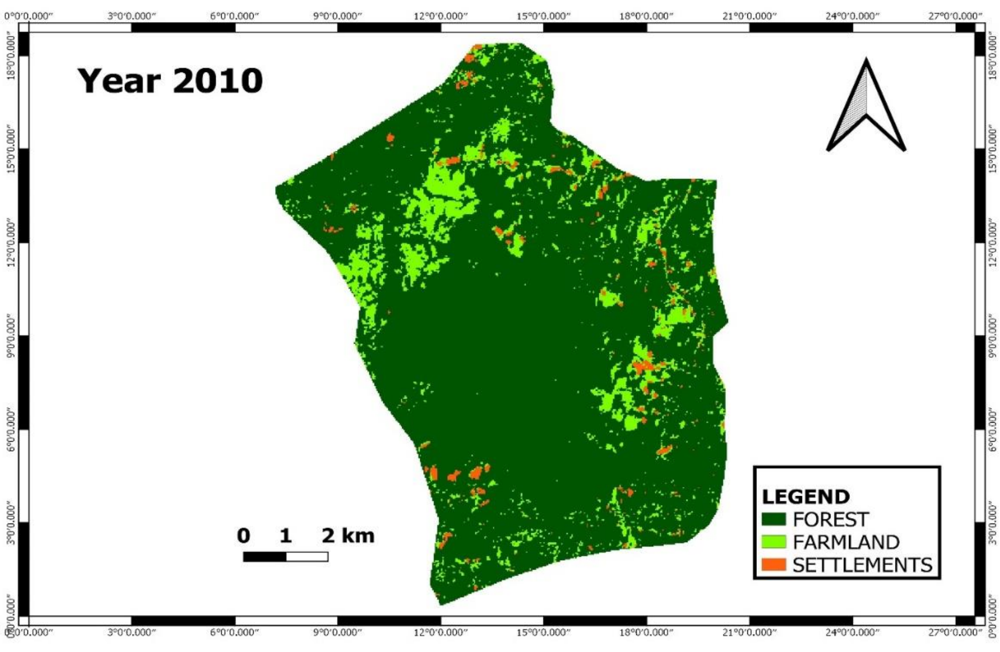

Figure 5: Land use land cover map of Ise forest reserve for year 2010

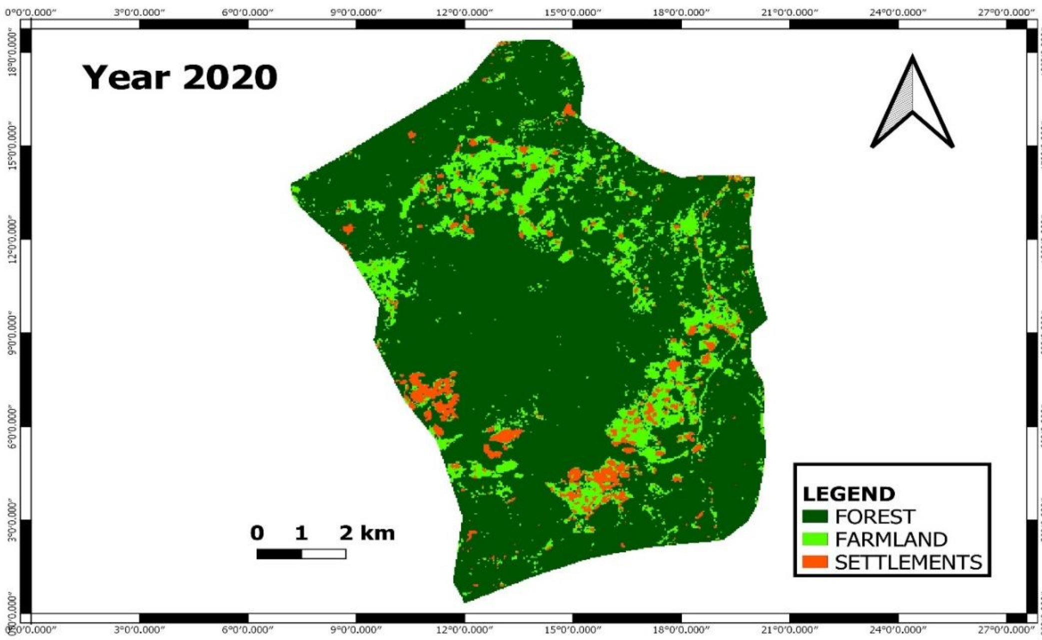

Figure 6: Land use land cover map of Ise forest reserve for year 2020

Change Detection Analysis

From Table 2, the trend of change from 2000 to 2010 shows that the forest had a negative change with a decrease of -0.53 km^2/yr. Farmland had an increase of 0.28 km^2/yr, while settlement had an increase of 0.25 km^2/yr. The trend of change from 2010 to 2020 shows that the forest had a negative change with a decrease of -0.44 km^2/yr while farmland and settlement had an increase of 0.35 km^2/yr and 0.09 km^2/yr respectively. The LULC trend for 2000 to 2020 shows that forest decreased with -0.98 km^2/yr, while farmland and settlement increased with 0.3 km^2/yr and 0.34 km^2/yr, respectively.

Table 2: Trend of Land cover change in Ise Forest Reserve during 2000 to 2020

Land Cover Types	**Area (km^2/yr)**		
	2000-2010	2010-2020	2000-2020
Forest	-0.53	-0.442	-0.98
Farmland	0.279	0.352	0.631
Settlements	0.254	0.09	0.344

Accuracy Assessment

Table 3 shows the error matrix which was carried out by verifying the land classification result with the google earth pro data. The user's, producer and overall accuracy with the kappa statistics(k) for the year 2000, 2010, and 2020 was computed. The overall accuracy for the year 2000, 2010 and 2020 were 94.91%, 93.42%, and 90.9% respectively. The kappa statistics(k) for year 2000, 2010 and 2020 were 93%, 91% and 90% respectively.

Table 3: Accuracy assessment table of Ise forest.

LULC	2000		2010		2020	
	Pa	Ua	Pa	Ua	Pa	Ua
Forest	96.94	100	100	99.56	100	90
Farmland	100	82.52	96.99	86.67	90	90
Settlements	100	100	99.87	100	90.91	100
Overall accuracy	94.91		93.42		90.9	
Kappa statistics(k)	0.93		0.91		0.9	

Where: Ua is User accuracy and Pa is producer accuracy,

DISCUSSION

Land use land cover changes has a serious implication for environment as Land use Land cover is directly related to the degradation over the period of time and results in many changes in the environment (Desta and Fetene, 2020). It is important to monitor the location and distribution of land use land cover in order to establish links between the policy makers and land users. The LULC classes used in this study area provided information on the degradation of the land between the year 2000 to 2020. The result of this research reveals that the forest cover has reduced and converted into settlements and farmland over time. Initially, the forest area dominated the region, constituting the majority of the total land coverage. However, a clear trend of forest loss is observed, with forest coverage decreasing from 85.01 km^2 in 2000 to 72.26 km^2 in 2020. This decline highlights the ongoing challenges of deforestation and land degradation within the reserve. Conversely, the expansion of farmland and settlement areas indicates human-induced land-use changes and urbanization processes occurring within the vicinity of the forest reserve. Farmland coverage increased steadily from 10.74% in 2000 to 17.24% in 2020, reflecting agricultural expansion and encroachment into forested areas. Similarly, settlement areas expanded over the years, signaling anthropogenic activities in the region. These observations also corroborate with similar studies carried out in different study areas (Alo *et al*., 2022; Alo and Aturamu, 2014.; Bukoye *et al*., 2023; Duguma *et al*., 2019; Komolafe and Akintunde-Alo, 2023).

The accuracy assessment represents a critical aspect of our study, as it serves to validate the reliability of the land classification process conducted within the Ise Forest Reserve. By comparing the results of our classification with high-resolution data obtained from Google Earth Pro, we were able to gauge the accuracy of our findings. This verification step is essential in ensuring that the land cover classifications accurately represent the real-world conditions within the study area (Ye *et al*., 2018). The overall high accuracy observed across the different time periods studied underscores the robustness of our classification methodology. The consistently high levels of accuracy indicate that our classification process effectively captured the spatial distribution of land cover types within the Ise Forest Reserve over time. This suggests that the classification results are reliable and can be used with confidence in further analysis and decision-making processes. Furthermore, the calculation of kappa statistics provides a quantitative measure of agreement between the classified data and the ground truth obtained from Google Earth Pro (Nkomeje, 2017). The high kappa values obtained for each time period indicate strong agreement beyond chance, reinforcing the credibility of our classification results. This statistical validation adds another layer of confidence to our findings, enhancing the overall reliability of our study outcomes.

CONCLUSION AND RECOMMENDATIONS

The analysis of satellite imagery for the Ise forest reserve reveals a concerning trend of deforestation and land cover change due to human activities. This poses significant risks to biodiversity and ecosystem stability. Addressing these challenges requires a multifaceted approach involving policy interventions, education, community engagement, and regulatory measures. Policymakers must prioritize sustainable land management practices, including integrating land uses with existing ecosystems and implementing soil conservation measures. Education programs are vital for promoting environmental stewardship and inspiring collective action. Regulatory mechanisms are essential for protecting habitats and combating illegal activities. Establishing new protected areas can provide refuge for threatened species and support biodiversity conservation through ecotourism. Collaboration among policymakers, conservation organizations, and local communities is recommended to develop comprehensive conservation strategies. This includes research, monitoring, and evaluation to ensure the long-term health of natural ecosystems. Working together, we can safeguard biodiversity and ensure the resilience of ecosystems for future generations.

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SUB-THEME THREE

GENDER PARTICIPATION IN AGRICULTURAL DIGITALIZATION: THE CHALLENGES AND PROSPECTS

Gender Participation in Agricultural Digitalization: Prospects and Challenges

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KEYWORDS

Agricultural Digitalization,
Agricultural Sustainability,
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ABSTRACT

Agricultural digitalization offers new opportunities across the world, and holds promises for enhanced productivity growth and improved well-being of all citizens. However, a significant gender gap in the access, use and ownership of digital technologies is still present in many economies and beyond, limiting the equitable realization of the benefits of digital transformation. Gender access to digital tools and digital competencies affect rural smallholders' participation in agricultural digitalization. Total harmonization of both men and women in agricultural digitalization is a road map to agricultural sustainability and food security. Placing gender divide gaps among farmers in terms of access to technological tools will not only create a lacuna in the field of agriculture but also will subject the people to hunger and starvation. Gender-inclusive solutions that help address barriers related to access, knowledge and skills, among others, are highlighted in this paper. Closing the gender gap in agriculture would produce significant gains for society by increasing agricultural productivity, reducing poverty and hunger, and increasing economic growth of the nation. Gender participation in agricultural digitalization is hampered by structural challenges, such as access to internet connectivity, poor or weak infrastructure, policy environment and regulations, and the limited ability of individuals to use the digital solutions. Despite all these challenges, women generally have great potentials for sustaining agricultural production and family income, if given adequate incentives and gender equity. Improvement in their social status and productivity is to increase output. Therefore, women should be allowed to have access to all the productive resources necessary for agricultural production. This paper looks at digitalization in agriculture from gender perspective. It investigates the prospects and challenges of gender participation in agricultural digitalization and zooms in on the potential opportunities that digitalization provides to women, especially in the developing world, and on the obstacle they face to benefit from it.

INTRODUCTION

Agriculture is one of the main pillars of the society's sustainability and is thus shaped by digital era. There have been a great breakthrough, rapid development, high productivity and remarkable successes in the feeding of the world's teeming population curtsey of technologies such as big data, internet of things (IoT), augmented reality, robotics, sensors, 3D printing and others. However, this rapid proliferation of digital tools and services stands in stark contrast to the many systemic and structural barriers to technology access and adoption that many people in rural Africa still face (FAO, 2021). Despite significant growth in information and communication technologies (ICT) and digitalization for agriculture (D4Ag) in sub-Saharan Africa (SSA) over the last ten years, progress has been somewhat slow in serving African smallholders, particularly women.

The Organization for Economic Co-operation and Development (OECD, 2018) defines digitalization as the use of digital technologies, data and their interconnection, resulting in new activities or changes to existing activities. According to CTA (2019), digitalization for agriculture (D4Ag) is "the use of digital technologies, innovations, and data to transform business models and practices across the agricultural value chain and address bottlenecks in, *inter alia*, productivity, postharvest handling, market access, finance, and supply chain management so as to achieve greater income for smallholder farmers, improve food and nutrition security, build climate resilience and expand inclusion of youth and women."

Digitalization, the socio-technical process of applying digital innovations, is an increasingly ubiquitous trend (Anitei *et al.,* 2020). Digitalization comprises phenomena and technologies such as big data, internet of things (IoT), augmented reality, robotics, sensors, 3D printing, system integration, ubiquitous connectivity, artificial intelligence, machine learning, digital twins and blockchain among others (Klerkx *et al.,* 2019; Alm *et al.*, 2016; Smith, 2018; Tilson *et al.*, 2010). Digitalization has the capacity to improve productivity, sustainability and resilience in many economic sectors of the world. The digitalization of agriculture is seen as the next agricultural revolution that has the potential to respond to the teeming needs of a growing population in the context of ongoing economic and environmental challenges (Trendov *et al.*, 2019).

In the context of agricultural and rural development, digitalization can offer various value propositions and have been proven with the credentials of exerting a positive impact on activities, processes and stakeholders at different levels (OECD, 2018). Digitalization can also enhance the ability of agricultural producers for poverty reduction and other livelihood improvements (Izuogu *et al.,* 2023). The benefits of agriculture digitalization are humongous, but some challenges seem to limit farmers of these benefits brought about by these sophisticated technologies (Anitei *et al.,* 2020). Gender inequalities, intersecting with and compounded by other social differences such as class, race, age, to disability, etc., shape the extent to which different rural women and men are able not only to access but also use and benefit from these new technologies and ways of delivering information and services (FAO, 2021). There are gender gaps for a wide range of agricultural inputs and technologies (FAO, 2018; Peterman *et al.*, 2014). These differences apply across the spectrum of technologies from basic to sophisticated digital agriculture technologies and information and communication technologies (Simonetta *et al.*, 2022). A survey conducted by Antei *et al.* (2020) revealed that 100% of the participants agreed that digitalization is an opportunity for their activity; none of them consider digitalization a threat. Digitalization in farmer's view is a real help, which will lead to maximum efficiency in the carried-out activity.

A significant gender gap in the access, use and ownership of digital technologies is still present in many G20 economies and beyond, limiting the equitable realization of the benefits of digitalized agriculture. Recognising both the opportunities that digitalization is providing for the economic empowerment of all, including women, and the challenges of ensuring that the benefits of the digital transformation are being equitably shared.

DIGITIZATION IN AGRICULTURE

Digitization is the non-theoretical procedure of changing analogue messages into digital data. It involves the social, mental and economic process of adopting improved technologies (Rolandi *et al*, 2021; Brennen and Kreiss, 2021). Malabo Montpellier Panel Report (MMPR) (2019) has reported that Nigeria has a prospective supporting sphere for digitalization in agriculture with a score of 4.5 out of 9 in the World Banks' Ease of Business in Agriculture (EBA), Information and Communications Technology (ICT) as well as ensuring affordable phones and mobile-specific taxation (Global System for Mobile Communications (GSMC), 2019).

Digitalization of agriculture has reduced the role of middlemen, provided opportunities for farmers to expand their markets, and improved the linkage between extension and research centers, and productivity and livelihood of small-scale farmers (Izuogu *et al.,* 2023). As digitalization is impacting each component of our lives, different forms of digitalization started to be introduced in agriculture like: sensors, IoT (internet of things), big data, 3D printing, artificial intelligence, digital twins, augmented reality, system integration and the list may go on (Anitei *et al.,* 2020).

One of the prospects of women participation in digitalized agriculture is decision making to equate the gender balance. A clear look at the Nigerian agricultural sector indicates that the decision making machinery is monopolized by the male gender (Effiong, 2013).Consequent upon the traditional gender division of labour, which myopically assigns women the greater percentage of unpaid care work relative to the men piloting and performing the leading role as income providers, women are less involved in commercial agriculture than men and, when they do get involved, they tend to hold lower-skilled, lower-pay positions (Simonetta *et al*., 2022). Women often exhibit lower productivity in agriculture than their male counterparts, as they tend to be disadvantaged in access to education and training, coupled with time and mobility constraints (FAO, 2015; Glazebrook *et al*., 2020). Sharon (2008) viewed that both women and men play critical roles in agricultural production throughout the world, producing, processing and providing the food we eat.

GENDER DIVIDES IN AGRICULTURAL DIGITALIZATION

The benefits of digitalization in agriculture are currently not equally balanced between societal groups and genders and also the access, use and ownership of digital tools are not gender-neutral. The term “digital gender divide” is frequently used to refer to these types of gender differences in resources and capabilities to access and effectively utilize ICTs within and between countries, regions, sectors and socio-economic groups (UN Women, 2005). In the field of AI, gender segregation is observed in skills, roles, and sectors. Skills related to information retrieval, natural language processing, and data structures are prevalent among women, while women are less likely than men to have emerging skills, such as deep learning, neural networks, and computer vision (World Economic Forum, 2018).

CAUSES OF GENDER DIVIDES IN AGRICULTURAL DIGITALIZATION

There are a number of root causes of the digital gender divide, including hurdles to access, affordability, education (or lack thereof) and lack of technological literacy, as well as inherent biases and socio-cultural norms that lead to gender-based digital exclusion (OECD, 2018d; OECD, 2015a; Hilbert, 2011).

Affordability so to speak, is a challenge for all but affects disproportionally more women and girls than the male counterparts and remains one of the key hurdles in accessing ICTs. The digital gender divide is found to increase as technological sophistication and functionality grows and with the cost of ownership (BMZ, 2017). Case in point is the study by Intel and Dalberg (2012) who found out that affordability plague not only those who are not yet Internet users, but further prevents internet users from using the World Wide Web in its fullest.

Lack of awareness of the potential benefits that the Internet offers even at our closest comfort is yet another reason fewer women than men are found in the ICT world. Women are predominantly more likely than men to not use the Internet because of the misconception that they do not need it or does not benefit them any stretch (Fallows, 2005). Intel and Dalberg (2012) state it all when they found that25% of the women who disengaged themselves in online activities are generally not interested in using the Internet, and almost all of them believe that accessing the Internet profited them nothing. Evidently, lack of trust in digital devices may also be a decisive factor and low expectations about its usefulness and relevance to their local context (i.e. lack of use of local languages) can also be enlisted amongst many others.

Illiteracy further extends the bounds and hinders women’s and girls’ ability to access online services. Recent study have shown that about 83% of women worldwide are literate, compared to 90% of men (UNESCO, 2017), and illiterate women only appear to be using online platform services, such as Skype and YouTube, that are more familiar to them or are easier to access and use. In an attempt to address this hurdle, some search engines, such as Google, have installed voice navigation systems in local languages to make Internet search queries more accessible and inclusive.

The digital gender divide is also powered by digital illiteracy, which often translates in lack of comfort in usage of these technologies and the clear access to the Internet. Such “technophobia” is often a function of concurrent factors but not limited to education, employment status and income level. For instance, Intel and Dalberg’s (2012) survey shows that more than half of the women with minimum formal education are of the view that they were not familiar or comfortable with the technology. Although, this percentage fell to 15% in the case of women with at least high school education.

Besides access, affordability, digital illiteracy, socio-cultural and socio-economic factors such as social class, age, ethnicity, income, assets and cultural origin can also play an exceptional role in elucidating the digital gender divide and also contribute to explaining how and for which purposes people use the Internet (Hosman and Perez Comisso, 2020). For Instance, a country like India and Egypt, around one-fifth of the women were found to believe that the Internet was not appropriate for them, for a greater number of cultural beliefs. In India, around 12 % of women report not to use the Internet because of the negative societal and social perception associated to its use, and 8% due to the lack of acceptance by family members (Inteland Dalberg, 2012). Practically speaking, community norms tend to link mobile and Internet use with reputational risk and as such undermine women's use of digital technologies (Ganapathy and Mahindru, 2023). These factors eventually find expression in people especially, women and so cause them to face multiple and compounding interrelated obstacles to the use of technology for business purposes (UNCTAD 2023, Van Dijk, 2021).

THE POTENTIAL BENEFITS OF DIGITALIZATION IN AGRICULTURE

UNCTAD (2020b) reports that digital agriculture popularly called "agriculture 4.0" or "smart farming" refers to the use of modern technologies (e.g. AI, the Internet of Things, drones, big data analytics, mobile technologies and devices, and digitally-delivered services and apps) to target precision agriculture, which focuses on optimizing agricultural production processes by utilizing a set of information technologies and automated equipment (MacPherson *et al.*, 2022; Wolfert *et al.*, 2017). For instance, automation can help farming businesses free up the time, energy and effort that used to be invested in monitoring the crops; weeds can be controlled at the exact moment they start to form; and innovations such as robot harvesters (powered by machine learning) can help farmers during the harvesting stage (Miskinis, 2019).

Digitalization in agriculture has the potential to address the economic and environmental imbalances that have been noticed in global food markets (Simonetta *et al.,* 2022). Studies have shown as far back in the early 2000sthat developing countries were the net importers of agricultural raw commodities (FAO, 2022a, 2022b). In 2021, their imports accounted for over 65 per cent of world imports of cereals and oilseeds, and over 30 per cent of meat and dairy imports (FAO, 2022b). In 2020, African countries imported about 80 per cent of their food and 92 per cent of their cereal from abroad. Based on FAO (2022a), the top 10 per cent of the richest countries produce about 70 times more output per worker than countries in the bottom 10 per cent of the income distribution. Digitalization has the disposition of raising both efficiency and productivity for many small-scale farmers in undeveloped countries by facilitating market transparency, access to extension services, resource optimization, and improvement in agricultural supply chain management (Deichmann *et al.*, 2016).

A more recent case is the rise in food and fuel prices stemming from the outbreak of war in Ukraine which affected and severely hit the world's poorest countries, and the poorest segments of the population in those countries who tend to spend a disproportionately high share of their income on food. These ongoing challenges have led to an increased focus on sustainable food production to integrate social and environmental goals in the process of economic development, and digital technologies can be leveraged to achieve sustainability principles across food systems (FAO, 2022a; IPBES, 2019; MacPherson *et al.,* 2022).

GENDER PARTICIPATION IN AGRICULTURAL DIGITIZATION

Gender is a term often associated with the responsibilities of males and females in the society as a social classification of sex (Udemezue and Odia, 2021). SinkaiyeJibowo (2005) viewed it as the socio-cultural differences between males and females against the biological differences. It is also described as a concept used in social science analysis to look at roles and activities of men and women (International Institute of Tropical Agriculture (IITA, 1996).

Gender participation gives insight into the issues affecting women with the primary focus on the relationship of both men and women to the social and economic structure of a society (Agada *et al.,* 2018). In most parts of rural Nigeria, division of labour within the households is gender specific and according to age. Men and women do function in different capacities; have unequal decision-making power as well as differences in access to land, ICT technologies and control over agricultural productive resources (Udemezue and Odia, 2021). Gender report in Nigeria by the British Council, has it that women own 4% of land in the North-East, and just over 10% in the South-East and South-South has less than 10% of land allocated to women (Karl, 2005). Sequel to these differences, their views, needs, priorities and constraints to improving their productive potentials differ which eventually will affect their various outputs even in agricultural development.

Under social structures and political systems, dominated by men, women are not given equal access to land, technology, education and other resources (Tanko, 1994). The problem of food shortages and scarcity in Nigeria has been ascribed to an acute dearth of gender equality and a corresponding shift of farm responsibilities to the women (Uwadie, 1993; Chinasaokwu, 2021). Socio-economic and political obstacles have for long been magnifying gender inequality and exacerbating poverty among women (Rahman and Aruna, 1999; Chinasaokwu, 2021) should equal opportunity be given to all farmers devoid of gender bias, that is, allowing both men and women to grow whatever crops he/she wants to crop, have access to sophisticated agro - technological tools without gender disparity, there is this tendency that the result will lead to a potential boost in food security in Nigeria and the world in general.

The understanding of gender participation in agricultural digitalization: the prospects and challenges(constraints in food production, processing and marketing among rural farmers) in Nigeria is important owing to the current threat to food security as a result of the economic recession, upsurge in prices of essential commodities faced in the country and this calls for the urgent need to increase workforce (men and women participation) and sustain the enterprise among farmers (Udemezue and Odia, 2021).

DIGITALIZATION IN AGRICULTURE: PROSPECTS AND CHALLENGES

Digitalization can potentially pave the way for improving the efficiency and functioning of food systems, which in turn can have positive impacts on the livelihoods of women and men farmers and agripreneurs, through the creation of digital job opportunities for young women and men in rural areas (FAO, 2022). In this effect, an increasing number of solutions are being developed to improve the livelihoods and resilience of farmers by taking advantage of the decreasing cost of digital technologies.

Digital agriculture can help women and other smallholder farmers in developing countries overcome or offset for the barriers they face by providing tools that can help raise productivity, competitiveness, and access to export markets (Simonetta *et al.,* 2022). At farm level, the application of specific digital technologies can lead to positive impacts on productivity, improve farmers' incomes and livelihoods and make farmers more resilient to the effects of climate change (International Bank for Reconstruction and Development and World Bank, 2019). For example, digitalization through mobile technologies can connect farmers to supply chains, service provision, and directly to markets and consumers, maximizing profitability by avoiding intermediaries. That was shown in the case of a recent review of pilot e-voucher programmes for subsidized farm inputs in Guinea, Mali, and Niger (FAO, 2022).

Digital technologies can expand access to information on market opportunities (including foreign markets and how to access them), extension and advisory services, prices and products. By doing so, digital technologies can facilitate the integration of smallholders into the domestic and global value chains, both upstream and downstream, in turn becoming an important instrument for reducing rural poverty and contributing to more sustainable and inclusive development (Antonio and Tuffley, 2014; OECD, 2019b)

Digitalization of the agricultural sector has helped enhance the transfer of information and ideas especially as it relates to market information. This has helped in facilitating the profit maximization for the farmers (both male and female) (Oke *et al,* 2019). Generally speaking, farmers need real time information dissemination for efficient agronomic practices as this can also assist significantly in reducing production cost and wade off the risk as farmers are authorized to make sound decisions (Pesce *et al.,* 2019; Ibukun *et al.,* 2021). Digitalization of the agriculture will importantly aid in bridging knowledge gaps thereby narrowing the gender divide gap. The implication is the fact that majority of the farmers can access advisory services not regarding the insufficiency in the number of extension staff (Olagunju *et al.,* 2021).

Digitalization can result in increased food security while reducing agricultural environmental footprint (Fraser and Campbell 2019; Basso and Antle 2020). According to Fabregas *et al*. (2022) digital tools improve productivity, enhances the standard of living of the remote masses while supplementing the indigenous extension approaches. Weather forecast using up-to-date meteorological equipment coupled with intelligent transfer of ideas through internet services or mobile phones enables farmers in making knowledgeable commitment on the periods of their agronomic practices (Pesce, *et al.,* 2019; MMPR, 2020). Innovations in the areas of other automated equipment for agricultural production such as irrigation, light and heat control, satellite photography, Unmanned Aerial Vehicles (UAVs) is altering decision making in the farm labour sector for good (MMPR, 2019; Hermanus, 2021).

Through digitalization, the rate of post-harvest losses on the agricultural value chain is minimized with a corresponding increase in access to value addition facilities (MMPR, 2020). With emerging synergetic preparations which have given rise to increase in agricultural productivity and farm income, digitalization has made the agricultural sector more attractive to young farmers (Saiz-Rubio and Rovira-Más, 2020).

The adoption of digital technologies may come with negative alterations in the existing agricultural systems (Fielke, *et al*, 2019). For instance, Rose *et al.* (2021) opined that an increase in technology adoption may lead to the negligence of the former knowledge and detach farmers from the landscape. The digitalization of the agricultural sector may increase the level of unemployment in the rural areas. Trendov *et al.* (2019), Beirne and Fernandez (2022), Olomola and Nwafor (2018) and Osabohien *et al.* (2019) noted that the reduction in the cost of labour as a result of digitalization of the agricultural sector will invariably augment for the unemployment. Digitalization of agriculture has reduced the role of middlemen, provided opportunities for farmers to expand their markets, and improved the linkage between extension and research centers, and productivity and livelihood of small-scale farmers (Izuogu *et al.*, 2023)

Nonetheless, success stories abound showing how access to digital agriculture could boast and at the same time be a source of both empowerment and higher productivity for women. In India, Nano Ganesh is a remote control for water pumps developed by an Indian company, Ossian Agro Automation. Its electronic hardware for turning pumps off and on can be activated remotely by mobile phone. This helps women (and men) farmers use water more efficiently (Simonetta *et al.,* 2022). Without remote controls, farmers either must make special trips to the fields at night to turn pumps on (electricity is often available only during off-peak hours), or they must leave the pumps on to run on the intermittent electricity supply, wasting water, reducing income and eroding soil. Particularly for women farmers, nighttime trips can be risky and difficult. This innovation has also generated new activities, which provide additional sources of income for women in the company's rural call centres, electronics assembly, and marketing and training (Deichmann *et al.*, 2016).

The potential of digital technologies is confronted with a gender gap in technology adoption, which contributes to perpetuating women's lower productivity and segregation into positions of economic vulnerability in agriculture (Simonetta *et al.,* 2022). In a country like Kenya, women farmers can use smartphones to watch and predict weather trends. This information allows them to forecast optimal planting and harvesting – especially for the crops that need to be dried. Digital technologies can also support logistics, payments, certification processes, marketing and sales. They can build on women's indigenous knowledge of local and agroecological production as well (Dugbazah *et al.*, 2021). In Ghana, women dealing on shea nut farming, thanks to digital technology – could disengage from intermediaries and directly connect to a new market of international buyers through the Shea Network Ghana and increase their profits by even 80 per cent (Cline, 2019).

E-commerce, many of which in developing countries are owned by women can help small businesses flourish by reducing the starting capital needed to initiate operations. The greater time flexibility associated with online versus offline trade and the possibility to work from any location represent advantages for women who are time and mobility constrained (World Bank and WTO, 2020). More so, digital innovations that streamlined the need for face-to-face interactions can also help women overcome discrimination (OECD/WTO, 2017; World Bank and WTO, 2020). According to a survey of entrepreneurs using Jumia, Africa's largest e-commerce platform, women-owned enterprises tend to rely on their personal savings to start their business and when they approach a financial institution they tend to apply for small loans (IFC, 2021).

As individuals, women through digitalization can access online education and training. On one hand generally, this is potentially beneficial for everybody, but in the other hand, it can be a game changer for women and girls who are often constrained in access to quality education and information. Recent study by OECD (2018) have shown that increased access to information ultimately makes women feel safer, more autonomous and more self-confident. As citizens, women can interact with authorities at both the national and local levels in a more streamlined, transparent, friendly and less time-consuming manner. Technology has the potential to improve efficiency, transparency, and accountability of public administration, which can improve women' access to information, upon condition that investments are made to help women acquire digital skills at par with men (Ganapathy and Mahindru, 2023).

Several challenges are militating against the effective gender participation in digitalization of the agricultural sector. Foster *et al.* (2018) identified deficiencies in digital skill, poor financial strength as the core exclusionary barriers to digitalization. According to MMPR (2019), the absence of digital innovation hubs and other ICT public access spaces in rural areas is a major challenge of digitalization in many developing countries. Upon the creation of these hubs, they will facilitate the development of innovation habitat which is very essential in stimulating the conversion of the agricultural system as well as availing the sector the convenience for youths' participation in agriculture. The absence of infrastructure is among the core challenges impeding the utilization of digital technologies in Nigeria (Nigerian Communications Commission, 2021). According to Izuogu *et al.* (2023), challenges of digitalization of agriculture in Nigeria were lack of technical skill, poor infrastructure and high cost of purchase and maintenance of equipment.

CONCLUSION

Agriculture plays vital role in reshaping the society and is key for women's welfare and livelihood. Men and women tend to perform different economic tasks in the sector due to various sources of gender bias.Technology is one of the fields where women are significantly underrepresented among academic staff, experts, and entrepreneurs, a gap that is even more pronounced in the fields of AI. Technologies have the potential to create opportunities for women to lead, participate in, and benefit from technology developments. However, without the right policy enablers, digital technologies can also reinforce gender stereotypes and deepen economic and social exclusion.

In conclusion, farmers are very much aware of the benefits associated with gender participation in agricultural digitalization and do want to digitalize their activities, but some challenges seem to limit them. An efficient support of the digitalization of the agricultural sectors in Nigeria will ameliorate the negative influence brought to bear by digital gender divide as well as to other divides linked to gender, age and socioeconomic factors that determine individuals' ability to have access to digital technologies and use them in a productive and beneficial manner that has hampered its success.

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Socio-Cultural Factors Influencing Women Participation in Agricultural Digitization in Zangon Kataf Local Government Area of Kaduna State, Nigeria

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ABSTRACT

Agriculture, a fundamental sector globally, is undergoing a digital transformation, yet the participation of women in this transition remains variable due to socio-cultural dynamics. The research delved into how societal norms, cultural perceptions, access to resources, educational opportunities, and gender roles impact women's engagement in adopting digital tools and technologies within the agricultural sphere. This study analyzed between socio-cultural factors and women's involvement in agricultural digitization initiatives. Employing qualitative and quantitative methodologies, this research aimed to uncover the multifaceted barriers and facilitators influencing women's participation in agricultural digitization. The study drew upon interviews, surveys, and case studies to comprehend the nuances of socio-cultural factors that shape women's decision-making, access to information, and technology adoption in agricultural practices. Factors found to influence rural women farmers' decision on adopting agricultural digitalization were gender roles and expectations (0.000), access to land (0.098), networks and support systems (0.036), decision-making power (0.000), access to education (0.082), age of farmers (0.093), social stigma and discrimination (0.00) and Technological Literacy (0.044). Addressing socio-cultural barriers was crucial in ensuring equitable access to technological advancements, fostering economic empowerment, and sustainable development within the agricultural sector. Findings of this research would contribute significant insights into designing gender-inclusive policies, tailored interventions, and empowerment strategies aimed at enhancing women's agency and involvement in agricultural digitization.

INTRODUCTION

In Eastern Asia and Sub-Saharan Africa, women make up about 50% of the agricultural work force, whereas in Latin America, they make up 20% (Haile 2016); Planning, policies, and programs must incorporate them as a result for sustainable and successful development (Asamu *et al.*, 2019). In all emerging nations, women play a critical role in the agricultural and rural economies. Their responsibilities are evolving quickly in many parts of the world where social and economic factors are reshaping the agricultural sector, and they differ significantly between and within regions (Maksim *et al*., 2022). The promotion of digital agricultural services for women in agriculture is growing (FAO, 2023). Women are using digitalization services to help solve the issues preventing them from realizing their full productivity and economic potential. Tsan *et al.* (2017) opined that the promise of revolutionary digitization has been extolled in the literature; realizing these objectives depends in part on the recipients' capacity to utilize newly developed digital services. However, there is still a dearth of information in African digitalization literature regarding the variables that could affect rural farmers' acceptance and usage of digital services compared to their male counterparts (FAO, 2019). Problems with societal institutions (including families, friendship networks, and social standing) and cultural norms (like gender roles, values, and attitudes) that hinder the growth of women in agriculture are referred to in this context as socio-cultural hurdles. Success in society is impeded for women in male-dominated nations because of profoundly embedded, discriminatory cultural norms, attitudes, behaviors, and traditions (Kapinga and Montero, 2017). There are a number of root causes of the digital gender divide, including hurdles to access, affordability, education (or lack thereof) and lack of technological literacy, as well as inherent biases and socio-cultural norms that lead to gender-based digital exclusion. The study will fill a gap in the literature by providing a comprehensive analysis of socio-cultural factors specifically influencing women's participation in agricultural digitization within the context of Zangon Kataf Local Government Area of Kaduna State, Nigeria. It will offer insights into the unique socio-cultural dynamics that shape women's engagement with digital agricultural technologies in this specific geographic region, contributing to a deeper understanding of how to promote gender-inclusive approaches to agricultural digitization in rural Nigerian communities.

RESEARCH METHODOLOGY

The study was conducted in Zangon Kataf Local Government Area (LGA) of Kaduna State, Nigeria. Zangon Kataf LGA was purposively selected because, there were problems related to women participation and pilot study was conducted in the study area to check the existence of rural women’s participation towards agricultural digitalization. Multistage sampling had been used for this study. In this study, two sets of data were employed for the empirical analyses, primary and secondary data. The primary data were collected through field questionnaire administration and interview of 100 women farmers. Multiple Logistic regression model was used to assess the factors influencing rural women farmers’ participation in agricultural digitalization.

RESULTS AND DISCUSSION

Factors influencing women’s participation in Agricultural Digitalization

Multiple regression analysis of the data indicated in the Table show that eight (8) variables were significantly related to level of participation of women farmers in Agricultural digitization. The variables were gender roles and expectation, access to land, networks and support systems, decision-making power, access to education, age of farmers, social stigma and discrimination, and technological literacy.

Coefficient of gender roles and expectations was found to be positively related (0.231) to women participation in agricultural digitalization and significant at 1%. This means that female gender roles might limit women's access to education and technology, as they are often expected to fulfill domestic duties rather than engage in technology-related activities. This result agrees with the findings of Asamu *et al.* (2020) who found that women participation in agricultural production to be positively influenced by gender in Warri South Local government of Delta State Nigeria.

Coefficient of access to land was also found to be positively related (0.075) to women participation in agricultural digitalization and significant at 10%. This implies that the more women get access to land, the more they participate in agricultural digitalization.

Coefficient of networks and support systems was found to be positively related (0.052) to women participation in agricultural digitalization and significant at 5%. Limited access to supportive networks or mentorship opportunities for women in agriculture may hinder their ability to access information and resources related to digitization.

Coefficient of decision-making power was found to be positively related (0.031) to women participation in agricultural digitalization and significant at 1%. In some societies, women have limited decision-making power within households or communities and hence impede their ability to adopt or invest in agricultural digitization.

Coefficient of access to education was also found to be positively related (0.054) to women participation in agricultural digitalization and significant at 10%. Limited access to quality education, particularly in rural areas, can hinder women from acquiring the necessary skills to engage with digital tools in agriculture. This agrees with Kapinga and Montero (2017) who suggested access to education to one of the most needed factors in adopting technology in agriculture.

Coefficient of age of farmers was also found to be positively related (0.022) to women participation in agricultural digitalization and significant at 10%. Younger are more active in adopting agricultural digitalization compared to the older women.

Coefficient of social stigma and discrimination was also found to be positively related (0.007) to women participation in agricultural digitalization and significant at 1%. Societal prejudices and stigmas against women's involvement in certain sectors or roles might discourage their active participation in agricultural digitization initiatives.

Coefficient of Technological Literacy was also found to be positively related (0.482) to women participation in agricultural digitalization and significant at 5%. Socio-cultural norms might discourage women from learning about or using digital tools and technologies, leading to a lack of familiarity and comfort with agricultural digitization. This agrees with Maksim *et al*. (2022) who in their study found technology influencing knowledge-based innovation and digital economy.

Table 1. Regression Analysis Result of the Factors influencing women's participation in Agricultural Digitalization

Variables	Estimated Coefficients	Odds ratio	Wald statistics	Significance level
Gender roles and expectation	0.231***	3.516	0.459	0.000
Work-Life Balance	0.301	2.113	0.553	0.612
Access to land	0.075*	0.681	0.219	0.098
Networks and Support Systems	0.052**	1.924	0.807	0.036
Household size	0.008	0.295	3.217	0.513
Marital status	0.443	0.200	0.717	0.183
Decision-Making Power	0.031***	2.675	0.114	0.000
Farming experience	0.023	0.648	0.119	0.435
Farm sizes	0.282	2.773	0.306	0.428
Cultural Norms and Beliefs	-0.776	1.928	0.554	0.577
Extension contact	0.102	1.611	3.080	0.664
Access to Education	0.054*	6.546	5.703	0.082
Age of farmers	0.022*	2.844	2.906	0.093
Access to Resources	0.099	3.523	3.826	0.790
Social Stigma and Discrimination	0.007***	3.112	2.254	0.000
Access to credit	0.223	0.779	0..371	0.543
Technological Literacy	0.482**	1.026	0.019	0.044
Language and Cultural Barriers	0.465	1.478	2.902	0.801
* = significant at 10%		R^2= 0.782		
** = significant at 5%		Adjusted R^2 =0.657		
*** = significant at 1%		F-ratio = 12.77		
NS=not significant				

Source: Computed from Survey Data (2023).

CONCLUSION

This study was carried out in order to determine the influence of socio-cultural factors on adoption of digitalization in agricultural production among women farmers, and it was found thatgender roles and expectations (0.000), access to land (0.098), networks and support systems (0.036), decision-making power (0.000), access to education (0.082), age of farmers (0.093), social stigma and discrimination (0.00) and Technological Literacy (0.044) positively influenced.

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Gender Participation in Agricultural Digitalization in Zangon-Kataf Local Government Areas, Kaduna State – Nigeria

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ABSTRACT

This research collected primary data by administering 80 structured questionnaires to rural women within their communities, focusing on the domain of agricultural digitalization in the Zangon-Kataf Local Government Areas of Kaduna State, Nigeria. The data analysis employed various statistical methods, including descriptive statistics (frequency, percentage, mean and standard deviation), correlation analysis to investigate the relationship between education level and digitalization engagement, Analysis of Variance (ANOVA) to identify factors contributing to rural women's ability to promote agricultural digitalization, and chi-square tests to assess the association between challenges/prospects and effectiveness in promoting agricultural digitalization. The findings revealed that 46.2% of respondents belonged to the 46 to 60 years age group, 38.7% had a higher educational level, 30.0% were classified as 'married', 37.5% identified farming as their primary occupation, and 46.3% reported a higher percentage of women earning below N50. The tested hypotheses indicated a moderate to weak negative correlation of -0.140, illustrating the relationship between variables such as the level of education and involvement in digitalization activities. In conclusion, the study unveils significant socio-economic characteristics of rural women in the study area, providing valuable insights into their demographic profile and pivotal role in advancing agricultural digitalization. The research recommends that telecommunication companies, educational institutions and community-based organizations implement digital literacy programs tailored to the unique needs of rural women.

INTRODUCTION

In recent years, the global agricultural landscape has undergone a significant shift toward digitalization, departing from traditional farming methods. This transformative process involves integrating advanced technologies into various agricultural aspects to enhance efficiency, productivity and sustainability on a global scale (Trendov *et al.*, 2019; Sraboni *et al*., 2014). The advent of digital technologies in agriculture has created new possibilities, particularly regarding the roles of rural women in this evolving landscape (Jones, 2019; Huyer, 2016). Despite their historical contributions to crop cultivation, livestock management and household well-being, rural women have often been overlooked as unrecognized heroes in the agricultural sector (FAO, 2011). Recognizing their indispensable role, there is a growing need to explore and consider the specific contributions of rural women to agricultural digitalization, a fact that remains largely unexplored. This knowledge gap presents a challenge in developing targeted strategies to empower rural women in the digital agriculture era, hindering the potential for inclusive and sustainable development (Paidakaki *et al*., 2022).

The existing research falls short in investigating the socio-economic characteristics of rural women in the context of digital agriculture, limiting policymakers' and development practitioners' ability to create effective, targeted policies and interventions (Akter *et al.*, 2017). The absence of tailored strategies restricts rural women's capacity to fully leverage digital technologies, thereby impeding digitalization's overall impact on agricultural productivity and sustainability (Smith *et al*., 2020). This research gap extends beyond policy challenges, affecting broader goals of inclusivity and sustainable development. Urgent and broad research initiatives are necessary to uncover the unique challenges faced by rural women, including their digital literacy levels and the factors influencing their technology adoption (Mittal and Mehar, 2016). The emergence of digital technologies offers opportunities for rural women to redefine their roles in farming and actively participate in smart farming and precision agriculture (Rhavi and Narayanan, 2020).

Rural women form an integral part of the backbone sustaining food production and community well-being (United Nations, 2019). However, a substantial gap exists in considering their pivotal roles in advancing agricultural digitalization within their communities. This knowledge gap poses a significant challenge in developing targeted strategies for their empowerment. The existing research also falls short in exploring their socio-economic characteristics in the context of digital agriculture, presenting challenges for policymakers and practitioners in creating effective interventions (World Bank, 2022). The lack of tailored strategies limits rural women's potential to fully leverage digital technologies, hindering digitalization's overall impact.

The implications extend beyond policy challenges, encompassing broader inclusivity and sustainable development goals. Addressing this issue requires urgent research initiatives to uncover rural women's unique challenges, digital literacy levels and factors influencing technology adoption (FAO, 2020). This study aims to contribute to filling this crucial gap and provide perceptions to inform policies and interventions for empowering rural women in digital agriculture. Integrating digital technologies into agriculture holds immense potential for revolutionizing farming practices, offering opportunities for increased yields, efficient resource utilization and overall livelihood improvements (Davis *et al*., 2021). However, understanding how rural women navigate and contribute to this digital landscape becomes crucial in ensuring a sustainable, efficient and socially equitable global food system.

METHODOLOGY

The Study Area

The researchers conducted a survey in the year 2024 in Zangon-Kataf LGA of Kaduna State. The area is located between $9^o25^/$ N – $10^o20^/$ N and longitude $7^o45^/$ E – $8^o40^/$ E is bounded by Kaura LGA in the North, Jama'a in the South, Kachia in the West and Kauru LGA in the East (Agbese, 2015). The population size is 316,370 persons – with women constituting 49.22% of the total figure (NPC, 2007).

Sampling Technique and Sampling Size

Multi-stage sampling technique was employed to select samples for the study. In this survey, firstly purposive sampling was used to select all the Chiefdoms in the area, Anghan, Atyap, Bajju and Ikulu (Appendix 1). Secondly, random sampling was employed to obtain two districts each from the chiefdoms. Thus, eight districts were surveyed. They were Yangal and Kangun in Anghan, Manchong and Kibori from Atyap, Fadan Kaje and Afana in Bajju as well as Ampaga and Fansil in Ikulu. Then, for each district, stratified random sampling technique was used to select 80 women respondents aged 20 to 70 years with different educational backgrounds and occupations. This made a total sample of 80 questionnaires administered to the 80 respondents in the study area. For the second phase of data-collection, four groups of women from the four chiefdoms, one from each district were selected for an in-depth interview. Each group comprised of 5 to 10 women. In the third stage, ten (10) women were purposively selected from each of the districts (5 farmers from those involved in promoting agricultural digitalization only and the remaining five concerns those not involved in promoting agricultural digitalization) to give a total of 80 respondents for the analysis. This forms the sample size of the study represented by a proportional allocation of 10% (0.1) across board (Table 1).

Table 1: Sample Size and Sample Frame

Chiefdoms	**Districts**	**Sample Frame**	**Respondents:** Women involved in promoting lifelong education only	Women not involved in promoting lifelong education	Sample Size (10%)
Anghan	Yangal	104	5	5	10
	Kangun	96	5	5	10
	Sub-total	*200*	*10*	*10*	*20*
Atyap	Manchong	103	5	5	10
	Kibori	98	5	5	10
	Sub-total	*201*	*10*	*10*	*20*
Bajju	Fadan Kaje	103	5	5	10
	Afana	99	5	5	10
	Sub-total	*202*	*10*	*10*	*20*
Ikulu	Ampaga	102	5	5	10
	Fansil	96	5	5	10
	Sub-total	*198*	*10*	*10*	*20*
	Grand-total	**801**	**40**	**40**	**80**

Source: Field Survey Data, 2024.

Saunders *et al*. (2007) encouraged that a sample size of 10% or more would usually result in a sampling distribution that is very close to the normal distribution and the larger the absolute size of a sample, the closer its distribution would be to the normal distribution.

Method of Data Collection

This study employed a combination of primary and secondary data to form the foundation of its information. Primary data were gathered through the administration of 80 structured questionnaires. Additionally, secondary data were acquired and compiled from District Heads and administrators of non-formal learning centers in each sampled district to enrich the survey dataset. These centers played a crucial role in facilitating data collection from the women participants. A copy of the questionnaire was administered to those women who possessed strong reading and writing skills. For those who faced challenges in reading or writing effectively, interviews conducted by the researchers provided an alternative method of data collection.

Method of Data Analysis

In analyzing the data for this study, simple descriptive statistics such as frequency, percentage, mean and standard deviation were employed. The relationship between the level of education and engagement in digitalization activities was explored using correlation analysis.

RESULTS AND DISCUSSION

Socio-economic Characteristics

Age group: The study reveals that 46.2% of respondents were in the 46 to 60 years age group, which had the highest percentage, while only 6.3% were women between 18 to 30 years old, the lowest percentage (Table 2). The higher percentage for the 46-60 age group indicates that the product/service resonates more with this middle-aged demographic compared to younger or older age groups. In general, higher percentages in a specific age range often signal that the underlying attitudes, behaviours, or trends measured are more pronounced among that generational cohort versus others. Conversely, the lower percentage for women in the 18-30 age group could potentially suggest barriers or challenges for younger women entering certain industries, fields or the workforce in general. This research is in line with the findings of Parment (2013), who compared generational differences in consumer behaviors, supporting the interpretation that products/services resonate more with the 46-60 cohort. Similarly, Hooper (2017) highlighted workforce entry challenges for younger millennial women, aligning with the potential barriers suggested for women aged 18-30. In contrast, some studies suggest diminishing generational gaps in areas like technology adoption (Vogels, 2019), which could contrast the interpretation of distinct middle-aged preferences. Additionally, research by Yin (2005) found high workforce participation among younger urban professional women in emerging economies, contrasting the barriers for the 18-30 group observed in this study.

Educational level: In the study, 38.7% had a higher percentage for an educational level, while 6.3% had a lower percentage for no formal education (Table 2). A higher percentage of respondents attaining a certain educational level (example, high school, bachelor's degree or other related level) could mean that opportunities and access to that level of education are more widely available within that population. In general, a higher percentage for a given educational level points to the level's accessibility, societal prioritization, economic support structures, evolving generational trends or development goals at play within that context. A lower percentage in the "no formal education" category may suggest that more people in the study population have had opportunities to obtain at least some level of formal schooling compared to the past or other populations, indicating improved educational access and participation. In comparison, Barro and Lee (2013) found that higher educational percentages aligning with improved access, economic factors and generational shifts is consistent with their cross-country analysis. The UNESCO (2020) report's emphasis on higher percentages indicating better access, especially for disadvantaged groups, parallels the finding that a lower percentage with no formal education suggests improved participation. In contrast, Erasmus and Sonjica (2021) found persistently lower educational attainment in rural South Africa despite policies promoting access, contrasting the implications from the higher/lower percentage results. Additionally, Abuya *et al*. (2012) revealed demand-side constraints leading to lower percentages accessing education in Nairobi slums, in contrast to the supply-side focused interpretations.

Marital status: As illustrated in Table 2, 30.0% of the population falls under the "married" category, indicating a higher percentage, while 13.8% are classified as "widowed," reflecting a lower percentage. The prevalence of a higher percentage in the "married" category suggests a societal inclination where marriage is highly esteemed and regarded as the conventional or anticipated life path. This pattern aligns with cultural and social norms surrounding marriage prevalent in certain contexts (Rendall *et al*., 2011).

Conversely, the lower percentage in the "widowed" category may imply specific dynamics in marriage patterns. Potential factors contributing to this phenomenon could include a higher prevalence of individuals remaining single, increased divorce rates reducing the duration of widowhood, or a tendency for older widows and widowers to remarry (Rendall *et al*., 2011). Wu and Schimmele's research (2007) supports this notion, as their findings indicate a rising trend in divorce and remarriage among older adults, providing additional context for the lower percentage of widowed individuals in this study.

However, Daloğlu *et al*. (2019) present a contrasting perspective, suggesting that the prevalence of widowhood may be more common than implied by the interpretations provided here. Their study explores potential drivers such as cultural norms surrounding divorce and remarriage, contributing to a distinctive consideration of marital status dynamics. Carr (2004) further emphasizes that many older widowed adults choose not to remarry, challenging the assumption that a lower widowed percentage solely reflects remarriage trends. Thus, the analysis of marital status should consider various societal and individual factors, including cultural norms, divorce rates, and personal choices, as demonstrated by the diverse perspectives presented in the literature (Rendall *et al*., 2011; Wu and Schimmele, 2007; Daloğlu *et al*., 2019; Carr, 2004).

Primary occupation: In our study, 37.5% of participants identified farming as their primary occupation, with a smaller percentage choosing civil service roles. The larger proportion engaged in farming while also holding civil service positions suggests a trend of individuals diversifying their income sources. This dual occupation approach is seen as a strategic means to attain economic stability by combining earnings from agricultural activities with a consistent salary from civil service.

The lower percentage of women in civil service roles hints at a workforce structure where fewer women pursue careers in public service or administrative positions compared to men. This gender disparity may be influenced by various factors, including cultural norms, limited educational opportunities, and societal expectations surrounding gender roles in the workforce.

Conversely, the smaller percentage of individuals whose primary occupation is civil service implies that the predominant occupations in the community lie in sectors such as agriculture, manufacturing, services, or entrepreneurship. This suggests a diversified economic landscape where government employment does not heavily dominate and individuals pursue livelihoods in various fields.

Our findings are in agreement with the insights of Rendall *et al*. (2011), who investigated occupational dynamics within a specific population. Both studies recognize the significance of farming as a primary occupation, but our research introduces the unique dimension of individuals engaging in both farming and civil service concurrently. The suggestion that this dual occupation strategy serves as a mechanism for economic stability resonates with Rendall *et al*.'s emphasis on the multifaceted nature of occupational choices. The lower representation of women in civil service roles, as observed in our study, mirrors a potential workforce structure described by Rendall *et al*. (2011), offering insights into broader societal and cultural factors influencing gender distribution in various occupations. However, our study diverges from Rendall *et al*.'s findings regarding the percentage of individuals whose primary occupation is civil service, emphasizing the dominance of other sectors in our community.

Monthly Income Range: As depicted in Table 2, 46.3% of respondents reported a higher percentage for women earning below ₦50, while 3.8% indicated a lower percentage for respondents with incomes above ₦200 in the monthly income range. The elevated proportion of women below ₦50 stresses a significant segment of the female population facing financial vulnerability, with potential challenges in meeting fundamental needs such as housing, food, healthcare, and education. Conversely, the reduced percentage of respondents with incomes exceeding ₦200 suggests the presence of income inequality within the surveyed population, implying a concentration of individuals in lower-income brackets and highlighting disparities in economic well-being. This research is in consonance with the insights of the World Bank (2022), an institution renowned for its regular publication of reports and studies on global economic trends, including broad analyses of poverty and income inequality.

Table 2: Distribution of respondents according to Socio-economic Characteristics in Zangon-Kataf Local Government Area (n = 80)

Characteristics	Frequency	Percentage (%)	Mean	Standard Deviation
Age group:				
18-30 years	5	6.3	2.90	0.851
31-45 years	18	22.5		
46-60 years	37	46.2		
Above 61 years	20	25.0		
Educational Level:				
No formal education	5	6.3	-	-
Primary education	20	25.0		
Secondary education	24	30.0		
Tertiary education	31	38.7		
Marital Status:				
Single	28	35.0	-	-
Married	24	30.0		
Widowed	11	13.8		
Divorced/Separated	17	21.2		
Primary Occupation:				
Farming	30	37.5	-	-
Trading	26	32.5		
Civil servant	5	6.3		
Pensioners	19	23.7		
Monthly Income Range:				
Below ₦50	37	46.3	1.70	0.786
₦50 - ₦100	33	41.3		
₦101 - ₦200	7	8.7		
Above ₦200	3	3.8		

Source: Computed from Field Survey (2024).

Roles in Advancing Agricultural Digitalization

The study aimed to analyze the specific roles played by rural women in advancing agricultural digitalization such as digital training and capacity building, use of digital agriculture tools and applications as well as advocacy and awareness creation within Zangon-Kataf Local Government Area of Kaduna state. The null hypothesis (H_O) on no significant relationship between the specific roles played by rural women and the advancement of agricultural digitalization within the study area was tested. The correlation coefficients revealed a moderate to weak negative correlation of -0.140 for relationships between variables such as the correlation between the level of education and involvement in digitalization activities (Table 2). The negative sign indicates an inverse relationship, where as one variable increases, the other tends to decrease. Consequently, the null hypothesis (H_O) was rejected because it was significant at either the 0.05 level (2-tailed) or the 0.01 level (2-tailed). This result probably implies that the negative sign (-0.140) indicates an inverse relationship between the two variables. This means that as the level of education increases, the involvement in digitalization activities tends to decrease, or vice versa. A correlation coefficient of -0.140 is considered weak to moderate in strength. A correlation coefficient ranges from -1 to +1, with -1 indicating a perfect negative correlation, 0 indicating no correlation and +1 indicating a perfect positive correlation. A value of -0.140 is closer to 0 than to -1, suggesting a relatively weak negative correlation.

The correlation coefficients measure the strength and direction of a linear relationship between two variables. In this case, the negative correlation implies a linear decreasing trend, where higher levels of education are associated with lower levels of involvement in digitalization activities or lower levels of education are associated with higher levels of involvement in digitalization activities. However, further analysis and consideration of other variables would be necessary to draw more definitive conclusions and understand the underlying reasons for this negative correlation.

This result is in line with the findings of van-Dijk (2005) who discusses the concept of "digital skills" and how they are influenced by factors such as education, age, and socioeconomic status. He found that individuals with higher levels of education tend to have better digital skills, which can lead to greater engagement with technology and digital activities. However, van-Dijk (2005) also acknowledges that there can be variations in technology adoption patterns within different educational levels. In some cases, individuals with lower levels of education may be more involved in certain digitalization activities due to factors such as occupational requirements or personal interests.

Another relevant study is "Digital Divide and Digital Literacy Among Adult Learners of a Rural Community in the United States" by Ramirez *et al*. (2021). This study found a positive correlation between education level and digital literacy but also highlighted the influence of age and socioeconomic factors on technology adoption and usage.

In contrast to the findings in the study, a study by Eszter and Amanda (2008) reported a positive correlation between education level and engagement with certain online activities, such as seeking information for school or work. So, it is important to note that the relationship between education and digitalization activities can be complex and may vary depending on the specific context, population and activities under consideration. Further research and analysis would be necessary to fully understand the nuances and potential reasons behind the negative correlation observed in the study.

Table 2: Correlation Estimates relationships between variables such as the correlation between the level of education and involvement in digitalization activities (n = 80)

Correlation Variables	**Involvement in any agricultural digitalization activities in the community**	**Roles played in agricultural digitalization activities in the community**
Pearson Correlation	1	
Sig. (1-tailed)		
Pearson Correlation	-0.140	1
Sig. (1-tailed)	0.107	

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

CONCLUSION

This study unveils significant socio-economic characteristics of rural women in Zangon-Kataf Local Government Area, offering valuable perceptions into their demographic profile and their pivotal role in advancing agricultural digitalization. The age distribution discloses a predominant majority (46.2%) within the 46-60 years age group, signaling potential resonance of digital products/services with this middle-aged demographic. Conversely, the diminished representation of women in the 18-30 age group suggests barriers or challenges for younger women entering specific industries or fields. This observation coincides with existing literature stressing generational disparities in consumer behaviours and workforce entry challenges faced by younger individuals.

Concerning education, the higher percentage of respondents attaining specific educational levels implies increased accessibility, societal prioritization, and evolving generational trends. However, the identified weak negative correlation between education and involvement in digitalization activities challenges conventional assumptions, emphasizing the intricate relationship between education and technology adoption. This stresses the necessity for a nuanced approach in designing digital literacy programs tailored to the unique needs of rural women.

Marital status dynamics spotlight a higher percentage of married women, reflecting societal values around marriage. The dual engagement in farming and civil service suggests a strategic approach for economic stability. Nevertheless, the underrepresentation of women in civil service roles stresses gender disparities influenced by cultural norms and societal expectations. Interventions aimed at addressing these disparities should be targeted and culturally sensitive.

Monthly income ranges underscore disparities, with a significant percentage of women earning below ₦50, indicating financial vulnerability. The concentration of individuals in lower-income brackets accentuates the imperative for multifaceted economic interventions that address root causes. These interventions should empower women economically, enabling them to overcome financial challenges effectively.

The study also delves into the roles of rural women in advancing agricultural digitalization. The identified weak negative correlation between education and involvement in digitalization activities suggests a pressing need for tailored digital literacy programs. Strengthening support systems for women in agriculture and fostering collaboration with stakeholders can collectively create an enabling environment for promoting agricultural digitalization

RECOMMENDATIONS

Based on the findings, the following recommendations are proposed:

1. Youth Inclusion Programs should collaborate with government agencies, Non-Governmental Organizations and educational institutions to develop targeted programs and initiatives to address barriers faced by younger women (18-30) in entering industries or fields where digitalization is prevalent.
2. Government education departments, local community leaders and private sector partnerships should continue efforts to improve educational access, tailoring initiatives to specific needs and contextual factors.
3. Community and religious leaders, counseling services and legal aid organizations should recognize diverse factors influencing marital status dynamics.
4. Agricultural extension services, government commissions and entrepreneurial organizations should support initiatives encouraging dual engagement in farming and other occupations, addressing gender disparities in civil service roles.
5. Microfinance institutions, business development agencies and government social welfare programs should develop targeted economic interventions addressing disparities in monthly income ranges.
6. Telecommunication companies, educational institutions and community-based organizations should implement digital literacy programs catering to the unique needs of rural women.
7. Agricultural extension services, community leaders and government agencies should enhance support systems for women in agriculture, ensuring access to digital tools and information.
8. Community-based organizations, local government authorities and technology developers should recognize contextual nuances influencing challenges and prospects for promoting agricultural digitalization.

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The Assessment of Gender-Based Participation in Agricultural Digitization in Obi Local Government Area, Nasarawa State, Nigeria

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KEYWORDS

Constraints,
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ABSTRACT

Agriculture is recognized as an engine of growth at local and international levels as it has the potentials to improve food security of a country. Gender disparities in agriculture are mainly characterized by unequal access to agricultural inputs. The current wave of increased crisis over land tenure between farmers and herders in Nigeria calls for serious concern. Agricultural digitization has created a veritable opportunity for women to scale through modern day agricultural barriers. Therefore, we seek to address three major objectives, which are to; assess the factors affecting gender participation in agriculture, evaluate the level of agricultural digitization among farming households and determine gender-based constraints to agricultural activities in the study area. A total number of eighty (80) respondents were interviewed to generate the data for this research. The results revealed that majority (78.8%) of the household heads were male while (21.2%) were females. Furthermore, the result shows that men and women participated averagely in agricultural activities with the mean level of 2.48 and 2.43 respectively. On the adoption of agricultural digitization, result shows that majority of the respondents do not have access to digital tools and therefore, find it challenging to adopt new innovations. Also, the female gender faces more challenges that hinder them from participating in agricultural activities in the study area than men. The study therefore recommended that deliberate efforts needs to be put in place to enhance digitalization of agricultural activities among male and females in Obi LGA of Nasarawa State, Nigeria.

INTRODUCTION

Agriculture plays a significant role in economic prosperity of the world economy and has a vital importance in developing and underdeveloped countries. There is no doubt that this sector accounts for a small share of the global economy but still remains central to lives of the poor. 26.7% of the world population is directly employed in agriculture in 2019-2020 but just contributed 4% to global economic output (World Bank, 2020). It is recognized as an engine of growth at international levels as it has potential to improve food security of a country.

Gender disparities in agriculture are mainly characterized by unequal access to agricultural inputs (Kristjanson *et al.,* 2017). Pervasive inequality, especially over the ownership of agricultural land, continues to limit women's contribution to the household food baskets (Palacious-Lopez and Lopez, 2015). Most women do not have access to agricultural inputs, apart from their labour (Rufai *et al.,* 2018). Despite the pivotal role played by women in agriculture, very few women own and control productive resource. Such resources are land, credit, technical services, market outlets, information.

The current wave of increased crisis over land tenure between farmers and herders in Nigeria calls for serious concern, there is therefore the need for digital and sustainable technological advancement among gender while limiting ecological impact as suggested by Fatma *et al.,* (2018). Also, World Population Prospect (2012) proposed about 70 % increase in agricultural production through digitization. It can therefore be postulated that the advent of agricultural mechanization alone in Nigeria is no longer sustainable due to land degradation, pollution and loss of biodiversity, but incorporating digital innovations such as Artificial Intelligence (AI) and Machine Learning (ML) into agricultural mechanization has in no doubt brought about a paradigm shift that can lead to self-sufficiency Musa *et al.,* (2023).

Agricultural digitization has created a veritable opportunity for women to scale through modern day agricultural barriers, unlike in the past where there was no desired recognition despite their vital role in crop and livestock production in addition to their reproductive and community roles. It is against this background that we seek to assess the factors affecting gender participation in agriculture and agricultural digitization among farming households in Obi local government area of Nasarawa State, Nigeria.

MATERIALS AND METHODS

Study Area

Obi is a Local Government Area located in the southern part of Nasarawa State, Nigeria. It's headquarter is Obi town and has land area of 967 km^2 with a population of 148,874 (NPC, 2006). The inhabitants of Obi Local Government Area are predominantly farmers who are involved in the cultivation of food crops and rearing of livestock.

Sample and sampling techniques

A multi-stage sampling technique was used for this study. Obi Local Government Area consists of ten (10) electoral wards. First, from these electoral wards, four (4) electoral wards were selected using simple random technique. In each electoral ward, 20 household were randomly selected for the study and one individual was randomly selected to represent the household. The total number of eighty (80) respondents was used to generate data for the research. Structured questionnaire was constructed and administered to the respondents; the researchers personally administered the questionnaires to the respondents in the study area.

Validation and reliability of the research instrument

A test and re-test method was used to test for the reliability of the instrument. The gender involved in agricultural activities were randomly selected and questionnaire was administered to 10 (five male and five female) respondents through paper balloting from each of the ten (10) wards of the study area. Seventy (70) percent of pilot-test score was recorded, which shows that the result is positive and the questionnaire can be administered. The questionnaire was pilot tested, to show that the research instrument is reliable, that is, to guide the choice between alternative methods of collecting data, ordering the questions and wording. The ten (10) test-try respondents were not involved in the main study.

Data Analysis

Simple descriptive statistics such as frequency counts and percentages was used to classify the respondents into their respective socio-economic groups. Participation index was constructed using a 3 point Likert-type scale. The 3 points scale was weighed in order of importance from= 1; Never involved = 2; rarely involved = 3; Always involved. The respondents were asked to indicate their level of participation in the agricultural production activities.

RESULTS AND DISCUSSION

Socio-economic characteristics of the respondents in the study area

Tables 1 revealed that majority (78.8%) of the household heads were male while (21.2%) were females similar to findings of Sa'aondo *et al.,* (2024). This finding implies that participation in agricultural operations in the study area is mostly carried out by the males. The result of the demographic characteristics was also similar to that of Rotowa *et al.,* (2022) who works in the same area in 2022 this finding show that most of the respondents were within the age bracket of 21 – 30. Furthermore, the two results followed a similar trend for other demographic characteristics such as education status, occupation and their income level.

Table 1: Socio-economic characteristics of the respondents in the study area

	Variables	Frequency	Percentage
Sex	Male	52	78.8
	Female	28	21.2
	Total	80	100
Age	<20	3	3.8
	21-29	14	17.5
	30-38	28	35
	39-47	25	31.3
	48-56	8	10
	57-65	2	2.5
	Total	80	100
Marital Status	Single	30	37.5
	Married	46	57.5
	Divorced	3	3.75
	Widow/widower	1	1.25
	Total	80	100
Educational Level	Non formal education	14	17.5
	Primary school	2	2.5
	Secondary school	9	11.3
	Diploma/NCE	26	32.5
	HND/Degree	27	33.8
	Others	2	2.5
	Total	80	100

Source: (field survey, 2023)

Agricultural activities in the study area

The result in Table 2. shows that greater percentage of the male gender was always involved in the agricultural activities (crops) more than their female counterparts. This result is contrary to the findings of Uzokwe *et al.,* (2017), except that of irrigational activities as recorded in the Table 2.

Types of crops cultivated

The study revealed that most of the crops in the study area are cultivated by men except cowpea and millet which are mostly cultivated by female as shown in Table 3. This result is in line with the earlier report of Olakojo (2017) who reported that gender productivity gaps vary across selected crops and it is more pronounced in cassava, yam and maize production, while it is mild in other crops.

Agricultural activities in the study area (animals)

The study revealed that greater percentage of the male respondents are involved in fencing, culling, taking sick animals to veterinary, marketing of animals, record taking, tethering, vaccination and castration against women who mostly involved in feeding, given drinking water and cleaning of cages/pens. It shows in the Table 4, that men are involved in the agricultural activities (animals) more than their female counterpart in the study area.

Table 2: Agricultural activities in the study area (crop)

	Male			Female			
Agricultural Activities (crop)	**Never involved**	**Rarely involved**	**Always involved**	**Never involved**	**Rarely involved**	**Always involved**	**Total**
land clearing	8(16.7)	13(27.1)	27(56.3)	6(18.8)	11(34.4)	15(46.9)	80(100)
Tillage	9(18.4)	9(18.4)	31(63.3)	7(22.6)	9(29.0)	15(48.4)	80(100)
Planting	5(8.8)	10(17.5)	42(73.7)	4(17.4)	8(34.8)	11(47.8)	80(100)
Weeding	7(10.6)	10(15.2)	49(74.2)	3(21.4)	4(28.6)	7(50.0)	80(100)
Herbicide	5(7.9)	10(30.2)	39(61.9)	2(11.8)	7(41.2)	8(47.1)	80(100)
Pesticides	6(9.8)	18(29.5)	37(60.7)	3(15.8)	7(36.8)	9(47.4)	80(100)
Harvesting	7(11.3)	10(16.1)	45(72.6)	3(16.7)	5(27.8)	10(55.6)	80(100)
Processing	5(9.1)	12(21.8)	38(69.1)	5(20.0)	7(28.0)	13(52.0)	80(100)
Marketing	8(14.3)	13(23.2)	35(62.5)	4(16.7)	6(25.0)	14(58.3)	80(100)
Irrigation	17(29.8)	13(22.8)	27(47.4)	6(26.1)	5(21.7)	12(52.2)	80(100)

Source: Field survey, (2023)

Table 3: Types of cultivated crops

	Male		Female	
Cultivated crop	Frequency	Percentage	Frequency	Percentage
Sesame	25	5.77	17	3.93
Maize	40	9.25	37	8.54
Rice	43	9.93	33	7.62
Cowpea	12	2.77	21	4.85
Cassava	35	8.17	33	7.54
Millet	25	5.77	28	6.47
Yam	41	9.47	31	7.16
Others	5	1.15	7	1.62
Total	226	206.6	52	47.71

Source: Field survey, (2023)

Table 4. Agricultural activities in the study area (animals)

	Male			Female			
Activities	**Not involved (%)**	**Rarely involved (%)**	**Always involved (%)**	**Not involved (%)**	**Rarely involved (%)**	**Always involved (%)**	**Total (%)**
Feeding	4(5)	5(6.25)	19(23.75)	7(8.75)	4(5)	41(51.25)	80(100)
Watering	7(8.75)	9(11.25)	23(28.75)	3(3.75)	6(7.5)	32(40)	80(100)
Fencing	13(16.25)	18(22.5)	36(46)	2(2.5)	4(5)	7(8.75)	80(100)
Cleaning of cages	8(10)	16(20)	8(10)	6(7.5)	3(3.75)	39(48.75)	80(100)
Culling	14(17.5)	21(26.25)	29(36.25)	1(1.25)	5(6.25)	10(12.5)	80(100)
Taking sick animals to a vet	14(17.5)	18(22.5)	31(38.75)	0(0)	3(3.75)	14(17.5)	80(100)
Marketing of the animals	7(8.75)	15(18.75)	29(36.25)	4(5)	4(5)	21(26.25)	80(100)
Record taking	11(13.75)	14(17.5)	35(43.75)	3(3.75)	4(5)	15(18.75)	80(100)
Tethering	10(12.5)	21(26.25)	31(38.75)	3(3.75)	3(3.75)	12(15)	80(100)
Vaccination	13(16.25)	2(2.5)	37(46.25)	1(1.25)	18(22.5)	9(11.25)	80(100)
Castration	20(25)	12(15)	39(48.75)	3(3.75)	3(3.75)	3(3.75)	80(100)

Source: Field survey, (2023)

Level of Gender Participation (Participation Index) in agricultural activities

Table 3 shows the distribution of respondents based on their participation in different agricultural activities. Both male and female respondents were involved in agricultural activities at different stages from land clearing to planting, culling to veterinary services, although the women were more into processing with the men leading in culling practice. It can therefore be concluded that men and women participated averagely in agricultural activities with the mean level of 2.48 and 2.43 respectively. This result agree with Keough (1998), participation in agricultural activities is a multidimensional dynamic process that takes varying forms as people will participate in any activity that will be beneficial to them.

Table 3: Level of gender participation (participation Index) in agricultural activities

	Male				Female			
Agricultural Activities (Crop)	**Never Involved**	**Rarely Involved**	**Always Involved**	**Mean**	**Never Involved**	**Rarely Involved**	**Always Involved**	**Mean**
Processing	5 (8.8%)	10 (20.0%)	37 (71.3%)	2.54	3 (9.8%)	4 (14.6%)	21 (75.6%)	2.61
Harvesting	6 (11.3%)	8 (16.3%)	38 (72.5%)	2.52	3 (11.5%)	9 (30.8%)	16 (57.7%)	2.39
Marketing	8 (15.0%)	11 (21.3%)	33(63.7%)	2.69	2 (7.4%)	8 (29.6%)	18 (63.0%)	2.46
Planting	5(10.0%)	10(18.8%)	37(71.3%)	2.75	5 (17.5%)	6 (20.0%)	18 (62.5%)	2.68
Weeding	6(11.3%)	8(15.0%)	38(61.1%)	2.30	5 (16.7%)	6 (22.2%)	17 (73.8%)	2.50
Tillage	9(17.5%)	9(17.5%)	34(65.0%)	2.52	2 (7.9%)	6 (21.1%)	20 (71.1%)	2.46
land clearing	8(15.0%)	14(27.5%)	30(57.5%)	2.67	2 (7.9%)	3 (10.5%)	23 (81.6%)	2.50
Herbicide	5(8.8%)	16(30.0%)	32(61.3%)	2.60	4 (15.2%)	8 (27.3%)	16 (57.6%)	2.39
Pesticides	5(10.0%)	16(30.0%)	31(60.0%)	2.42	9 (33.3%)	6 (20.8%)	13 (45.8%)	2.21
Irrigation	16(30.0%)	12(23.8%)	24(46.3%)	2.10	3 (11.9%)	6 (21.4%)	19 66.7%)	2.29
Vaccination	5(7.5%)	11(12.5%)	36(31.25%)	2.27	3 (10.0%)	7 (12.5%)	18 (26.3%)	2.36
Culling	4(7.5%)	10(18.75%)	38(31.25%)	2.42	3 (11.3%)	4 (13.8%)	21 (17.5%)	2.36
Mean level				2.48				2.43

Farmers level of adoption and use of agricultural digitization in the study area

Figure 1 shows that 46.25% of the males and 26.25% of the female respondents have no access to internet while 11.25% of males and 3.75% of females who have access to internet. This means that majority of the respondents cannot access and adopt new technologies through the use of Internet of Things (IoT) including smart phones. This result implies that majority of the respondents do not have access to smart phone and therefore, cannot use it to adopt new innovations thereby hindering the performance development of agricultural activities. This result agrees with the findings of MMPR (2019) who reported that the absence of digital innovation hubs and other ICT public access spaces in rural areas is a major challenge of digitalization in many developing countries.

Digital tools used by the respondents in the study area

The study showed that few of the male (14.6 %) and also 8.4 % of the female respondents were always using digital tools in getting new information on improved farming techniques while 28.6 % of male and 15.8 % of female were not. This implies that digital tools are not yet available and accessible to the respondents in the study area, thereby hampering the digitization of agricultural development.

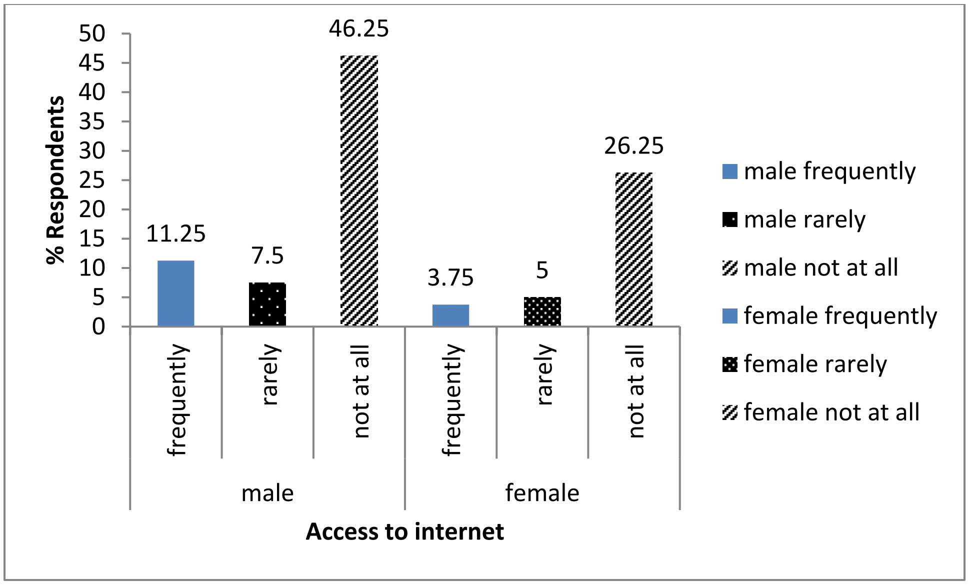

Figure 1: Percentage of respondents with access to Internet facilities

Table 4: Digital tools used by the respondents in the study area

Variables	Male			Female		
	Not involved (%)	**Rarely involved (%)**	**Always involved (%)**	**Not involved (%)**	**Rarely involved (%)**	**Always involved (%)**
Weather	38(73.08)	9(17.31)	5(9.62)	21(75)	4(14.29)	3(10.71)
New farming update	29(55.77)	11(21.15)	12(23.08)	18(64.29)	3(10.71)	7(25.0)
Communication with extension agent	41(78.85)	7(13.46)	4(7.69)	20(71.43)	5(17.86)	3(10.71)
Skills upgrade and training	32(61.54)	12(23.08)	8(15.38)	19(67.86)	4(14.29)	5(17.86)
Use of Radio	3(5.77)	5(9.62)	44(84.62)	1(3.57)	3(10.71)	24(85.71)
Mean	**28.6**	**8.8**	**14.6**	**15.8**	**3.8**	**8.4**

Source: Field survey, 2023

Constraints to gender participation in Agricultural Activities

The figure below shows that (98.1%) of the male respondents had the challenge of high cost of animal feed while that of female is (100%). Grazing route for animals, (94.2%) of the male respondents had the challenge while the female gender is (100%). In the same vein, (80.8%) of the male respondents had the challenge of encroachment by animals while it is (100%) for the female respondents. (90.4%) of male respondents had the constraint of space for rearing of animals while female (89.3%). On the whole, the male gender total mean percentage of challenge faced was (69.8%) while that of female counterpart was (88.29%) showing that the female gender face more challenges that hinder them from participating in agricultural activities in Obi Local Government Area of Nasarawa state, Nigeria, compared to male gender.

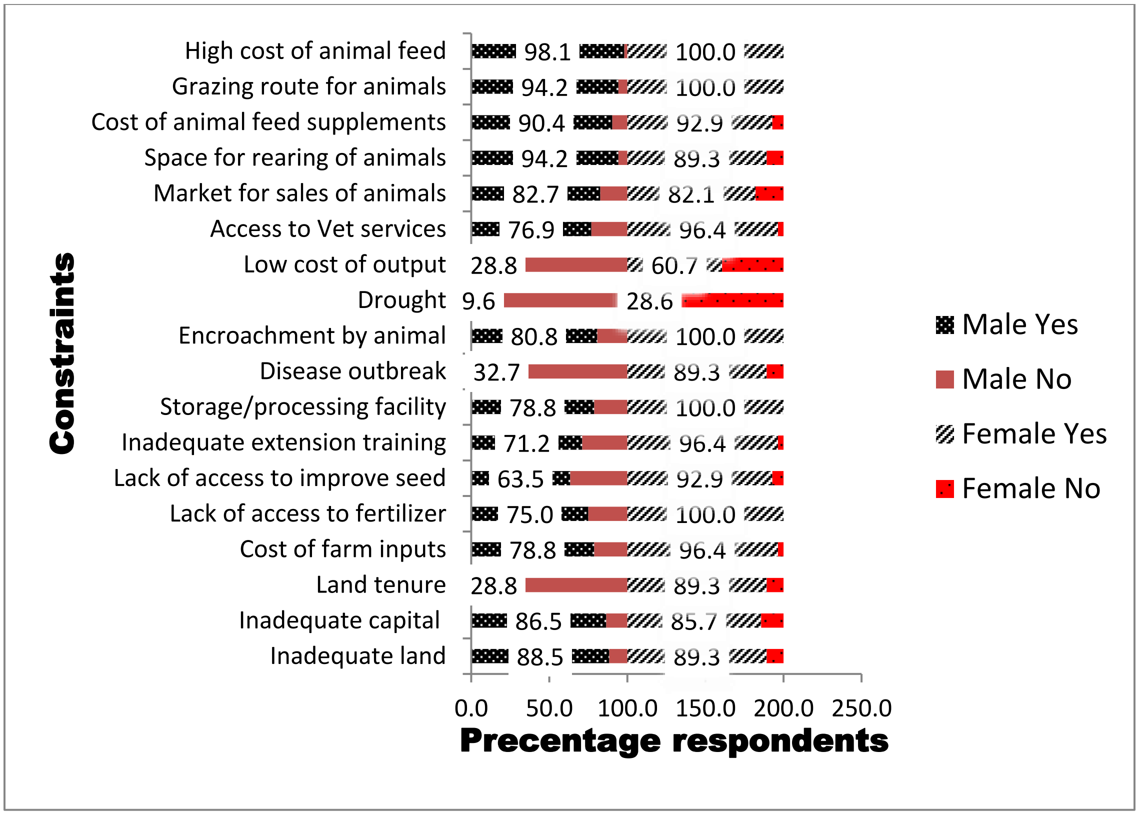

Figure 2: Constraints to Gender participation in Agricultural Activities. Field Survey 2023

CONCLUSION AND RECOMMENDATION

Based on the findings of this research, it was concluded that in terms of gender participation among farming households in the study area, the males were dominating in most of the agricultural activities than the females. However, the level of agricultural digitization among both gender is still low. Based on the findings of the study, it is recommended that strategies and approaches promoting gender equality in agriculture enhancing technology and access to productive resources (land, labour and capital) and economic opportunities should be devised and adopted among the community members.

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SUB-THEME FOUR

SUSTAINABLE AQUACULTURE: A LEAD WAY TO NATIONAL FOOD SECURITY, WEALTH CREATION AND NATURE CONSERVATION

Profitability of Catfish Production among Small holder Farmers in Awka South Local Government Area, Anambra State, Nigeria

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KEYWORDS

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ABSTRACT

Nigeria, fish farming, especially catfish production has been embraced by many, regardless of age and educational qualification. According to the Federal Department of Fisheries (FDF), fisheries subsector has made significant contributions to Nigerian economy. The broad objective of the study is to determine the profitability of catfish production among smallholder farmers in Awka South Local Government Area, Anambra State. Fish production in Nigeria is not on the same level as the rapid population growth of about 200 million; with the projection of above 200 million by 2030. Thus, there exists a great deficit of fish production in the country and the inability of this industry to meet up with the supply of fish consumed annually due to the fast growing human population. The production of catfish in Nigeria is given much attention as a result of its capability to fill the demand and supply gap. Catfish production is a sustainable aquaculture and therefore, it is a lead way to national food security, wealth creation as well as nature conservation A multi stage sampling procedure was adopted in the selection of the sample size. In the first stage, Awka South Local Government Area was selected because of the dominance of catfish production in the area. 100 catfish farmers were finally selected for the study. Descriptive statistics, gross margin analysis, multiple regression analysis and likert-type scales were used for data analysis. The study recommends that catfish is highly profitable and can contribute to food security and subsequently, economic development in Nigeria.

INTRODUCTION

In Nigeria, fish farming especially, catfish production has been embraced by many, regardless of age and educational qualification (Inoin *et al*., 2017). Nigeria is blessed with a large expance of water bodies, consisting of marine and fresh waters, which is about 900 kilometers and over 14 million hectares, respectively; out of which 75% of freshwater is suitable for fish farming (Adelaja *et al*., 2018). This has made Nigeria to become the largest producer of fish and fisheries products in sub-Saharan Africa and currently, second to Egypt in Africa (Bolorunduro, 2016). According to the Federal Department of Fisheries (FDF, 2016), fisheries subsector has made significant contributions to Nigerian economy.

In 2017, fish consumption per capita in Nigeria, rose to 13.3kg; although it is below the world's average of 20.5kg (FAO, 2018). With this, fish production in Nigeria is not on the same level as the rapid population growth of about 200 million; with the projection of above 200 million by 2030 (Adelaja *et al*., 2018). Thus, there exists a great deficit of fish production in the country and the inability of this industry to meet up with the supply of fish consumed annually due to the fast-growing human population (Adelaja *et al*., 2018). Umaru *et al*., (2021) opined that apart from fish being a major protein source, it is also recommended for those whose lives are threatened by cardiovascular diseases and other disorders, including rheumatoid, arthritis, diabetes, ulcer and renal diseases.

In Nigeria, the total annual demand for fish is estimated at 2.7 million metric tonnes (mmt). Just 30% of this demand is met domestically, resulting in an annual expenditure of N126 billion (US$625m) on fish imports. Nigeria's per capita fish consumption is 11 kg; this is significantly lower than the global average of 21 kg (NBS, 2016). With importation of more than 750,000 mt of fish, more than USD 600 million are spent on hard currency and thousands of jobs are exported (USAID, 2021). Catfish can easily be raised in warmer climates, both in fish ponds and tanks. The cultivation of catfish generally is becoming more popular by the day, as a result of its high market demand and health benefits. Raised catfish can be matured for harvesting at four months of age, thereby ensuring a quick business.

The production of catfish is given much attention today in Nigeria as a result of its capability to fill the demand and supply gap. Furthermore, it is known for its fast growth, high disease resistance, high prolificacy, omnivorous feeding, relatively cheap and environmental-friendly production (Ologbon *et al*., 2013). Catfish production is a sustainable aquaculture and therefore, it is a lead way to national food security, wealth creation as well as nature conservation. Several studies have been done on catfish production. A few of these studies examined profitability (Ugwumba and Chukwuji, 2010; Kassali and Mariana, 2011); technical efficiency of catfish production (Onoja and Chile, 2011; Emokaro and Ekunwe, 2009). Olajide (2016) carried out a study on the economics of catfish production in Osun State, Nigeria but to the best of my knowledge, this research is the first to establish the profitability of catfish production in Awka South Local Government Area of Anambra State. The major objective of the present study is to determine the profitability of catfish production among small holder farmers in Awka South LGA, Anambra State. Findings from this present study have therefore contributed to the scanty literature on the profitability of catfish production in Nigeria.

METHODOLOGY

Study area: The study was carried out in Awka South LGA of Anambra State, Nigeria. Anambra State is one of the states in Nigeria; it is located in the south eastern region of the country. It is located at Latitude 6 12′ 45N′ and 7 4′ 19′ E and Longitude 6.21269N and 7.07199E. It occupies a total land area of 144.5 Ha, with a population of 11 million residents (NPC, 2006). The state features two distinct seasons, which are the rainy and dry seasons, with an estimated total precipitation of about 2950mm. Average humidity is pegged at 70% while average temperature of the area is 27^0C.

The area is supports a wide range of farming activities, hence, it is predominantly occupied by farmers while its green vegetation supports livestock farming. Major crops grown in the area include food crops like yam, maize, cocoyam and cassava. Towns that make up Awka South Local Government Area include Amawbia, Awka, Ezenato, Isiagu, Mbaukwu, Nibo, Nise, Okpuno and Umuawulu. Anambra state has four Agricultural zones which are Awka south, Aguata zone, Anambra zone and Onitsha zone. Anambra state has 21 local government area which are; Awka south, Awka North, Dunukofia, Njikoka, Anicha, Anambra North, Anambra West, Oyi, Ayamelum, Orumba North, Orumba South, Aguata, Nnewi North, Nnewi south, Onitsha North, Onitsha South,Ihiala, Ekwusigo, Idemili North, Idemili South and Ogbaru.

Sampling Procedure and Sample Size:

A multistage sampling procedure was adopted in the selection of the sample size. In the first stage, Awka South LGA was selected because of the dominance of catfish producers in the area. All catfish farmers in Awka South LGA, formed the population of the study. In the second stage, 5 communities, which are Awka, Mbaukwu, Nibo Okpuno and Nise were randomly selected from the study area. In the third stage, 20 catfish farmers were randomly selected from each of the five communities; a total of 100 catfish farmers were selected for the study.

Method of Data Collection:

Primary data were used for the study. These were obtained through administration of a well-structured questionnaire to catfish farmers in the study area. The questionnaire contained pertinent questions that border on production pattern and inputs, socioeconomic characteristics of the producers as well as constraints faced by the farmers in catfish production. Questionnaire was administered by the researchers between February and May, 2023.

Analytical Tools and Techniques:

The following analytical tools were employed in the analysis

Descriptive Statistic: Frequency distributions and percentages, as well as mean distributions were adopted to describe the socio-economic characteristics of catfish farmers, describe catfish production pattern and constraints to catfish production in the study area.

Budgetary Analysis: Analysis of costs and returns was used to estimate the costs and returns while gross and net margins as well as rate of return on investment were used to measure the profitability of catfish production in the study area. Costs are expenses incurred during the operations of the production unit. Variable and fixed cost items used in the production were estimated. The depreciated values of the fixed cost items were also estimated. Revenue is the price per unit output multiplied by quantity of output. The gross margin of an enterprise gives the profit that is likely to be obtained from the production process. Afolami and Ayinde (2012) defined gross margin as the difference between the gross farm income (GFI) and the Total Variable Cost (TVC), while net farm income (NFI) was defined as the difference between gross margin and total fixed production costs. It is expressed as follows:

GM = TR – TVC
GM = TR – TVC
Where:
GM = Gross margim (N/Ha)
TR = Total Revenue (N/Ha)
TVC = Total Variable Cost (N/Ha)
And
NFI = GM – TFC
Farm Gross Ratio = GM/TR
Net profit (π) = Total Revenue (TR) – Total Cost (TC)
Rate of Returns (ROR) = (TR/TC)
Rate of Return on Investment (RORI) = (NM/TC)
Multiple Regression analysis: Multiple regression analysis was employed in the study, to determine the socioeconomic factors influencing catfish production in the study area. The regression functional analysis was used in four functional forms from which the lead equation was chosen on the basis of the values of the coefficient of Multiple Determination (R^2) as well as signs and significance of the regression parameters. This is used explicitly as:

$Y = a + b_1x_1 + b_2X_2 + X_n + e_i$

Where:

Y = Output

The regression function postulated for catfish production in the study area is shown in the explicit form, using four functional forms; the linear, semi-log, double log and exponential. The four functional forms were evaluated using the ordinary least square method. The explicit forms of the functional forms are as follows:

The model were explicitly specified as: linear, semi-log, Exponential and Double-log.

Linear: Y=b0+b1×1+b2×2+b3×3+b4×4+b5×5+b6×6+b7×7+e.......................(II)

Semi-log: Y=b0+b1log×1+b2 log X2+b3 log X3+b4 logx4+b5 logx5+b6 logx6+b7 logx7+log....(iii)

Exponential: log Y =Y=b0+b1×1+b2×2+b3×3+b4×4+b5×5+b6×6+b7×7+e.........................(iv)

Double-log: log Y=b0+b1log×1+b2 log X2+b3 log X3+b4 logx4+b5 logx5+b6 logx6+b7 logx7+loge......(v)

Likert scale rating technique

A likert scale is a psychometric scale in survey research. When responding to a likert questionnaire item, respondents specify their levels of agreement or disagreement on a symmetric agree - disagree scale for a series of item statement. The scale captures intensity of their feelings. A 4 - point rating scale was employed in this study. This was regarded as strongly agree (SA), agree (A), disagree (DA), and strongly disagree (SD), with corresponding values of 4, 3, 2, and 1 respectively. The mean score (MS) of the respondents based on the 4-point rating scale was computed as = 2.50 cut off point. Based on this, any score below 2.50 (MS<2.50) was taken as a weak factor and may not be considered while those with mean score of above 2.50 (MS>2.50) were taken as strong factors and thus be considered.

RESULTS AND DISCUSSION:

Socioeconomic Characteristics

The result of data visualization for the socioeconomic characteristics of the catfish producers in Awka South LGA is presented in Table 4.1. The information in Table 4.1 is discussed as:

Sex: the study revealed that the majority (64.0%) of catfish farmers are female, while the remaining 36.0% are male. This is an indication that catfish production in the area is dominated by women. This is against the observation of Ngeywo *et al*. (2015) who found that 82.5% of their respondents are male in socioeconomic and profitability analysis of catfish production in Nsukka, Enugu State.

Age: it was observed that a greater proportion of the respondents are within the age of 55 years and above, while the others are less than 35 years (28.0%), 45 – 54 years (20.0%), and the last 15.0% are 35 – 44 years. The average age of the farmers was found as 46 years. The farmers are mostly in their young and active age. The application of youthful energy will help to boost catfish production in the area.

Marital status: the table shows that the majority (61.0%) of the farmers are married, while the remaining 39.0% are single. This means that the enterprise is dominated by married respondents in the area. This result aligned with the assertion of FAO (2022) which noted that the catfish sector is also important for women and youth empowerment.

Experience: The study revealed a wealth of knowledge among farmers. Specifically, 44.0% of the farmers have 6-10 years of production experience. In contrast, 31.0% have less than 6 years of experience, 24.0% have between 11-15 years of experience, and a mere 1.0% have over 16 years of experience. On average, the farmers have approximately 8 years of experience. More experienced farmers are better equipped to identify and manage pests and diseases, which is crucial for the growth of the catfish sector (FAO, 2022).

Level of education: According to the study, 36.0% of the farmers had tertiary education, while 32.0% and 27.0% had secondary and primary education respectively. The remaining 5.0% had no formal education. The study suggests that the respondents are well-educated, which can help them understand the principles responsible for the growth of the sector. Education can also enable farmers to practice modern ways of catfish production.

Household: The study revealed that 49.0% of farmers have a household size ranging from 1-5 people, 46.0% have between 6-10 people, and a small 5.0% have more than 11 people in their households. On average, a farmer's household consists of approximately 6 people. Larger households can serve as a source of inexpensive labour supply.

Cooperative Membership: The study showed that 91.0% of the sampled catfish farmers are members of a cooperative. Being part of such an association aid in organizing their activities and enhancing their production experience. Conversely, the remaining 9.0% do not belong to any cooperative.

Access to Credit: The study also indicated that 89.0% of the farmers have access to formal credit. In contrast, the remaining 11.0% lack access to such credit facilities. Having access to credit can help farmers upscale their production capacity.

Cost and Returns of Catfish Production

Table 4.2 presents information regarding the cost and returns of catfish production in the study area. According to Danielle (2021), cost and returns analysis is a method used to compare the costs and benefits of various projects, policies, or actions. This approach is essential as it aids in decision-making, engages stakeholders, solves problems, and identifies areas for enhancement. The study determined that the sales revenue from mature catfish over a six-month period amounted to N2,149,082.25. The operating expenses, which represent the variable cost associated with producing marketable catfish, amounted to N1,706,126.15. Consequently, the profit margin derived by subtracting the operating expense from the sales revenue was N442,956.10. Additionally, depreciation on fixed costs for production was N14,386.75. When combined with operating costs, the total production cost reached N1,720,512.90. Notably, the net return stood at N428,569.35. An intriguing observation was the profitability index, which showcased a ratio of 79.4% when comparing operating expenses to sales revenue. This ratio indicates the portion of the gross profit that can fund the next production season's operating expenses. The return on investment (ROI) was 0.25, suggesting that for every N1 investment in the sector, farmers gain an additional N0.25. This ROI is notably close to the 0.19 figure reported by Olasunkanmi (2013). These results align with Emaziye *et al*. (2020), who emphasized that catfish production is indeed a lucrative endeavor.

Socioeconomic Determinants of Production Output

Table 4.3 presents the socioeconomic factors influencing production output. Out of the four potential production functions assessed, the Double-log regression model was selected as the primary equation. The analysis was conducted using RStudio version 4.3.1. This analysis yielded an Adjusted R-square value of 0.828, signifying that 82.8% of the variability in catfish production output can be explained by the chosen explanatory variables. The remaining 17.2% can be ascribed to factors outside the farmers' control, such as high inflation, pests, diseases, and other external influences. Furthermore, the F-statistics value of 54.07***, significant at the 1% level, indicates that at least one of the assessed variables has a significant impact on farmers' output.

A notable observation was the age coefficient, which stood at 0.150 and was negatively significant at a 5% probability level. This suggests that for each unit increase in a farmer's age, catfish output would decline by 0.150 units. This result underscores the relationship between age and risk avoidance: older farmers might find it challenging to handle the demands of catfish production.

Marital Status Coefficient: The coefficient for marital status was determined to be 0.078, positive and significant at the 5% probability level. This suggests that the inclusion of one more married farmer would enhance the overall farmers' output by an additional 0.078 units. This rise might be attributed to the increased labor supply typically observed among married individuals.

Education Coefficient: The coefficient for education stood at -0.011 and was found to be significant at the 1% level. This means that with each unit increase in the number of farmers advancing in educational qualifications, there is a decrease in the farmer's output by 0.011 units. Contrary to initial expectations, the data indicated that individuals with higher educational qualifications in the area tend to seek white-collar jobs rather than engage in catfish farming.

Household Size Coefficient: The coefficient for household size was -0.041 and was significant at the 10% probability level. This implies that for each unit increase in household size (i.e., people sharing meals from the same source), the farmer's output diminishes by 0.041 units. Such a result suggests that a significant portion of the farmers' production might be set aside for family consumption, impacting the quantity of fish available for sale.

Cost of Feed Coefficient: With a coefficient of 0.341, the cost of feed was positive and significant at the 1% level of significance. This suggests that an increase of one unit in the cost of feed will augment output by 0.341 units. This further points to the efficiency of the fingerlings in converting feed. Moreover, it seems that farmers prioritize the quality of the feed over its cost, reflecting the idea that any added expense will be passed onto the final product.

Cost of Labor Coefficient: Standing at 0.157, the coefficient of the cost of labor was positive and significant at the 1% probability level. This indicates that a unit increment in available labor will enhance the output by 0.157 units. Within the region, labor is viewed as a critical component in catfish production.

From the analysis, the significant determinants influencing output in the area include age, marital status, education, household size, cost of feed, and cost of labor. Based on these significant variables, we reject the null hypothesis.

Constraints to Catfish Production

The challenges facing catfish production are detailed in Table 4.4. Data was collected using a 4-point Likert scale. A decision on each variable was based on a mean threshold of 2.5. This means that any variable with a mean score below 2.5 was considered to disagree with the identified challenges, while those scoring 2.5 or above were in agreement with the stated challenges. Out of the nine listed items, seven met or exceeded the mean threshold of 2.5.

The research pinpointed several significant challenges to catfish production in the area, along with their associated mean scores:

- Inadequate capital (M = 3.01)
- Unorganized marketing (M = 2.93)
- Pest and disease issues (M = 2.67)
- High cost of feeds (M = 2.77)
- Scarcity of fingerlings (M = 3.12)
- Inadequate extension services (M = 2.98)
- Limited space (M = 2.99)

With a grand mean of 2.71, it is evident that the majority of the outlined challenges resonate with the surveyed farmers. Additionally, the standard deviation of 0.83, which exceeds the 0.5 threshold, indicates varied responses from farmers concerning the challenges. This variability underscores the robustness and validity of this study's findings.

SUMMARY OF FINDINGS

Summary of Findings

Socioeconomic Characteristics: The study focused on the socioeconomic characteristics of catfish producers in Awka South LGA. The majority of catfish farmers were found to be female (64.0%). Most farmers were in the age group of 55 years and above, with an average age of 46 years, indicating a predominantly young and active demographic. The majority were married (61.0%), and 44.0% had 6-10 years of production experience. A significant portion (36.0%) had tertiary education, and 91.0% were members of a cooperative. Access to formal credit was high (89.0%), indicating potential for production capacity enhancement.

Cost and Returns of Catfish Production: The cost and returns analysis revealed that over a six-month period, sales revenue from mature catfish was N2,149,082.25. Operating expenses amounted to N1,706,126.15, resulting in a profit margin of N442,956.10. The net return was N428,569.35, with a profitability index of 79.4%. The return on investment (ROI) was 0.25, indicating a positive economic outlook for catfish production.

Socioeconomic Determinants of Production Output: The study employed a double-log regression model to assess socioeconomic determinants of production output. The model had an Adjusted R-square value of 0.828, indicating that 82.8% of the variability in catfish production output could be explained by the chosen variables. Significant determinants included age (negative impact), marital status (positive impact), education (negative impact), household size (negative impact), cost of feed (positive impact), and cost of labour (positive impact).

Constraints to Catfish Production: Challenges identified through a Likert scale included inadequate capital, unorganized marketing, pest and disease issues, high cost of feeds, scarcity of fingerlings, inadequate extension services, and limited space. The grand mean of 2.71 and a standard deviation of 0.83 indicated that these challenges were significant and diverse among surveyed farmers.

CONCLUSION AND RECOMMENDATIONS

he research provides valuable insights into the socioeconomic characteristics, cost and returns of catfish production, socioeconomic determinants of production output, and constraints faced by catfish farmers in Awka South LGA.

In terms of socioeconomic characteristics, the study highlights that catfish production in the area is predominantly led by women, contrary to findings in other regions. The majority of farmers are in their active age, married, well-educated, and members of cooperatives, which indicates a diverse and knowledgeable farming community. Access to formal credit is prevalent among the farmers, suggesting financial support for production activities.

The cost and returns analysis revealed a positive net return for catfish production, indicating its profitability. The profitability index and return on investment align with previous studies, reinforcing the notion that catfish farming is a lucrative venture. The study emphasizes the importance of cost and returns analysis in decision-making for farmers and stakeholders.

The socioeconomic determinants of production output, analyzed through a double-log regression model, underscore the influence of various factors. Age, marital status, education, household size, cost of feed, and cost of labor are identified as significant determinants affecting catfish production output. The findings provide valuable insights for policymakers and practitioners to tailor interventions that consider these determinants to enhance production.

The research also identifies key challenges faced by catfish farmers in the area. Inadequate capital, unorganized marketing, pest and disease issues, high cost of feeds, scarcity of fingerlings, inadequate extension services, and limited space are highlighted as major constraints. These challenges, with varying degrees of impact, indicate the need for targeted interventions to address specific issues and enhance the overall resilience of catfish farming in the region.

In conclusion, the study contributes significantly to the understanding of the catfish farming landscape in Awka South LGA. The findings provide a foundation for informed decision-making, policy formulation, and interventions aimed at improving the socioeconomic conditions of catfish farmers and fostering sustainable growth in the sector.

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Assessment of Consumer Preferences for Boiled, Smoked, and Barbecued Catfish (*Clarias gariepinus*) in Awka, Anambra State, Nigeria

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ABSTRACT

Acceptability of smoked, boiled and barbecued catfish by consumers are dependent on numerous factors. Consumer acceptability study allows industries to tailor the supply towards the preference of consumers so that market could be optimized for their turn-over and profits. This study investigated consumer acceptability of boiled, smoked and barbecued African catfish in Awka, Anambra state, Nigeria. A total of 70 questionnaires were administered adopting multi-stage techniques to elicit information from the respondents about socio-economic characteristics of respondents, determinants of consumer preference, forms of fish consumed, The obtained data were subjected to descriptive and inferential statistical analysis. The results showed that majority of the respondents in the study preferred barbecued catfish (47.15) irrespective of their socio-economic profile when compared to smoked catfish (40.0%) and boiled catfish (12.9%).It is recommended that efforts from government, private sectors and fish folks should be put into subsidizing the production inputs of catfish as this will in turn reduce price of catfish and encourage increased regular consumption of catfish.

INTRODUCTION

Fish and fishery products play an important role in food and nutritional security around the world. Fish has been an important dietary source of protein and other nutrients throughout human history. Moreover, fish has little or no religious rejection which gives it an advantage over pork and beef (Akinola *et al*., 2016). Beside from being very nutritious, the protein in fish is said to be very easy to digest. Fish fiber is shorter than those in beef and chicken (Angelina, 2019). This makes fish meat easily cooked and digested in the body, especially for the children. The content of saturated fat and cholesterol in fish is very low compared to chicken or beef. Saturated fat has been said to increase chances of getting heart diseases. Nigeria is the world's largest producer of catfish, one of the most commercially important freshwater fish species in Africa (Agupusi, 2022). The FAO statistics showed that the country's aquaculture production grew from 22,000 tonnes in 1999 to over 300,000 in 2017. According to Okechukwu (2022), the Federal Government of Nigeria announced that the number of Nigerians engaged in primary and secondary fish production across the country is over 10 million. Okechukwu (2022) further said that Nigeria's total demand for fish in general is 3.6 million tonnes annually, while we are producing 1.1 million tonnes from all sources (artisanal, aquaculture and industrial sectors), leaving 2.5 million tonnes of deficit.

The catfish (*Clarias gariepinus*) is a remarkable fish species in Nigeria, where it is the leading aquatic crop (Megbowon *et al,* 2014*)* . It has the credentials of fast growth, resistance to disease and handling stress. Catfish can be preserved, processed and consumed in different ways ranging from smoking, freezing, canning, barbecuing, frying, filleting etc. In Nigeria, frozen fish, smoked catfish and catfish barbecue are most popular.

Smoking is one of the oldest methods of fish preservation developed in prehistoric period. In recent times smoking is used as a method of preservation with the incorporation of smoke flavour and development of colour. Dipanjan *et al.* (2017) states that in under-developed countries this method is used as a means of preservation only, while in developed countries this method is used to impart smoke flavour to the product since in these countries there are other sophisticated means of preservation of fish. Smoking is a method of preservation effected by the combination of drying, deposition of naturally produced chemicals resulting from thermal breakdown of wood and salting (Dipanjan *et al,* 2017). All these three factors help in preservation of fish. Smoked fish is ready to eat and has great demand in western sophisticated markets. Smoking is also used as an intermediary step in the preservation of canned smoked fish. Here before canning, fish is smoked to impart smoky flavour. Smoke is a good preservative since it contains bacteriocidal and antioxidant properties. According to Marit (2023), the composition of omega-3 fatty acids calculated as a percentage of the total lipids [fats] does not change during the smoking process. Around 2% of the total world catch is used for preparing smoked fish all over the world.Barbecue fish refers to any type of fish cooked over high heat on a wood pellet, gas, charcoal, or electric grill (Beverly, 2022). Grillers often coat fish with barbecue sauce towards the end of its cook time to infuse it with extra smoky flavor. Grilling can be used to enhance the value of fish to produce barbecued fish which is a recent delicacy in the study area.

Catfish (*Clarias gariepinus*) so far has being the most available species in Nigeria that suits the tropical region for culture in aquatic environment and is also a cheap and the most acceptable animal protein to the common man. It provides upto 40% of animal protein consumed by an average Nigerian (FOS, 1990: Fegbenro, 2014). Due to its wide spread availability in Nigeria, different forms and ways of consuming, preservation and processing of this catfish has been developed. The citizens of Awka, Anambra state is faced with three choices; either they preferred consuming the boiled *Clarias gariepinus*, the barbecued *Clarias gariepinus* or the smoked *Clarias gariepinus*. The preference of each individual depends on a number of factors which includes but no limited to: family use, knowledge of Agriculture, general educational level, income, age, occupation etc.

The evaluation of consumers` preference for fresh, smoked or barbecued catfish product can be used for production planning and distribution of fish across the country (Adeniyi, 2020). This work looks into the functional relationship between the type of fish consumers chooses to consume based on some selected variables which will reflect the socio-economic status of the residents of Anambra state, thereby furnishing fisheries experts, Agricultural firms, those responsible for the allocation of Agricultural and Aquacultural utilities in the government, sociologists and even economists with information useful to their work.The main aim of this study is to evaluate the consumers preference on fresh, barbecued and smoke dried catfish (*Clarias gariepinus*) products in Awka, Anambra state.

MATERIALS AND METHOD

Description of Area of Study

Awka is the capital of Anambra state, Nigeria. It coordinates: Latitude 6.2220ºN and Longitude 7.0821ºE, with an estimated population of 2.5 million as of a 2018 estimate. The city is located at 199.1 kilometres (123.7 mi), by road, directly north of Port Harcourt in the center of the densely-populated igbo heartland in South-East Nigeria.The major farm produce dominated in Awka is the food crops such as Cassava, Yam, Plantain, Maize and varieties of fruit. The citizens of Awka also engage in Fish farming and livestock farming.

Methodology Survey

Questionnaires were the major tool for the survey, which were designed to capture and record responses to specific questions on consumers` preference for fresh, smoked and barbequed catfish. The surveys were carried out in Awka, Anambra state, Nigeria.

Sampling Procedures and Data Collection

The study was conducted in Awka, Anambra state of Nigeria. The population of the study involved catfish consumers of different status in Awka metropolis. The primary data were collected using structured questionnaires, which were administered by random selection of respondent across the study area.

Data Analysis

The data collected were analyzed using both descriptive and inferential (Chi square) statistics. The descriptive statistics used include: percentages and frequencies of distribution to show the socio-economic profile of respondents in the study area. Bar charts were used to show respondents perception on general catfish consumption. The inferential statistics used was Chi-square test of Association to find out the relationship that exists between the choice of African catfish consumed by consumers and various socio-economic attributes in Awka, Anambra state. All the analysis was conducted using SPSS version 23.

RESULTS

The frequency table for sex of the respondents in the study area are presented in Table 1.This descriptive analysis showed that the response of 29 males (41.4%) and 41 females (58.6%) were samples in this research with females forming majority of the respondents. For the age of the respondents (Table 1), respondents within the ages of 20 -29 years dominates in this sample with a total number of 35 respondent and a percentage score of 50.0%. There are 9 respondents within the ages below 20 years (12.9%); 15 respondents within the ages of 30-39 years (21.4%); 6 respondents within the ages of 40-49 years (8.6%) and 5 respondents within the ages of 50 and above (7.1%). The marital status of the respondents as presented in Table 1 revealed that majority of the respondents for this research are the single group with a total number of 43, with percentage score of (61.4%). The total number of respondents who are married are 25 in number (35.7%) while the total number of respondents who are divorced and widowed is 1 each and having a percentage score of (1.4%) each. The household size of the respondents are presented in Table 1. The results indicated that the household size that are below 4 are 26 in number (37.1%), while those on 5-8 are 41 in number (58.6%); those on 9-12 are 3 in number (4.3%).

The income range of the respondents are presented in Table 1.Total number of respondents with the income range below ₦10,000 is 6 with a percentage score of (8.6%). Respondents with income range within ₦10,000 -₦ 50,000 dominates with a total of 32 (45.7%) while those within ₦50,000 - ₦150,000 are 12 in number (17.1%); those within ₦150,000 -₦ 250,000 are 9 in number (12.9%); those within ₦250,000 - ₦400,000 are 8 in number (11.4%) and lastly, those with income range above ₦ 400,000 are 3 in number (4.3%).The educational level of the respondents are presented in Table 1. The respondents that fall within B.Sc/HND category has the highest occurrence in this sample with a total count of 39 and a percentage score of 55.7%. Respondents within FSLC category are 3 in number (4.3%); within SSCE/Equivalent category are 16 in number (22.9%) within NCE/OND category are 5 in number (7.1%) while respondents within M.Sc/PhD and above category are 7 in number (10.0%). All respondents with a total number of 70 (100%) are Christians in the study area (Table 1).The frequency for the forms of African catfish preferred by respondents are presented in Table 2, the respondents (12.9%) prefer consuming boiled catfish, while 28 respondents (40.0%) prefer consuming smoked catfish and 33 respondents (47.1%) prefer consuming barbecued catfish. The result shows that the major reason for choosing the different forms of African catfish is taste, with a total response of 57 (81.4%). Those that chose cheap are 3 in number (4.3%) while respondents that chose how it looks and availability are 5 each (7.1%). The rate of catfish consumption in the study area is shown in Table 2, from the results, majority (48.57%) of the respondents consumed catfish on a regular basis, followed by those that consumed occasionally (30.0%) and those who rarely consume fish (18.57%), while those who are indifferent to fish consumption had 2.86%. The challenges affecting catfish consumption by the respondents in the study area are presented in Table 2. Price of the fish (50.0%) and income of the respondents (28.57%) were the major constraints affecting catfish consumption by the respondents in the study area.

Table 1: Socioeconomic Characteristics of Respondents in the study Area

Attributes	**Frequency**	**Percent (%)**
Sex		
Male	29	41.4
Female	41	58.6
Total	70	100.0
Age		
Below 20	9	12.9
20 - 29	35	50.0
30 - 39	15	21.4
40 - 49	6	8.6
50 and Above	5	7.1
Total	70	100.0
Marital Status		
Married	25	35.7
Single	43	61.4
Divorced	1	1.4
Widowed	1	1.4
Total	70	100.0
Family Size		
Below 4	26	37.1
5 - 8	41	58.6
9 - 12	3	4.3
Total	70	100.0
Educational Level		
FSLC	3	4.3
SSCE/Equivalent	16	22.9
NCE/OND	5	7.1
B.Sc/HND	39	55.7
M.Sc/PhD and above	7	10.0
Total	70	100.0
Income Range		
Below ₦10,000	6	8.6
₦10,000 -₦ 50,000	32	45.7
₦50,000 - ₦150,000	12	17.1
₦150,000 -₦ 250,000	9	12.9
₦250,000 - ₦400,000	8	11.4
Above ₦ 400,000	3	4.3
Total	70	100.0
Religion		
Christianity	70	100.0
Islam	0	0.00
Traditional	0	0.00
Total	70	100.0

Source: Field Survey, (2023)

Table 2: Preferrence, Rate and Challenges of Catfish Consumption

	Response	Frequency	Percent (%)
African Catfish Preference by Respondents in the Study Area	Boiled Catfish	9	12.9
	Smoked Catfish	28	40.0
	Barbecued Catfish	33	47.1
	Total	70	100.0
Reason for Preferred Catfish by Respondents	Cheap	3	4.3
	Taste	57	81.4
	How it looks	5	7.1
	Availability	5	7.1
	Total	70	100.0
Rate of Catfish Consumption by Respondents	Regularly	34	48.57
	Occasionally	21	30.00
	Rarely	13	18.57
	Indifferent	2	2.86
	Total	70	100.0
Challenges Affecting Catfish Consumption by Respondents	Income	20	28.57
	Price	35	50.00
	Availability	5	7.14
	Hygiene	10	14.28
	Religion	0	0.00
	Traditional belief	0	0.00
	Total	70	100.0

Source: Field Survey, (2023)

DISCUSSION

It was reported that socio-economic factors such as educational level, household size and the number of household members working, price of the commodity, occupation, age and expenditure on other food and non-food items could influence household consumption behaviour (Adeniyi *et al*., 2012; Adeleke *et al*., 2020). This result is similar to the report that the size of households, gender, taste and the nutritional value of fish significantly influenced the purchasing behaviour of people among Malaysian consumers (FarahAhmed *et al.,* 2011). Family size had been identified as one factor affecting the preference and consumption of fish products (Sari and Muflikhati, 2018). In this study, the females prefer barbecued catfish. This can be attributed to the delight females attach to food, cravings and higher nutrient requirement by a female (Sandra, 2021). A percentage total of 50.0% of the respondents are around the ages of 20-29. This may be due to easier co-operation when it has to do with response. Respondents who are below 20 and within the ages of 20-29 are observed to prefer barbecued catfish. This can be attributed to the fact that barbecued catfish is a more recent form of fish processing as opposed to smoked and boiled catfish which have been practiced for ages in Nigeria (Chukwuemeka, 2019). This supports the indication that respondents within ages of 30 and above would readily prefer smoked catfish. Although, respondent within the ages of 30-39 has slightly varying preference for the three catfish forms. Canm *et al.* (2015) observed that age group had significant influence on catfish consumption preference.

Marital state have been reported to influence catfish consumption as seen in this study. According to Idris *et al*, (2018), the married group would experience increased purchases and increased consumption due to household expansion and greater responsibility, therefore, smoked fish which is mostly used to prepare soup and other food comes first in scale of preference. Income of respondents appears to have no association with choice of catfish to consume (p=.363). This result is in support of the report of Musa and Ala (2013), that respondents consume any form of catfish of their choice regardless of their income. The majority of the respondents preferred barbecue catfish in the study area. What majority of the respondents liked about the fish was its taste. Taste, health benefits, nutrition, price and availability are identified factors guiding consumption behaviour (Kumar *et al*., 2008). Fish quality such as taste, health benefits, nutrition, price and availability are factors that could influence consumers' preferences (Dalhatu and Ala, 2011, Kumar *et al.*, 2008). Price of the fish and income of the respondents were the major constraints affecting catfish consumption by the respondents in the study area. This results agrees with the findings of Adeniyi *et al*. (2012), who observed similar results among households in Ibadan North Local Government Area of Oyo State, Nigeria.

CONCLUSION AND RECOMMENDATIONS

Fish consumption is influenced by many factors and these factors mainly determine the consumers` acceptability for catfish. This study indicates that most of the respondents preferred barbecued catfish with a good number also having a preference for smoked catfish. Majority of the respondents agreed that taste is the main reason for making their preferencesS. Price and income level were agreed by the respondents to be a challenge to regular consumption of processed catfish. Based on the findings of this study, it is recommended that more effort should be made to maintain or improve on the taste of different forms of processed catfish as it largely determines how consumers consumes such form of processed catfish. Awareness measures should be taken to educate the populace about the nutritive components of various forms of processed catfish. Also, efforts from government, private sectors and fisher folks should be put into subsidizing the production inputs of catfish as this will in turn reduce price of catfish and encourage increased regular consumption of processed catfish.

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SUB-THEME FIVE

SOIL SMART AGRICULTURE FOR ECOSYSTEM SERVICES AND FOOD SECURITY

Economics of Poultry Manure Use as Fertilizer in Imo State

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KEYWORDS

Evaluation,
Imo state
Manure generation,
Poultry manure,
Sustainable development,

ABSTRACT

The study was carried out in three agricultural zones notably Owerri, Okigwe and Orlu to evaluate the economics of poultry manure use as fertilizer in Imo State, Nigeria. A total of 240 respondents were randomly selected and interviewed from twelve local government areas drawn from the three zones. Data collected were on socio-economic characteristics, stock size and manure generation, poultry manure and environmental pollution and economic consideration of recycling poultry droppings. Structured questionnaires were used for data collection. Analytical tools used were descriptive statistics such as mean, frequency distribution and percentages. The result of the survey revealed that the dominant players in the poultry industry are those between the ages of 41-50 years implying that in future, there will be decline in productivity since youths are not actively participating in the business. The survey observed that 78.33% of poultry farmers in the state stores poultry manure within the farm premises which directly contributes to environmental pollution. Result also shows that 70.83% of poultry farmers recycle poultry manure into vegetable production while those with larger output sell the excess to crop farmers. The economic benefit of recycling poultry manure by farmers for economic prosperity is high (90.83%) and this is traced from its role in conservation agriculture and soil enrichment. The study therefore recommends the use of poultry manure by all farmers as Nigeria can conserve its foreign exchange by reducing its fertilizer importation up to 50%.

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INTRODUCTION

Agriculture is the world’s oldest and largest primary industry and its role in the economic life of virtually all nations regardless of their state of development cannot be underscored (Brueno, 2020).One of the most important aspect of African or Tropical Agriculture is farm animal production which according to International Institute of Rural Reconstruction (IIRR) and African Conservation Tillage (ACT) provides power, manure, hides, milk and meat to improve the standard of living of the human populace (IIRR and ACT, 2005).

Livestock with particular reference to poultry production generates waste products which directly or indirectly not utilized constitutes environmental pollution. In the poultry industry, two main types of waste are produced depending on the rearing system adopted in the farm. They are waste from the deep litter systems and cage layer waste (Shibi Thomas *et al*., 2020). In developing countries like Nigeria, the technology for converting poultry waste into biogas or biofuel is yet to be developed hence the recycling as manure and landfill disposal.

Poultry manure (excreta) which is obtained from poultry or bird droppings is one of the best organic manures. Poultry manure is composed of poultry beads, feathers, water droplets, poultry feed and straws of rice husks which can be utilized to generate renewable energy (Agblevor *et al*., 2010). Yousaf *et al*. (2022) reported that animal manure has considerable potential as soil conditioners and fertilizers for the home gardeners, florists, crop farmers and nursery operators. Animal waste is therefore a valuable resource because it is high in salts, micro and macro elements. It contains thirteen (13) essential plant nutrients that are used by plants which include nitrogen, phosphorous, potassium, calcium, Magnesium, Sulphur, manganese, copper, zinc, chlorine, boron, iron and molybdenum (Shibi Thomas *et al*., 2020). Suffice it to say that using poultry manure as fertilizer provides both macro and micro nutrients to crops and plants for their growth and productivity.

European countries had achieved a milestone of 20% renewable energy in which biomass energy had major portion (Eurostat, 2019; World Bank, 2021), and these countries have set a target to achieve 30% of total electricity from renewable energy resources by 2030 (Agency, 2018). Sub-Saharan Africa and Nigeria in particular, the African giant is yet to acquire this modern technology of thermal conversion method (Pyrolysis) hence the resort to the application on agricultural land as fertilizer and landfills.

Sustainable agriculture ensures resource efficiency by integrating biochemical, economic and physical sciences to develop new practices that are safe, cost effective and environmentally friendly. However, such a system must support an ecosystem that accommodates and provides for the development of all classes of plants and animals (Si Ho Han *et al*., 2016).

Poultry manure fertilizer as a soil amendment to sustain crop yields in developing countries and the world all over has been found effective for major crops and also increases the soil's water infiltration rates directly proving the structure (Adeleye*et al*., 2010; Aniefo *et al*., 2013; Ishieze *et al*., 2019,)

A chicken will produce approximately 0.23 kilogramme of fresh manure from a kilogramme of feed consumed with a moisture content of about 75 percent (University of Georgia Extension News, 2022). The manure produced by poultry usually loses water due to evaporation, resulting to a final product of 20-40% moisture content depending on bedding type and quantity, birds' concentration, watering equipment and ventilation system.

Hamma *et al*. (2017) observed that 12t/ha poultry manure produced higher mean values of vine length, number of leaves, leaf area, fruit weight, girth and commutative yield of cucumber (Cucumis sativum) while Eze and Baiyeri, (2019) reported higher fruit yield/ha at the rate of 10t/ha but however, recorded decreased yield at a rate above 10t/ha. Ayeni *et al*. (2008) reported 30 and 43 percent increase on immediate basis, 73 and 93 percent on residual basis for poultry manure at 5t and 10t/ha on the production of crops. The impact of poultry manure on crop productivity was also measured by Ikeh *et al*. (2012) who observed significant impact on the application of 10t/ha compared than 0 and 4t/ha on plant height, number of leaves, branches and number of fruits.

Atusa (2018) recommended that 20t/ha should be adopted for the cultivation of Occimum gratissium. Furthermore, reiterated that plants that received different levels of 15t/ha, 20t/ha, 25t/ha and 30t/ha were not significantly different in the number of leaves, branches, total leaf area, weights of harvested leaves and inflorescences. Irene *et al*. (2015) opined that 6t/ha poultry manure best supports the performance of fluted pumpkin in the degraded ultisol.

In an experiment carried out by Si Ho Han *et al*. (2016) on the effect of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (Liriodendron tulipifera lin.) in a nursery system in the Forest Practice Research Centre of Korea Forest Research Institute, it was discovered that organic manure significantly increased the soil pH and the concentration of nitrogen, available phosphorus, exchangeable potassium, calcium and magnesium.

In Imo State, it appears that poultry manure is not used to its maximum potential because of dearth of information on its economic value as a source of plant nutrients, failure to recognize how and where to use it and the inability of crop and poultry farmers early adoption of this innovation as a strategy for environmental sustainability and hence the relevance of this study.

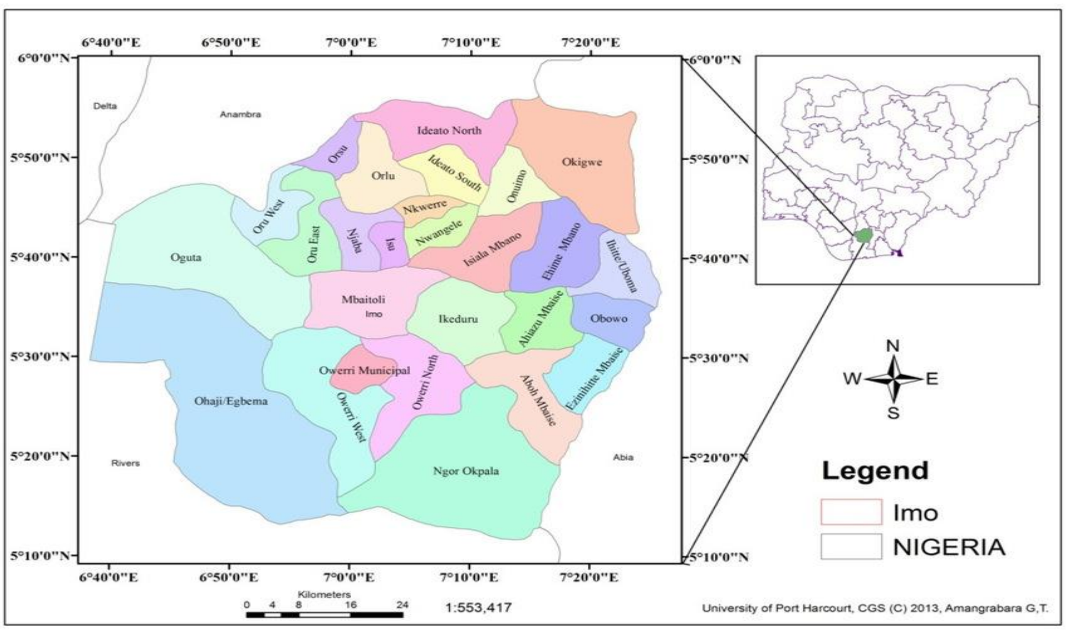
MATERIALS AND METHODS

The Study Area.

The study was conducted in three agricultural zones of Imo State notably, Owerri, Orlu and Okigwe, respectively (Fig 1). Imo State is a state in the South-East geopolitical zone of Nigeria, bordered to the north by Anambra State, River State to the west and South, and Abia State to the East (Encyclopaedia Britannica, 2022). Geographically, the state is divided between the Niger Delta swamp forests in the Far East and the drier Cross-Niger transition forests in the rest of the state. The State is located between latitude 4°45′N and 7°15′N and longitude 6°50′E and 7°25′E, with an area of about 5100 km^2. It lies within the humid tropics and is generally characterized by a high surface air temperature regime year-round. Mean minimum temperature is 23.5°C and mean maximum temperature is 32.1°C. Imo typically receives about 234.25 millimeters (9.22 inches) of precipitation and has 268.89 rainy days (73.67% of the time) annually. Two seasons, wet and dry, are observed in the year. The rainy season begin in April and lasts till October. The State experiences climate variations following rainfall variability (NIMET, 2018).

The major occupation of the people is farming while livestock production which borders on the rearing of poultry, pigs, sheep, goat, fisheries etc though more of a small holder dimension is an integral part of the people of Imo State.

Fig 1: Map of Imo State showing her Local Government Areas



Source: Ministry of Works and Housing Owerri, Imo state

Sampling Technique

Multi-stage procedure involving stratified, purposive and random sampling technique was used in the selection of sample. Imo State was stratified based on the three existing agricultural zones namely Owerri, Okigwe and Orlu. Four local government areas were selected from each agricultural zone making a total of twelve local government areas out of the 27 local government areas in Imo State. In Owerri agricultural zone, Ezinihitte -Mbaise, Owerri West, Owerri North and Ngor okpala were purposively selected, in Okigwe Zone, Isiala Mbano,Onimo, Okigwe and Obowo were chosen while in Orlu zone, Ideato South, Oru West, Ohaji/Egbema and Nkwere were purposively selected (Table 1). Twenty (20) poultry farmers were randomly selected from each LGA making up a total population of 240 sampling size (Table 1).

Table 1: Global Positioning System (GPS) of sampled zones in Imo State

S/N	Zone	LGAs Selected	GPS Coordinates	Total Number of Respondents
1	Owerri	4	$5^{0}\,29^{1}\,20.6124^{0}$ N and $7^{0}\,1^{1}\,3.3168^{11}$ E	80
2	Orlu	4	$5^{0}\,47^{1}\,44.34^{11}$ N and $7^{0}\,02^{1}\,6.47^{11}$E	80
3	Okigwe	4	$5^{0}\,47^{1}\,45.01^{11}$ N and $7^{0}\,21^{1}$ 2.02 E	80

Source: Imo State GPS Coordinate, www.countrycoordinate.com

Method of Data Collection

The researchers collected both primary and secondary data for this study. Primary data came through the use of structured questionnaires and personal observation by the researcher. In collecting such data, the researcher asked the larger and smaller farm holders relevant questions pertaining to poultry production and recycling of poultry dropping (manure). The secondary data for this survey were gathered from existing findings in form of books, Journals, Newspapers, Magazines, Bulletins, Project work etc. through literature review.

Data Analysis Techniques

The data collected were analyzed using descriptive statistics which include measure of central tendencies such as mean, frequencies and percentages.

RESULTS AND DISCUSSION

Socio-economic characteristics of poultry farmers in the study area

Age is one of the socio economic characteristics influencing output and labour availability in the poultry industry. Respondents whose ages ranged between 41to 50 years dominated the farming population (33.33%)(table 1). This was followed by age range of 31-40 years (29.17%). According to Nigerians National bureau of statistics, (2020) about 65% of the population was aged between 16-40 in 2015 and of these 37% (about 42 million people) were engaged in agriculture (Alawode, 2016). However, the dominant players in the poultry industry are those between the age of 41-50 years implying that in the years to come there will be a decline in productivity since ageing is a complex multifactorial process characterized by progressive changes in body tissue, which eventually lead to decline in function and death of individual (Jayanthi *et al.*, 2010).

40% of poultry farmers have secondary education followed by tertiary education which recorded 29.17%.Poultry farming on global outlook is going scientific and technical training is required for entrepreneurial skills and competence. Greater proportions of the farmers are males (58.33%). Poultry production is a seven day a week job and intensive labour is needed for maximum efficiency and profitability which of course may not be achieved by the female counterparts.70% of poultry farmers population in the area are married and the implication is that high level of responsibility would be ensured and married couples are better considered in loan/credit grants from financial institution than youths and moreover, their children also contributes in daily routine operations which hitherto enhances productivity (Mgbakor and Nzeadachie, 2013). 33.33% of poultry farmers in the area have 6-9 years cognate experience while those of 20 years and above farming experience is only 5%. The data on farming experience shows that the awareness on poultry production just came a decade ago.

59.17% of poultry farmers reared their stocks intensively while 33.33% are on semi-intensive system. Intensive system generates birds with faster growth rate and gives room for record keeping which is an efficiency assessment factor.

Table 2: Socio-Economic characteristics of respondents in the study area

i. Age range	**Frequency**	**Percentage**
21-30	40	16.67
31-40	70	29.17
41-50	80	33.33
>50	50	20.83
Total	**240**	**100.00**
ii. Sex	**-**	**-**
Male	140	58.33
Female	100	41.67
Total	**240**	**100.00**
iii. Marital status	**-**	**-**
Married	168	70.00
Single	72	30.00
Total	**240**	**100.00**
iv. Educational Level	**-**	**-**
No. Formal Education	30	12.50
Primary Education	44	18.33
Secondary Education	96	40.00
Tertiary Education	70	29.17
Total	**240**	**100.00**
v. Years of farming Experience	**-**	**-**
<5	68	28.33
6-9	80	33.33
10-15	60	25.00
16-19	20	8.34
20 and above	12	5.00
Total	**240**	**100.00**
vi. System of poultry management	**-**	**-**
Intensive	142	59.17
Semi-intensive	80	33.33
Extensive	18	7.50
Total	**240**	**100.00**
vii. Types of feed used in feeding Stock (Poultry)	**Frequency**	**Percentage**
Commercial formulated feed	154	64.17
Locally formulated feed	86	35.83
Total	**240**	**100.00**

Source: Field Survey, 2022

Stock size and manure generation.

Majority of poultry farmers (52.50%) reared less than 100-110 birds in the area implying that they are mainly small holder poultry dimension while 40% kept stocks ranging from 110-1000 birds. 7.5% of poultry farmers are under the category of medium scale keeping 1100-10,000 birds. Stocking rate in the poultry industry determine the quantity of waste that are generated from poultry units (Barura and Omodara, 2018). Moreover, the quantity of waste generated varies depending on the rate of consumption of feed and water intake. Statistics revealed that poultry farmers housing 110, 1000 and 10,000 birds generates 5,913.6, 53,760 and 537,600 kg of droppings (approximately 30-40% moisture content) on yearly basis respectively (Mariusz *et al*., 2019; University of Georgia Extension News, 2022) and this aligns with the findings of Baruwa and Omodara (2018) that effective waste management method is a panacea for a long-term productivity, growth and environmental sustainability of poultry enterprises. 70.83% of poultry farmers in the area recycle their manure into vegetable production while those with larger output sell the excess to crop farmers.

Table 3: Stock size and manure generation

Characteristics	Frequency	Percentage
i. How many birds do you keep	-	-
100-110	126	52.50
111-1000	96	40.00
1100-10,000	18	7.50
Total	**240**	**100.00**
ii. Do you recycle your poultry manure	**-**	**-**
Yes	170	70.83
No	70	29.17
Total	240	**100.00**
iii. Do you consider the use of Poultry Manure in Crop production laudable?		
Yes	186	77.50
No	54	22.50
Total	240	**100.00**

Source: Field Survey, 2022

Poultry manure as pollutant

72.50% of poultry farmers are of the view that poultry manure is a very serious threat to HUMAN health and THE environment while 27.50% of respondents maintained that the use of poultry manure should be intensified considering the fact that it doesn't constitute environmental menace (Table 3). 78.33% of respondents stores poultry manure within the farm premises despite their contention that the product is an environmental menace while 21.67% dispelled the notion that it doesn't constitute health nuisance but rather binds soil particles together, provides home for earthworms and other beneficial organisms and improves the soil. 81.67% of respondents agreed that channeling this by product in crop production will help in reducing environmental pollution emanating from the odour threshold and directly improves irrigation efficiency, soil retention and uptake of plant nutrients (Shibi Thomas *et al.,* 2020).

Economic consideration of recycling poultry manure.

Table 4 indicated that 90.83% of poultry farmers in the state are of the opinion that poultry manure is the best manure in conservation agriculture, because it improves soil fertility and leads to higher yields of crops in terms of increased productivity, and soil health improvement

On the rate of manure utilization, 59.16% of respondents applied poultry manure at the level of 10-20t/ha while 29.17% applied 40t/ha. 8.34% of respondents apply at the rate of 45-50t/ha while 3.33% of respondents are ignorant of any specific application rate but rather contented that the utilization depends on output or stocking capacity.

91.66% of poultry farmers in the state reported that poultry manure can be used to cushion the effect of high cost of poultry feed. For instance, at an estimated rate of N400.00 per bag of poultry manure (mixed with wood shavings and other organic materials), a poultry farm that uses 225 bags of feed, would generate about 75 bags of poultry waste which attracts N30,000 on monetary terms and when added to farm income raises the profit margin for broiler enterprise to about 16.80% (Bamire, and Amuyoyegbe, 2013).

Table 4: Poultry manure as a pollutant

Characteristics	Frequency	Percentage
i. Does air emission from poultry manure constitute a threat to human health or environment?	-	-
Yes	174	72.50
No	66	27.50
Total	**240**	**100.00**
ii. Do you store your poultry manure within the farm premises?	-	-
Yes	188	78.33
No	52	21.67
Total	**240**	**100.00**
iii. Do you consider poultry manure as environmental menace?	-	-
Yes	172	71.66
No	68	28.34
Total	**240**	**100.00**
iv. Does Poultry manure constitute handling problems due to the formation of crust and sediments during storage?	-	-
Yes	93	77.50
No	27	22.50
Total	**120**	**100.00**
v. Does the use of poultry manure in crop production offers solution to environmental pollution in the state?	**Frequency**	**Percentage**
Yes	196	81.67
No	44	18.33
Total	**240**	**100.00**

Source: Field Survey, 2022

Table 5: Economic consideration of recycling poultry droppings characteristics

Characteristics	Frequency	Percentage
i) Does the use of poultry manure conform to the principles of conservation Agriculture?	-	-
Yes	218	90.83
No	22	9.17
Total	**240**	**100.00**
ii. What is the rate of Poultry manure utilization in your farm?	**Frequency**	**Percentage**
(a) 10-20t/ha	142	59.16
(b) 21-40t/ha	70	29.17
(c) 45-50t/ha	20	8.34
(d) No specific level	08	3.33
Total	**240**	**100.00**
iii. Does the use of poultry manure in organic agriculture save cost?	**Frequency**	**Percentage**
Yes	220	91.66
No	20	8.34
Total	**240**	**100.00**
iv) Do you think that the use of poultry manure has positive effect on the farmer’s net revenue?	**Frequency**	**Percentage**
Yes	210	87.50
No	30	12.50
Total	240	**100.00**

Source: Field Survey, 2022

CONCLUSION AND RECOMMENDATION

The study investigated the economics of poultry manure use as fertilizer in Imo State. Poultry farmers in the study area uses poultry manure in the fertilization of their crops because of its availability, least cost involvement and leaching repellent properties on erosion prone soils. Based on the findings of this study, the following recommendations are made;

i. Government should assist poultry farmers by giving them loans/subsidies so as to enhance their productive capacity and by extension establish crop farms as 50-65% of grains utilized in livestock feed manufacture are obtained from crop farms.

ii Government should intensify the use of poultry droppings by embarking on public enlightenment campaigns in the rural areas to change the philosophy and mindset of rural conservative farmers on the adoption of new technology aimed at boosting food security.

iii. Apart from recycling poultry waste as fertilizer in the crop farm, waste can also be channeled into biogas production for energy generation.

iv. Synergy between animal agriculture and organic farming in Nigeria will open a window of opportunity for the utilization of these benefits.

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Soil Fertility Capability Evaluation along River Kaduna Watershed, Northern Nigeria

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ABSTRACT

This study was conducted along the Kaduna River watershed with the goal of evaluating the fertility potential of the watershed soils. Six profile pits in all were excavated and described. The parameters used in the study to evaluate fertility capabilities were condition modifiers, substrata type, and type. The silt clay loam soil texture class dominated the examined soils. The textures of nearly all of the investigated soils (pits 1, 2, 3, 5, and 6) ranged from silt clay loam at the top horizons to silty loam or silt clay down the horizons. The only exception was Pit 4, where silty loam was predominant at both the top and sub layers. The pH of the soil was mostly neutral (pH > 5.0 <6.0), with Pit 4 being the lone exception. Pit 4's pH was higher (pH = 4.92) in terms of $CaCl_2$. All tested areas, with the exception of Pit 1, had a limitation of dryness (d) according to condition modifier classification, indicating a situation in which soils experience dryness > 60 consecutive days/year within 20 cm to 60 cm depth. With the exception of Pit 4, all other examined soils had Effective Cation Exchange Capacity (ECEC) values greater than 6 Cmolkg $^{-1}$ soil below, indicating significant exchangeable cation leaching. One of the main problems with the investigated soils was their low nutritional reserve (exchangeable K < 0.20 c mole kg -1 soil). Fertility Capability Classification placed Pit 1 as LCgv; Pit 2 Ldkv; Ldk in Pits 3, 5 and 6 and Ldek in Pit 4. Application of organic compounds rich in exchangeable basic cations especially K should be practiced by farmers near river Kaduna watershed. Also, the usage of river Kaduna for irrigation purposes should be increased to enhance dry season farming since rainfall duration is short in North Western Nigeria.

INTRODUCTION

Fasina *et al.* (2005) discovered that the main problem restricting agricultural growth and development in the tropics, particularly in Nigeria, is a lack of accurate information and proper knowledge of soil and land characteristics. As a result, a complete understanding of soil formation processes as well as soil physical and chemical features in connection to fertility is critical for maximizing the use of available soil resources for agriculture (Delgado and Gomez, 2016). The inherent ability of soils to give nutrients for crop growth and the maintenance of soil physical conditions to optimum crop yields, according to Raju *et al.* (2005), are the most essential components of soil fertility that basically define the productivity of agricultural systems. As a result, understanding the soil resources of any particular land is essential for planning its agricultural growth (Sangita, 2015).

Fertility of most of our upland soils is fast reducing due to continuous cropping of the limited available land for agriculture hence the need to explore watershed soils. The Fertility Capability Classification (FCC) is a technical system for grouping soils according to the kind of problems they present for agronomic management, though it was developed for upland soils, FCC was extended to wetland soils by Sanchez and Buol (Buol, 1986; Sanchez, 1997 and Adhikary *et al.,* 2010). Soil fertility capability classification (FCC) was created for interpretation purposes using soil taxonomy and other supplementary soil attributes information that is directly beneficial to plant growth (Buol *et al*., 1975)., Sanchez and colleagues (1982).

River Kaduna and its tributaries are very essential to the north central and North Western Nigeria as they supply irrigation water for dry season farming and their floodplains makes farming possible all year round. Most soils within the River Kaduna watershed are used for irrigation farming due to their proximity to the source of irrigation water. River Kaduna watershed constitutes, of numerous uplands and ridges as well as floodplains where agricultural activities take place. Many cereal crops, legumes and vegetables are farmed on these regions as these crops may easily be irrigated from the river. However, only little soil information is available to the farmers, extension agents, researchers and students on the soils of River Kaduna watershed. The fertility capability classification of watershed soil of River Kaduna will provide useful information for assessment and monitoring of the behaviour of the soils for agricultural uses. This research work will fill the information gap that is needed by stakeholders thereby enhancing agricultural productivity in the region as well as proper management and productivity of these soils. The major objective of this study is to carry out the Fertility Capability Classification of soils along River Kaduna, North Western Nigeria for sustainable utilization and management.

Materials and Methods

Location

River Kaduna watershed is located on the Latitudes 10o 36’ and 10° 60’ N and Longitudes 7o25’ and 7° 40’E respectively and in Kaduna state, North Western Nigeria. The study area has been characterized as a region where the rainfall is unimodal in pattern and between 900 – 1300 mm per annum (Uyovbisere and Lombin, 1991). The region also has an undulating plain topography, with general elevation ranging from about 450 to 700 m, covered in highly sandy soils, which are usually very low in organic matter, may degrade rapidly under conditions of intensive rainfall. The region is characterized by high annual average temperature (28-32°C), short wet season and long dry season (6-9 months). Generally, soil moisture and temperature regimes in the area are inferred to be ustic and isohyperthemic respectively. During the rainy season however, mean temperature drops to 25ºC – 28ºC (June to September) and decreases to less than 20ºC in the months between December and February (Gabasawa*et al.,* 2017). Tree cover varies from open woodland to light forest which has been reduced to bare land due to uncontrolled tree felling for fuel as well as farming activities (Carsky*et al.,* 1998) while abundant short grasses (<2 m) are also available (Sowunmi and Akintola, 2010).

Table 1: GPS Coordinates of Soils around River Kaduna

Location	Latitude	Longitude	Elevation (m)
Pit 1	10º.492267”	7º.431442”	574
Pit 2	10º.492842”	7º.431392”	574
Pit 3	10º.492200”	7º.430547”	577
Pit 4	10º. 493270”	7º.429865”	579
Pit 5	10º.493277”	7º.429058”	577
Pit 6	10º.492886”	7º.477420”	583

Existing Information on Soil

Generally, soil such as that of dry land of Northern Nigeria are named as ‘Aridisols’ by soil taxonomists (Soil Survey Staff, 1975) and are characterized by less than 1200 mm annual rains which are usually slowly permeable, leading to most of the water being lost to run-off (Fitzpatrick, 1980). Most of the rainfall received by the river Kaduna watershed drains to the river itself and this causes flooding along the watershed at the peak of rainy season around October in most years. The watershed soon experiences aridity as the dry seasons sets in between December and May. Soils along River Kaduna watershed might have been formed under aridity from wind-stored desert sands that accumulated over long periods of time. In addition, some soils within this region of North Western Nigeria, in states such as Kaduna, Katsina, Kebbi, Sokoto and Zamfara have been also attributed to ferruginous tropical soils (D’Hoore, 1965) and characterized as having sandy texture, covering large areas of land with very low water-holding capacity and low organic matter, nitrogen and phosphorus content, neutral or moderately acidic in pH and also having a low cation exchange capacity.

Large expanse of arable land exists within the River Kaduna watershed having the potential for the production of largely grain crops like maize, sorghum, millet, rice and wheat.

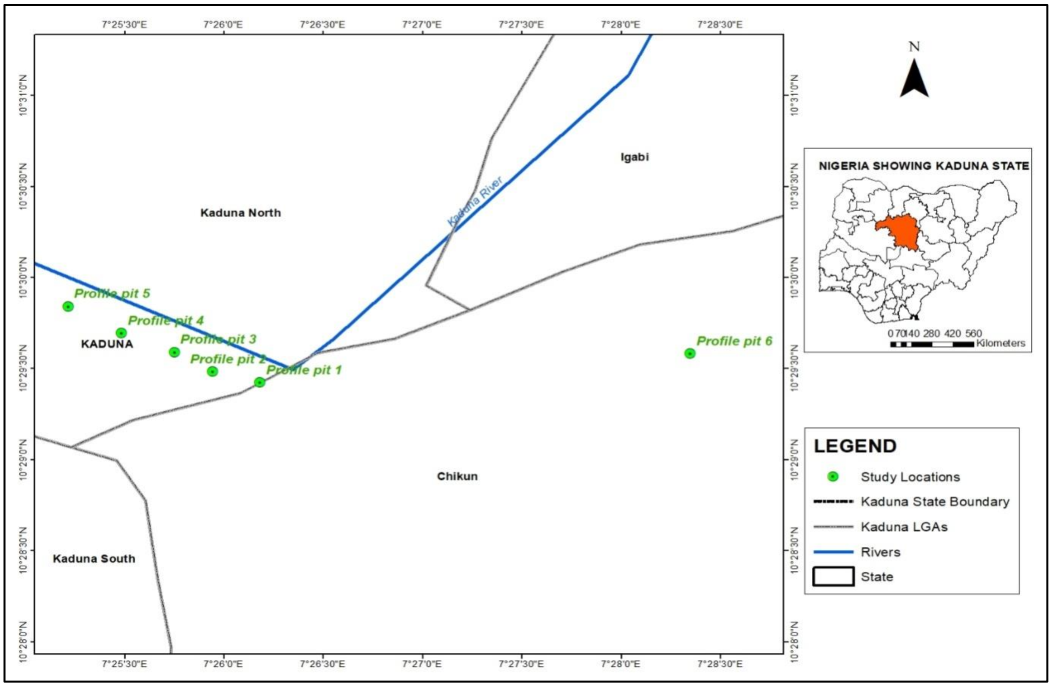

Fig. 1: Map of Study Area showing Sampling points

Vegetation

The vegetation around River Kaduna watershed is tropical guinea savannah located in North Western Nigerian. The increased activities of man which include bush burning, and increased farming have apparently converted major part of the original vegetation to bare lands. Fitzpatrick (1980) showed that the vegetation in such desert areas is usually sparse and the surface is bare for long periods. This may contribute to soil degradation by wind erosion and, hence, cause soil fertility to decline in the area. Such a problem is one of the major contributing factors to soil and environmental degradation. However, few shrubs and grasslands are still available. The region has been occupied by some grasses such as; Elephant grass *(Pennisetum purpurem)*, Giant star grass *(Cynodonplectostachyus)*, Wild groundnut *(Calopogoniummucunoides)*, butterfly pea *(Centrosemapubescens)*, Goat weed *(Sida acuta)*.

Socioeconomic Activities

The major occupation of the people of Kaduna is subsistence farming with food crops dominating the practice. Cereals are the most important stable food crop in this region (Muhamman and Gungula, 2006). Harris (2000) reported that "In sub-Sahelian northern Nigeria farmers focus on growing millet, sorghum, groundnut, sesame and cowpea and in the Sahelian part they resort to the most drought-tolerant crops: millet and cowpea". However, the main subsistence crops among them are sorghum and millet (both early and late varieties). Aregheore, (2005) noted that farmers grow crops such as millet, sorghum, maize, cowpea, groundnut, and sometime soybean in parts of Katsina, Kano, northern Kaduna, Sokoto and Zamfara states. The cropping systems of cereals predominate in the farming systems with one or several other crops in mixture. The mixture mostly found in the region is sorghum, millet, cowpea; sorghum, millet; sorghum/groundnut and sorghum/cowpea (Muhamman and Gungula, 2006). However, millet and sorghum are frequently grown on the same plot in areas such as Kano, Kebbi and Sokoto States. Millet is sown with the first rains and sorghum is interplanted later when the rain become more reliable (Mortimore, 1989). According to Asadu*et al*, (2004) crops that cover the soil, such as cowpea, are integrated in to different cropping system; crop rotation and mixed cropping. These systems include, maize, cowpea; yam, maize, cowpea; millet, cowpea; millet, sorghum, cowpea; and sorghum, millet, cowpea, okro, maize.

Field Work

A reconnaissance survey was carried out and the study location identified along a farming location lying along River Kaduna watershed. A region of the watershed was delineated into mapping units to represent some of the major cropping aspects of River Kaduna. Depending on the identified soil groups, Pedons were sunk in each of the delineated mapping units. A total six profile pits were dug cutting across the Kaduna River watershed. Soil samples were collected according to the profiles horizonation while core samplers were used to collect samples for bulk density. About 1kg samples were collected from the different horizons of each pedon. Samples were carefully packaged and labeled and transported to the soil laboratory of Ahmadu Bello University Zaria for analysis.

Laboratory Analysis

The sand, silt and clay contents of the soils were determined by hydrometer method using sodium hexametaphosphate (Calgon) as dispersing agent (Gee and Or, 2002). Bulk density (gcm^{-3}) was determined using the method described by Grossman and Reinsch (2002). Total porosity was calculated from particle and bulk densities of the soils. Moisture content was determined using gravimetric method (Obi, 1990).The silt clay ratio was calculated by dividing the value of silt with value of clay.The soil pH was determined using pH meter.Total nitrogen was determined by micro Kjeldahl method (Bremner and Mulvaney, 1982).Organic Carbon was determined by chromic acid wet oxidation method as described by Nelson and Sommers (1982). Available phosphorus was determined using Bray II solution (Olsen and Sommers, 1982).Total Exchangeable Acids (TEA) was determined by summing up all exchangeable acids (H^+ and Al^{+3}) while Total Exchangeable Bases (TEB) was determined by summing up all the exchangeable bases (Ca^{+2},K^+,Mg^{2+},Na^+).

Table 2: Fertility Capability Soil Classification System: Version 4

FCC class and short description	Symbols	Definitions and some interpretations
Type: texture is the average of plough layer or 0 to 20 cm depth, whichever is shallower	S	Sandy topsoil: loamy sands and sands
	L	Loamy topsoil: < 35% clay
	C	Clayey topsoil: > 35% clay
	O	Organic soil: >12% organic C to a depth of 50 cm or more (Histosols and histic groups) Substrata
Substrata type: used if textural change is encountered within top 50 cm	S	Sandy subsoil: texture as in type
Condition	modifiers	Identifying criteria (if more than one, they are listed in decreasing desirability)
Modifiers related to soil physical properties Waterlogging (gley): anaerobic condition, chemical reduction, denitrification; N2O and CH4 emissions	G	Aquic soil moisture regime; mottles < 2 chroma within 50 cm for surface and below all A horizons or soil saturated with water for > 60 days in most years
	g+	Prolonged waterlogging; soil saturated with water either naturally or by irrigation for > 200 days/year with no evidence of mottles indicative of Fe3+ compounds in the top 50 cm; includes paddy rice soils in which an aerobic rice crop cannot be grown without drainage; continuous chemical reduction can result in slower soil N- mineralization and Zn deficiencies in rice
Strong dry season (dry): Limits year-round cropping, interrupts pest cycles, Birch effect	D	Ustic or Xeric soil moisture regime: dry > 60 consecutive days/year but moist >180 cumulative days/year within 20 cm to 60 cm depth
	d+	Aridic or torric soil moisture regime: too dry to grow a crop without irrigation
Modifiers related to soil reaction Sulfidic (cat clays)	C	pH < 3.5 after drying; jarosite mottles with hues 2.5Y or yellower and chromas 6 or more within 60 cm sulfaquents, sulfaquepts, sulfudepts

Aluminium toxicity for most common crops	A	When > 60% Al saturation within 50 cm, or < 33% base saturation of CEC (BS 7) determined by sum of cations at pH 7 within 50cm, or pH < 5.5 except in organic soils (O)
	a-	10 to 60% Al saturation within 50 cm for extremely acid-sensitive crops such as cotton and alfalfa
No major chemical limitations (includes former h modifier)	No symbol	When < 60% Al saturation of ECEC within 50 cm and pH between 5.5 and 7.2
Calcareous (basic reaction): common Fe and Zn deficiencies	B	Free CaCO3 within 50 cm (fizzing with HCL), or pH > 7.3
Salinity	S	When > 0.4 sm-1 of saturated extract at 25°C within 1 m; salic groups; solonchaks
	s-	0.2-0.4 s m -1 of saturated extract at 25°C within 1m (incipient alkalinity)
Alkalinity	N	When > 15% Na saturation of ECEC within 50 cm; most solonetz
	n-	6% to 15% Na saturation of ECEC within 50 cm (incipient alkalinity)
Modifiers related to soil mineralogy	K	When < 10% weatherable minerals in silt and sand fractions within 50 cm, or siliceous mineralogy, or exchangeable K < 0.20 c mole kg -1 soil, or exchangeable K < 2% of sum of bases, if sum of bases is < 10 cmolc kg – 1 soil
High P fixation by Fe and Al oxides (> 10 mg kg – 1 P added to achieve adequate soil test levels); Ci soils have excellent structure but low water holding capacity; Ci sub soils retain nitrates	I	Dithionate-extractable free R2 O3: clay ratio > 0.2, or > 4% citrate dithionate – extractable Fe in of topsoil, or oxisols and oxic groups with C type, or hues redder than 5YR and granular structure
	i-	As above, but soils have been recapitalized with P fertilizers to supply long- term P to crops; soil test > 10 mg Kg – 1 P by Olsen method
	i+	as above; potential Fe toxicity if soils waterlogged for long time (g +) or adjacent uplands have I modifier
Amorphous volcanic (X-ray amorphous); high P fixation by allophone (> 200 mg Kg -1 P added to achieve adequate soil test levels); low N mineralization rates	X	Within 50 cm pH > 10 (in 1 M NaF) or positive to field NaFtest , or andisols and andic subgroups, other indirect evidences of allophone dominance in the clay size fraction, or > 90% P retention
	x-	P retention between 30% and 90% ; medium P fixers
Cracking clays (vertic properties): very sticky plastic clay, severe topsoil shrinking and swelling v	V	> 35% clay and > 50% of 2:1 expanding clays, or coefficient of linear expansibility > 0.09 or vertisols and vertic groups.
High leaching potential (low buffering capacity, low ECEC)	e	< 4 c mole kg – 1 soil as ECEC, or < 7 c mole kg – 1 soil by sum of cations at pH 7, or < 10 c mole kg – 1 soil by sum of cations + Al3+ +H+ At pH 8.2
Modifier related to soil biological properties (new)		
Low organic carbon saturation (soil organic matter depletion, C sequestration potential)	M	80% total organic C saturation in the topsoil compared with a nearby undisturbed or productive site the same soil, which is equal to 100% OR < 80% 333 Mm KMnO4-extractable topsoil organic carbon saturation compared with a nearby undisturbed or productive site of the same soil which is equal to 100%

Source: Sanchez *et al.,* (2003)

RESULTS AND DISCUSSION

Soil Physical Properties

Soil particle size distribution also known as soil texture of River Kaduna Watershed were as shown in Table 3. Sand, clay and silt were; 5, 40.5 and 55.2 % in pit 1; 8•5, 27.8 and 62.2 % in pit 2; 3, 36.25 and 60.3 % in pit 3; 23, 19.2 and 43.2 % in pit 4; 3, 31 and 65.25 % in pit 5; 6.5, 22 and 65.25 % in pit 6 respectively. The studied soils were dominated by soil texture class of silt clay loam. Almost all studied soils (pits 1, 2, 3, 5 and 6) had their textures ranged from Silt clay loam at the top horizons to silty loam or silt clay down the horizons. The only exception to this was the pit 4 which was dominated with silty loam at the top and its lower horizon.

The trend of distribution of sand showed a decrease in Pit 1 and 2, increased in pit 3, 4 and 6 with no defined trend in Pit 5. The clay content of the investigated soils showed an increase in all Pits (1 – 5) with exception of Pit 6 where clay rather decreased down the profile. Silt content had a decrease in Pit 1, 3, 4 and 5 while it increased in Pit 6 and Pit 2 which later decreased. The increasing clay content observed in most of the profile Pits (Pit 1 – 5) suggests that illuviation (clay movement down the profile) is taking place. These results clearly show that pit 1, 2, 3, 5 and 6 were in the Backswamp depositional area of the watershed. This is evident by the very low mean sandy (4, 10, 3.5, 12.8 and 4 %) respectively) content of these locations. Profile pit 4 with relatively higher sand content (38.6 %) was located in the terrace area of the watershed. In these Backswamp soils, there was evidence of huge depositions of clay and silt. The dynamics of variability in the investigated soils using coefficient of variation suggests that; sand exhibited high variability (CV≥35%) except in pit 3 and 5 where it was moderate (CV≥15<35%). Clay exhibited mostly moderate variability (CV≥15<35%) except in pit 2 and 3 where it had low variability (CV≤15%) and pit 6 with high variability (CV≥35%). The silt content of the soils all indicated low variability (CV≤15%) except pit 4 where it varied highly (CV≥35%).

Table 3: Soil Properties of Studied Location

Horiz. Depth	pH	OM	Avail. P	Ca	K	Exch. Acidity (H+Al)	ESP	ECEC	Base Saturat.	Bulk. Den	Particle Size Distribution (%)				
	0.01 N $CaCl_2$	(g. kg^{-1})	(mg. kg^{-1})	(Cmol. kg-1)	(Cmol. kg-1)	(Cmol. kg-1)	%	(Cmol. kg-1)	%	(g.cm^{-3})	Sand	Clay	Silt	Silt/ clay	Text. Class (USDA
Pit 1															
0 – 25	5.80	5.07	15.26	9.40	0.61	0.10	5.24	13.35	99.25	0.96	6	26	68	2.62	Silty Clay Loam
25 – 50	6.00	4.39	6.69	4.60	0.19	0.20	3.41	6.45	96.90	1.14	4	42	54	1.29	Silty Clay
Mean	5.50	5.88	8.16	6.40	0.27	0.20	3.22	8.91	97.34	1.154	5	40.5	55.2	1.36	
CV (%)	14.37	71.5	52.1	49.16	69.1	61.24	44.14	48.44	1.88	11.19	50	21.81	13.70	44.86	
Pit 2															
0 – 25	7.70	4.06	32.93	6.00	0.29	0.20	1.40	7.84	97.45	0.89	11	27	62	2.29	Silty Clay Loam
25 – 50	5.60	5.74	4.63	6.00	0.17	0.60	2.39	8.78	93.17	1.00	6	32	62	1.94	Silty Clay Loam
Mean	5.74	5.64	9.91	5.12	0.17	0.80	2.28	7.66	89.00	1.20	8.5	27.8	62.2	2.24	
CV (%)	20.08	36.0	130.0	26.29	39.1	53.03	45.84	23.56	7.05	20.66	62.1	13.55	4.60	11.07	
Pit 3															
0 – 25	6.10	4.95	4.97	9.20	0.12	0.10	0.73	12.27	99.19	0.97	2	32	66	2.06	Silty Clay Loam
25 – 50	6.10	2.70	18.01	5.00	0.26	0.10	2.33	6.87	98.54	1.22	4	38	58	1.53	Silty Clay Loam
Mean	5.88	2.84	7.27	7.65	0.14	0.13	1.77	10.20	98.37	1.14	3	36.25	60.3	1.66	
CV (%)	4.89	51.6	98.8	50.8	59.2	40	57.38	48.26	1.40	10.75	28.6	9.66	7.29	17.12	
Pit 4															
0 – 25	4.80	1.67	2.40	4.40	0.20	0.60	6.53	6.02	90.88	1.33	18	15	67	4.47	Silty Loam
25 – 50	5.60	9.12	8.75	4.00	0.11	0.40	2.78	5.05	93.04	1.10	28	22	50	2.27	Silty Loam
Mean	4.92	3.69	4.39	4.76	0.13	0.76	3.37	5.53	89.01	1.19	23	19.2	43.2	2.25	
CV (%)	12.14	94.7	62.6	29.17	35.3	53.93	59.85	26.17	7.31	13.42	52.4	29.32	39.7	51.09	
Pit 5															
0 – 25	4.90	3.72	3.09	5.20	0.08	1.20	2.36	8.05	85.09	1.23	4	24	72	3.00	Silty Loam
25 – 50	5.30	1.67	2.40	6.60	0.18	0.40	4.27	9.36	95.73	1.29	2	30	68	2.27	Silty Clay Loam
Mean	5.15	3.70	4.50	5.50	0.13	0.85	2.28	8.16	89.17	1.21	3	31	65.25	2.10	
CV (%)	4.62	77.9	54.3	14.08	40.2	61.88	71.76	10.18	7.74	6.59	33.	17.07	8.79	40.76	
Pit 6															
0 – 25	5.60	0.34	2.92	5.20	0.18	0.40	0.96	7.26	87.28	1.44	4	30	66	2.20	Silty Clay Loam
25 – 50	5.70	2.03	2.40	6.60	0.11	0.20	2.03	8.88	97.75	1.59	9	28	63	2.25	Silty Clay Loam
Mean	5.70	1.26	3.82	4.35	0.13	0.25	1.50	6.90	94.45	1.46	6.5	22	65.25	2.97	
CV	1.43	55.1	56.5	44.64	28.2	40	55.22	25.15	5.14	7.33	62.3	37.11	5.51	27.65	

According to Smith *et al.* (1998), there is a high correlation between specific surface area, soil compatibility, compressibility, and measurements of particle size distribution specifically, the percentage of silt and clay and organic matter. These factors all have an impact on the productivity of soils. Thus, except in oxide soils, soil fertility within a mineralogical class correlates with clay content. This conclusion indicates that there will probably be less plant development, particularly for annual crops, in the Backswamp due to its high clay content, which was caused by debris deposited by the River Kaduna due to the occasional flooding activities in most years.This is due to clay's interacting effect on the water and nutrient condition of the soil (Scholes *et al*, 1994; Iheka *et al.*, 2015). The availability of these nutrients is dependent on the activities of the clay in the soil. Because clay soils have the capacity to hold and trap specific nutrient elements in their colloidal surfaces, they are appropriate for heavy tuber crops and perennial crops whose roots naturally have the capacity to absorb nutrients.

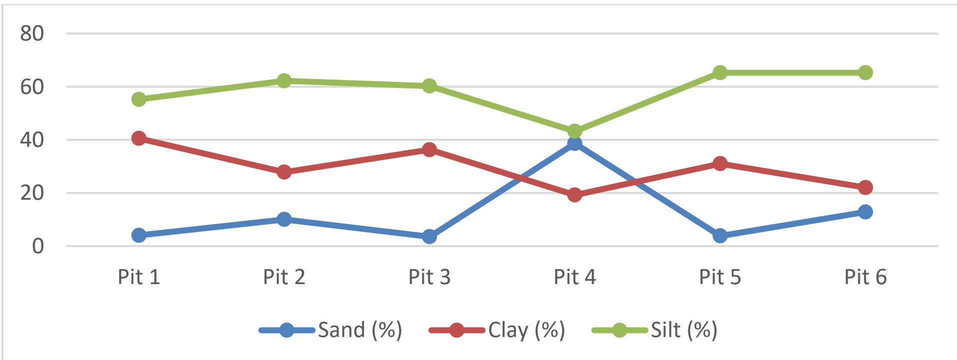

Fig. 2: Particle Size Distribution

Soil Chemical Properties

Soil Reaction

Soil pH was investigated in 0.01N $CaCl_2$ as shown in Table 3. The trend of distribution of pH across horizons was not in any particular form as it either decreased or increased within the horizon in all investigated profile pits. Mean soil pH in $CaCl_2$ for the different pits are; Pit 1; 5.50; Pit 2; 5.74; Pit 3; 5.88; Pit 4; 4.92; Pit 5; 5.15 and Pit 6; 5.70 as measured in $CaCl_2$. Soil pH was moderately acidic (pH > 5.0< 6.0) when measured in $CaCl_2$. The exception to this trend was observed only in Pit 4 where pH was more acidic; 4.92 as measured in $CaCl_2$. This higher pH when compared to other locations may be attributed to a more degree of weathering taking place in this location. It is worthy to note that this location has the highest sand content (38.6%) which will possibly encourage the leaching of exchangeable cations which predisposed the soil to acidic condition.

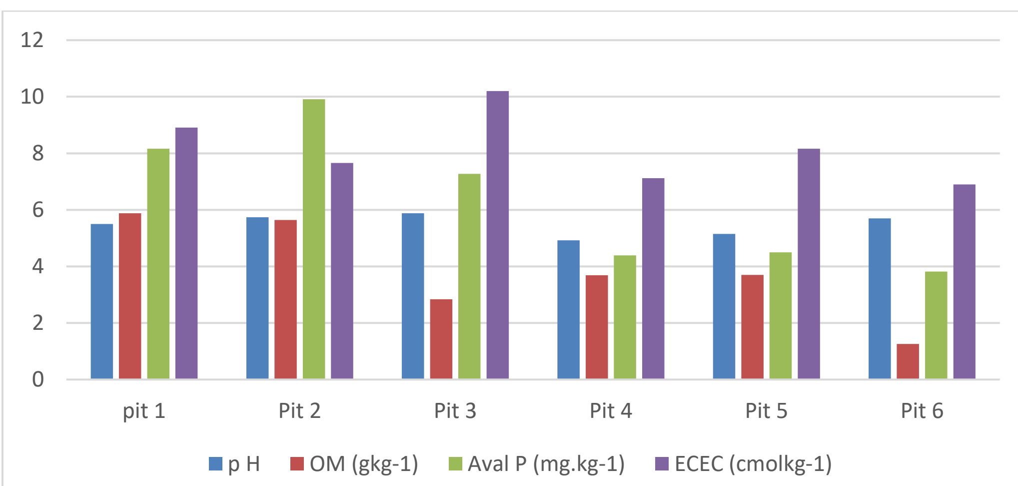

Fig. 3: Chemical Properties of Studied soils

Soil Organic Matter

Soil organic matter means were as shown in Table 3. OM recorded 5.88; 5.64; 2.85; 3.69; 3.70 and 1.26 gkg^{-1} in pits 1 – 6 respectively. Organic matter distribution displayed an irregular pattern in virtually all the profile pits studied, concentrating more towards the middle of the horizons in each profile pit examined. A deviation from this trend was observed in Pits 3, 4 and 6 where there was a consistent decrease of OM down the profile although the surface horizons of Pit 4 and 6 were lower than the horizon immediately after it. Organic matter is a product of dead and decayed organic materials (litters) on the surface of the soil and these products decrease down the profile in a normal soil. These OM contents of these soils are very low and poor (<20 gkg^{-1}). Tabi *et al*, (2012) recognized OM of <20 gkg^{-1} as low. The reason for this may be due to the fact that these locations have been under intense farming activity which takes organic substances from the soil without adequate restoration or rejuvenation. The soils under investigation have equally been affected by continual overflow of the River Kaduna leading to the high silt and clay presence observed in most of the studied soils. This situation has altered the physical and chemical properties of the soil as observed by the irregular distribution of soil OM. Organic matter varied highly (CV≥35%) in all studied soils of River Kaduna watershed.

Available Phosphorus

The available P content of the studied soils had no particular trend of distribution down the horizons in most of the studied soils although it ultimately decreased in Pits 1 – 3 and increased in Pits 4 – 6. Decrease in P with depth can be due to decrease in organic matter content with depth. Organic matter plays a key role in P availability due to its ability to coat aluminum and iron oxides, which reduces P sorption (Debicka*et al.*, 2015).Mean available P distribution as shown in Table 3, were 8.16, 9.91, 7.27, 4.39, 4.50 and 3.82 mgkg^{-1}in Pits 1 – 6 respectively. The Available P status indicated that Pits 1, 2 and 3 had moderate P contents (5 - 15 mgkg^{-1}) while low (< 5mgkg^{-1}) according to Tabi *et al.* (2012) in Pits 4, 5 and 6. Among the factors which affect P availability is the pH status of the soil. When the pH too low (high acidity) or too high (high alkalinity), the available P may be fixed under any of these circumstances. All studied soils had pH suggesting slightly to moderately acidic. Locations within Pits 4 and 5 had pH 4.92 and 5.15 respectively indicating more acidity compared to other locations. This may have caused the low available P obtained in these locations. Available P varied highly (CV≥35%) in all investigated soils along River Kaduna watershed.

Exchangeable Cations

The exchangeable bases were major nutrient cations and includes Ca, Mg, K and Na as shown on the Table 3. The distributions of means of exchangeable bases are as follows; Calcium (Ca) – 6.40, 5.12, 7.65, 4.76, 5.5 and 4.35 for Pits 1 – 6. For Magnesium (Mg) – 1.73, 1.42, 2.14, 1.27, 1.48 and 1.36 in Pits 1 – 6. Potassium (K) – 0.27, 0.17, 0.14, 0.13, 0.13 and 0.13 for Pits 1 – 6. Also, Sodium (Na) – 0.28, 0.18, 0.15, 0.23, 0.20 and 0.11 for Pits 1 – 6 respectively. There was no particular trend of distribution of exchangeable bases across different profile pits although most of the profile pits had highest concentrations in lower horizons. However, Ca distribution was moderate (5 – 10 cmolkg^{-1}) in Pits 1, 2, 3 and 5 and low (<5 cmolkg^{-1}) in Pits 4 and 6 when Ca critical limits were considered according to (Tabi *et al.*, 2012). Furthermore, Pit 1 had a moderate (1.5 – 3.0 cmolkg^{-1}) Mg content while the Pits 2 – 6 all had low (< 1.5 cmolkg^{-1}) Mg concentrations. Potassium and Na were low across their respective horizons having ranges of < 0.3 cmolkg^{-1} in all studied locations. The low exchangeable bases observed may have been caused by excessive leaching taking place in the studied soils.

Obasi *et al.*, (2015) noted that most tropical soils are prone to leaching. Also, the dynamics of moisture within River Kaduna watershed and continuous farming activities may have depleted the exchangeable basic cations, leading to their low availability. Effective Cation Exchange Capacity (ECEC) was moderate (6 – 12 cmolkg-1) in all studied soils from Pits 1 – 5 and low in Pit 6 where it was <6 cmolkg-1. The ECEC distributions were as follows as shown in Table 3. 8.91, 7.66, 10.20, 7.12, 8.16 and 5.90 cmolkg-1 in Pits 1 – 6 respectively. Landon (1991) pointed critical ECEC as follow; low (<6 cmolkg-1), medium (6 – 12 cmolkg-1) and high (>12 cmolkg-1). The percentage base saturations were high in all the locations - 97.34, 89.00, 98.37, 89.01, 89.17 and 94.45% in pits 1 – 6 of the studied soils. The coefficient of variation of Effective cation exchange capacity (ECEC) indicated high (CV≥35%) in Pits 1 and 3, moderate (CV≥15<35%) in Pits 2 and 4 while low (CV≤15%) in Pit 5. Base saturation exhibited low (CV≤15%) variability in all investigated soils.

Table 4: Fertility Capability Studies

Locations	Type	Subtrata Type	Modifiers d	e	g	k	v	FCC Classification
Pit 1	Silty Clay Loam	Silty Clay	-	-	+	-	+	LCgv
Pit 2	Silty Clay Loam	Silty Clay Loam	+	-	-	+	+	Ldkv
Pit 3	Silty Clay Loam	Silty Clay Loam	+	-	-	+	-	Ldk
Pit 4	Silty Loam	Silty Loam	+	+	-	+	-	Ldek
Pit 5	Silty Loam	Silty Clay Loam	+	-	-	+	-	Ldk
Pit 6	Silty Clay Loam	Silty Clay Loam	+	-	-	+	-	Ldk

Soil Fertility Capability Classification

The fertility capability classification was presented in Table 4 using parameters based on the soil fertility classification guide in Table 2 (Sanchez *et al.,* 1982). Considering Type and Subtrata type of the FCC classification, the soil texture class of silt clay loam predominated in the soils investigated. The textures of almost all of the soils studied (pits 1, 2, 3, 5, and 6) ranged from Silt clay loam at the top layers to silty loam or silt clay down the horizons. The lone exception was Pit 4, which was dominated by silty loam in its upper and lower horizons. Classification under condition modifiers revealed that all studied locations had a limitation of dryness (d) in all investigated locations except Pit 1 which was slightly flooded due to the time of sampling, suggesting a situation according to Obasi *et al.*, (2020) in which soils experience dryness> 60 consecutive days/year within 20 cm to 60 cm depth. Rainy season in the region mostly span from June to early October while dry season extends from November to May in a normal year. Cation Exchange Capacity (CEC) or Effective Cation Exchange Capacity (ECEC) (e) was not a limitation in the studied soils except in Pit 4 where ECEC values was less than 6Cmol.kg $^{-1}$ soil. Effective Cation Exchange Capacity < 6 Cmol.kg^{-1} suggest serious leaching of exchangeable cations (Landon 1991). This may be as a result of low rainfall associated with North Western Nigeria which had led to low leaching of exchangeable cations enhancing their availability in most studied locations. The modifier g which signifies a waterlogged condition was partially observed in locations of Pits 1 and 2 which as a result of time of sampling when moisture was still in parts of that location. The studied soils had a major challenge of low nutrient reserve, (exchangeable K < 0.20 c mole kg -1 soil, or exchangeable K < 2% of sum of bases, if sum of bases is < 10 Cmol.kg $^{-1}$ soil). In the investigated soils, only pit 1 had exchangeable K > 0.2 Cmolkg^{-1} while all other locations were lower. Condition modifier V, suggesting vertic properties were only observed in Pits 1 and 2 where rice cultivation was practiced. This effect was not well pronounced as the soil texture was similar to that obtained in other studied locations. Fertility Capability Classification placed Pit 1 as LCgv; Pit 2 Ldkv; Ldk in Pits 3, 5 and 6 and Ldek in Pit 4.

CONCLUSION

The soil texture class of silt clay loam predominated in the soils examined, according to the fertility capability classification parameters based on the soil fertility classification guide of Type and Subtrata type of the FC classification. Nearly all of the soils under study (pits 1, 2, 3, 5, and 6) had varying textures, from silty loam or silt clay at the horizons to silt clay loam at the upper layers. Pit 4 was the only exception, with silty loam predominating in both its upper and lower layers.Classification under condition modifiers showed that, with the exception of Pit 1, which was slightly flooded at the time of sampling, all investigated locations had a limitation of dryness (d). With the exception of Pit 4, where ECEC values were less than 6 Cmol.kg – 1 soil, Cation Exchange Capacity (CEC) or Effective Cation Exchange Capacity (ECEC) (e) was not a constraint in the examined soils.Low nutrient reserves (exchangeable K < 0.20 c mole kg -1 soil) posed a significant problem for the investigated soils as only pit 1 exhibited exchangeable K > 0.2 Cmolkg-1 in the tested soils; exchangeable K was lower in all other places. Condition modifier V indicates that only the rice-growing areas in Pits 1 and 2 had vertic qualities when the soil texture at this location was comparable to that seen in other analyzed locations, this effect was not as noticeable. Pit 1 was classified as LCgv by Fertility Capability Classification, Pit 2 as Ldkv, Ldk in Pits 3, 5, and 6, and Ldek in Pit 4.

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Soil Physicochemical Properties as Influenced by Land Use Practices in Ifite Ogwari, Anambra State

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ABSTRACT

Land use remains one of the major factors that can degrade soil properties with consequences on the provision of ecosystem services. This study was conducted at the faculty of Agriculture, Ifite Ogwari annex of Nnamdi Azikiwe University to investigate the influence of land use practices on selected physicochemical properties of soil. Three land use types (cassava farm, rice farm, grassland) with different histories were selected for the study. Soil samples were taken from each of the land use types in three replicates at 0-20cm and 20-40cm depths. To determine the physicochemical properties of soil under the land use types, samples were subjected to laboratory analysis. Data generated were subjected to statistical analysis and Duncan's multiple range test was used to separate significant means at 5% probability level. The results showed a predominant clay textural class under the land use types. Highest soil bulk density and lowest total porosity was obtained under cassava farm with values of 1.94 g/cm^3 and 30.31% respectively at 20-40cm depth. Soil hydraulic conductivity under the land use types ranged from 0.01- 0.03cm/hr. Aggregate stability of soils ranged from 0.32-0.56 across the depths. The silt clay ratio under land use types was generally low and showed a highly weathered soil. The soil pH was generally acidic. Soil organic carbon was generally low and ranged from 0.40-1.32% across the depths. The total nitrogen ranged from 0.01- 0.11% which was generally low across the depths. Available phosphorus was highest under cassava farm with a value of 8.33mg/kg at 0-20cm depth while grassland had the lowest available phosphorus content with a value of 0.86 mg/kg at 20-40cm depth. The cation exchange capacity under land use types ranged from 5.89 -8.65 cmol/kg at 0-20cm depth and 3.68 -7.55 cmol/kg at 20-40cm depth. It was generally observed that soil nutrients decreased as the depth increased. The studied land use types influenced the selected soil properties and this calls for soil conservation practices that could improve soil productivity.

INTRODUCTION

Soil is the basis of agriculture and natural plant communities and according to Ogunkunle (2015) it remains the root of food shortage, food insecurity or undernourishment which has assumed global dimension in the last three decades. The inherent quality of Nigerian soils is generally low, hence they are easily degraded in terms of physical, chemical and biological properties as soon as the land is opened up for cultivation and other kinds of uses. According to the report of Terr Africa in 2006 about 20% of the world's agricultural lands have been irreversibly damaged due to accelerated land degradation and intensive land use, leading to a reduction of about 15-30% of their productivity. Furthermore, land resources have been altered by rapid land use accelerated by changeable socio-economic factors including high population growth, rapid urbanization (Fabiyi, 2006) as well as agricultural intensification and government policies. Human activities exert tremendous effects on land cover through a variety of land uses and have altered the structure and functioning of the ecosystem (Turner *et al*., 1994). Most soils in southeastern Nigeria are formed from sandy parent materials and occur mainly in the high rainfall areas hence they are fragile, highly leached, acidic and subject to water erosion (Udom *et al.,* 2013) and this calls for special attention for their proper management to ensure sustainable agricultural productivity and environmental quality. There is a growing need for information relating to soil conditions, their current status, changes due to land use types and management practices and appropriate conservation measures to ensure sustainable land utilization. Therefore, exploring ways and means to optimize sustainable land use, management and recovery suitable to develop strategies against low productivity and to enhance the provision of ecosystem services is important.

MATERIALS AND METHODS

The study was conducted at the Faculty of Agriculture, Ifite- Ogwari annex of Nnamdi Azikwe University situated in Ayamelum Local Government Area of Anambra State. The area lies within latitude $6^0$14'28" N and $6^0$14'51"N and longitude $7^0$6'46" E and $7^0$6'47" E. The soils are of Imo shale geologic formation (FDALR, 1990). According to Chukwu (2007), the vegetation of Ifite Ogwari is derived savanna with some patches of rainforest. The natural vegetation consists of grasses and trees. It experiences two major seasons of rainy season and dry season. The rainy season starts at the end of the month of March and lasts till October, while the dry season starts from the month of November and ends in the month of February. Data from Nigeria meteorological Agency for the year 2022 showed that Ifite ogwari had an annual rainfall of 2737.4mm and relative humidity of about 70%. The inhabitants of this region are predominantly farmers having rice, cassava, plantain and okra as their major food crops.

Description of land use practices in the study area

Three land use types namely; cassava farmland, grassland and rice farm were selected for the study**.** The selection of these land use types were based on the common farming practices within the study area**.** The grassland had been under grass cover for over three (3) years having spear grass, bahamas grass (*cynodon dactylon*), *panicum maximum, Elusine indica*, as well as *mimosa pudica* as dominant species. The rice farm had been under continous rice cultivation for over 5years while the cassava farm had been under continuous cultivation of cassava which sometimes is intercropped with maize and yam for more than 6 years. These farmlands (cassava and rice farms) are usually rainfed and cleared of weeds using herbicides.

Soil Sampling and Handling

Disturbed and undisturbed soil samples were collected with the aid of auger and core samplers from each of the land use types in three replicates at 0-20cm and 20-40 cm depths. The collected soil samples were bagged, properly labelled, air dried, and taken to the laboratory for analysis of selected physicochemical properties of soil.

Laboratory Analysis

The following physical and chemical properties of soil were carried out in the laboratory.

i. Particle size Distribution: The hydrometer method as described by Gee and Or (2002) was used to determine the particle size distribution of the samples, while the soil textures were determined using the USDA Textural triangle.

ii. Bulk Density: The bulk density was determined by core method as described by Grossman and Reinsch (2002)

iii. Soil Total Porosity: This was calculated from the bulk density as shown in this equation:

$$\text{Total porosity (\%)} = (1 - \frac{\text{Bd}}{\text{pd}}) \times 100$$

Where Bd =Bulk density
Pd =particle density (2.65g/cm^3)

iv. Saturated Hydraulic conductivity (k_{sat}): Saturated hydraulic conductivity was determined by the constant head permeability procedure according to Young (2001). Darcy's equation for vertical flow of liquid was used for the computation of K as shown in the equation:

$$K_{sat} = \frac{QL}{AT\triangle H}$$

Where Q is water discharge (cm), L is length of soil column, A is the interior cross-sectional area of the volume of soil not occupied by soil column (cm), H is the head pressure difference causing the flow and it is dimensionless, T is the time of flow measured in seconds.

v. Gravimetric Moisture Content: Moisture content of the soil was determined by oven drying at a temperature of 1050C and percentage of moisture in soil calculated mathematically as follows:

$$GMC = \frac{W2-W3}{W3-W1} \times 100$$

Where W_1=Weight of the can
W_2=Weight of wet sample + can
W_3=Weight of oven dried sample + can

vi. Soil pH was measured electrometrically by glass electrode in pH meter in both KCI (1 N) and distilled water suspension using a soil: liquid ratio of 1: 2.5 (International Institute for Tropical Agriculture, 1979)

vii. Soil organic carbon was determined using the wet dichromate oxidation method of Walkley and Black (1934). Organic matter was calculated by multiplying the value of organic carbon by a factor of 1.724 (Van Bemmelen factor).

viii. Total Nitrogen (TN): This was determined by the Kjeldahl digestion method according to Jackson (1965).

ix. Exchangeable Basic Cations (calcium, magnesium, potassium and sodium): These were extracted in 1N, NH_4OAC at pH 7 and was followed by Calcium and Magnesium determination using Atomic Absorption Spectrophotometer and Potassium, Sodium determination using flame photometer.

x. Exchangeable acidic cations: Hydrogen and Aluminum was estimated titrimetrically.

xii. Available phosphorus: Bray II method was used according to Olsen and Sommer (1990).

xii. Base Saturation: This was calculated on a percentage basis by dividing total exchangeable bases (Ca^{2+}, mg^{+}, K^{+}, Na^{+}) by cation exchange capacity multiplied by 100%.

$$BS = \frac{TEB}{CEC} \times 100$$

xiii. Cation Exchange Capacity (CEC): This was computed as the sum of the exchangeable bases and the exchange acidity.

CEC= TEB+ TEA

xiv. Exchangeable Sodium Percentage (ESP): This was calculated by dividing the exchangeable sodium by available CEC as shown in the equation:

$$ESP = \frac{\text{Exchangeable Na value}}{CEC} \times 100$$

Where TEB=Total Exchangeable Bases
CEC=Cation Exchange Capacity

Statistical Analysis

Data collected were subjected to analysis of Variance using SPSS 13.0 (SPSS Inc., Chicago, IL, USA). Significant difference between the means were separated using Duncan's multiple range test at 5% probability level.

RESULTS AND DISCUSSION

Physical properties of soil in relation to land use types

The results in table 1 showed that the soils under rice farm had the highest sand content of 388 g/kg at 20-40cm depth while the soils under grass cover had the lowest sand content of 306 g/kg at 0-20 cm depth. Cassava farm had the highest and lowest mean clay contents of 495g/kg and 392 g/kg at 20-40 cm and 0-20 cm depths respectively. Highest silt content with a value of 280 g/kg was obtained under cassava farm at 0-20cm depth while grassland had the lowest silt content of 173g/kg at 20-40cm depth. The soils under the studied land use types were predominantly of clay textural class with the exception of cassava farm with clay loam texture. Soil bulk density was highest under cassava farm having a value of 1.94 g/cm^3 at 20-40cm depth and lowest under grassland and rice farm with values of 1.60g/cm^3 respectively at 0-20cm depth. Soil bulk density under land use types were not significantly different however the highest bulk density obtained under cassava farm could be attributed to the activities and management practices during the cultivation process. The study observed that soil bulk density increased with an increasing depth and could be as a result of low organic matter content as well as pore space distribution which corroborates with the findings of Singh *et al*., (2015). Grassland and rice farm recorded the highest total porosity with equal values of 39.81% respectively at 0-20cm while cassava farm recorded the lowest total porosity having a value of 30.81% at 20-40cm depth. Soil moisture content was highest under grassland with a value of 10.99% at 0-20cm depth while cassava farm had the lowest moisture content having a value of 5.84% at 20-40cm depth. Soil moisture content was significantly higher under grassland when compared with rice farm at 0-20cm depth. The hydraulic conductivity of soils under land use types were generally low and ranged from 0.01 - 0.03cm/hr. Aggregate stability of soils under the land use types were generally low and ranged from 0.32-0.56 across the depths; the low values of soil aggregate stability obtained revealed a less stable aggregates which could be as a result of exposure of the studied land use types to water erosion. However, the aggregate stability of soil under grassland was significantly higher than the rice farm at 0-20cm depth. The silt clay ratio under the studied land use types were generally low; it decreased as the depth increased. The lower the silt clay ratio the more weathered the soils become.

Table 1: Physical Properties of Soils as influenced by land Use types at 0-20cm and 20-40cm depths.

LAND USE	Depth (cm)	Bulk density (g/cm)^3	Total porosity (%)	Ksat (cm/hr)	Moisture Content (%)	Aggregate Stability	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Textural Class	SCR
Cassava farm (CM)	0-20	1.68bc	36.73a	0.02b	9.17ab	0.52ab	321a	280a	392a	Clay loam	0.80a
	20-40	1.94ab	30.81a	0.03b	5.84ab	0.47abc	314a	215a	495a	Clay	0.80a
Grassland (GL)	0-20	1.60c	39.81a	0.02b	10.99a	0.56a	306a	206a	486a	Clay	0.70a
	20-40	1.82abc	31.31ab	0.02b	7.17ab	0.49abc	326a	173a	473a	Clay	0.41a
Rice Farm (RF)	0-20	1.60c	39.81a	0.01b	6.13b	0.32c	325a	246a	428a	Clay	0.73a
	20-40	1.82abc	31.31ab	0.01b	8.81ab	0.37bc	388a	193a	405a	Clay	0.56a

Note: same alphabets represent non-significant difference while different alphabet represents significant difference. SCR- Silt clay ratio

Chemical Properties of soil in relation to land use types.

From the results obtained as shown in table 2, soil pH under the studied land use types ranged from 5.68-5.77 at the 0-20cm depth and 4.84-5.87 at 20-40cm depth. The pH of soil under land use types within the 0-20cm depth was moderately acidic and ranged from very strongly acidic to moderately acidic at 20-40cm depth across the land use types. Cassava farm had the highest soil organic carbon content with a value of 1.32% at 0-20cm depth while grassland had the lowest soil organic carbon content with a value of 0.40% at 20-40cm depth. The total nitrogen in soils of the studied land use types ranged from 0.01- 0.11% which was generally low across the depths. Available phosphorus was highest under cassava farm having a value of 8.33 mg/kg at 0-20cm depth while grassland had the lowest available phosphorus content of 0.86 mg/kg at 20-40cm depth. The total exchangeable cations (ca^{2+}, mg^{2+}, $k^{+,}$ Na^+) obtained in soils under land use types and across the depths varied from moderate, low to very low based on FDALR (1990) classification. Calcium content ranged from 1.80 -4.07 cmol/kg (very low to low), magnesium content ranged from 1.20-2.40cmol/kg (moderate), potassium content ranged from 0.17 -0.34cmol/kg (very low to low) while sodium content ranged from 0.08-0.22cmol/kg (very low to low). Total exchangeable acidity was highest with a value of 1.67 cmol/kg under cassava farm at 0-20cm depth while it was lowest with a value of 0.80 cmol/kg under grassland at 20-40cm depth. The cation exchange capacity of soils under land use types studied ranged from 5.89 -8.65 cmol/kg at 0-20cm depth and 3.68 -7.55cmol/kg at 20-40cm depth. The cation exchange capacity of soils under cassava farm was significantly higher compared to other land use types. The cation exchange capacity of soils under the land use types studied were generally low and could be a reflection of the soil's inability to retain nutrients as reported by Nwosu *et al*. (2020). Highest exchangeable sodium percentage was obtained in cassava farm with a value of 3.21% at 20-40cm depth while the lowest was obtained under rice farm at 0-20cm depth having a value of 1.52%. Exchangeable sodium percentage identifies the degree to which the exchange complex of a soil is saturated with Na^+. A soil is considered sodic (high level of Na^+) when the ESP is 6 or greater; however the results obtained in this study were less than 6 and could imply a non-sodic soil. The soil base saturation under the land use types ranged from 78.20-82.23% which decreased as the depth increased. The percentage base saturation is often considered to be an indication of soil fertility. This study showed that the soil base saturation under the land use types was high based on Landon (1991) classification who classified soil with percentage base saturation of <20% to be low, 20-60% to be medium and >60% to be high in fertility. The general decrease in nutrients as the depths increased in this study could be attributed to the vertical loss of nutrients from the soil surface to the sub surface.

Table 2: Chemical Properties of Soils as influenced by land use types at 0-20cm and 20-40cm depths.

Land use	Depth (cm)	pH	SOC (%)	SOM (%)	TN (%)	AvP (Mg/kg)	Ca^{2+}	Mg^{2+}	K^+	Na^+	Al^{3+}	H^+	TEA	CEC	ESP (%)	BS (%)
							←		Cmol/Kg					→		
CF	0-20	5.77a	1.32a	2.27a	0.11a	8.33a	4.07a	2.40a	0.34a	0.18ab	1.03a	0.63a	1.67a	8.65a	2.03bc	82.23ab
	20-40	5.87a	1.25a	2.14ab	0.10a	6.81a	3.46abc	2.07ab	0.30abc	0.22a	0.83ab	0.40bcd	1.26abc	7.12ab	3.21ab	82.03ab
GL	0-20	5.71a	0.49bcd	1.26bcd	0.06ab	3.54ab	2.67abc	1.60ab	0.32ab	0.18ab	0.86ab	0.27cd	1.13bcd	5.89ab	2.90ab	79.70ab
	20-40	4.84b	0.40cd	0.71cd	0.01bc	0.86ab	1.80c	1.20b	0.17d	0.08c	0.50cd	0.23d	0.80ed	3.68bc	2.23abc	78.20ab
RF	0-20	5.68a	1.21a	2.09ab	0.10a	6.67a	3.46abc	1.80ab	0.19cd	0.10bc	0.93ab	0.45bc	1.38abc	6.92ab	1.52c	79.77ab
	20-40	5.61a	1.04ab	1.79ab	0.09a	5.95ab	3.67ab	2.00ab	0.21bcd	0.17abc	1.00ab	0.50ab	1.50ab	7.55ab	2.28abc	78.20b

Note: same alphabets represent non-significant difference while different alphabet represents significant difference; CM= Cassava Farm, GL=Grassland, RF= Rice Farm

CONCLUSION

The study observed that the studied land use practices influenced majority of the soil properties hence the low values obtained; this showed that land use and management practices usually cause changes to soil characteristics and oftentimes degrade the soils. For optimum soil productivity, appropriate conservation practices and measures are required to ensure sustainable land utilization which in turn improves the soil physicochemical properties.

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The Influence of Soil Health on Food Security and Nutrition: A Review

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Sustainable agriculture

ABSTRACT

This paper provided a review on the crucial role of soil in food production, nutritional quality, and sustainable agricultural practices. By analyzing soil composition and nutrient availability, soil management practices for sustainable agriculture, soil microorganisms and food safety, soil contamination and food quality, soil health and nutritional quality of crops, impact of climate change on soil fertility and food production, future perspectives and innovation, this article aimed to enhance our understanding of the interconnections between soil and food, ultimately contributing to the development of innovative agricultural practices and improved food security.

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INTRODUCTION

Soil plays a vital role in facilitating plant growth by offering essential elements like nutrients, water, oxygen, and physical support. Additionally, it serves as a habitat for soil organisms that contribute to the fertility and stability of the soil (FAO, 2015). The health of soil directly influences the nutritional quality of crops. Soil health indicators, such as organic matter content, nutrient availability, and microbial activity, influence the nutrient composition of harvested crops. Conversely, nutrient deficiencies or imbalances in the soil can result in nutrient-deficient crops, affecting human health and nutrition (Silver *et al.,* 2021). Adequate nutrient availability in the soil is essential for optimal plant growth, crop yield, and nutritional quality. Efficient soil management practices are crucial for maximizing food production and ensuring sustainable agricultural systems. Farmers employ various techniques to maintain soil health and fertility, including the application of organic and inorganic fertilizers, crop rotation, and integrated pest management. These activities may impair soil quality and reduce its capacity to support food production. One of the major challenges for soil management is to balance the demand for food with the conservation of soil functions and services. To overcome these challenges, it is necessary to enhance the effectiveness and sustainability of nutrient utilization, minimize soil erosion, and rehabilitate degraded soils (FAO, 2015; Silver *et al.*, 2021). Soil provides the essential foundation for plant growth, nutrient availability, and overall crop productivity. By implementing effective soil management practices and promoting soil health, we can enhance food production, improve the nutritional quality of crops, and foster sustainable food systems. This article aims to provide a comprehensive understanding of the intricate relationship between soil and food,examining the crucial role of soil in food production, nutritional quality, and sustainable agricultural practices, ultimately contributing to the development of innovative agricultural practices and improved food security.

Soil Composition and Nutrient Availability

Soil composition plays a crucial role in determining the availability of nutrients for plant uptake, ultimately influencing crop growth and productivity. The physical and chemical properties of soil, along with its mineral composition and organic matter content, collectively contribute to nutrient availability (Marschner and Rengel, 2023).The physical properties of soil, such as texture, structure, and porosity, affect nutrient retention and movement. Soils with finer particles, such as clay, have a higher cation exchange capacity, allowing them to retain and supply nutrients to plants over an extended period. Chemical properties of soil, including pH, organic matter content and nutrient-holding capacity, also impact nutrient availability. Soil pH significantly influences nutrient solubility and availability. Acidic soils with low pH levels can limit the availability of essential nutrients like phosphorus, calcium, and magnesium, while alkaline soils can restrict the uptake of micronutrients like iron and zinc (Aziz *et al.*, 2010).Organic matter in the soil plays a vital role in nutrient cycling and availability. It acts as a reservoir of nutrients, releasing them gradually over time for plant uptake. Soil fertility is closely linked to nutrient availability, as fertile soils contain adequate levels of essential nutrients required for plant growth. In addition to yield and nutritional composition, nutrient availability affects the overall health and resilience of plants. Balanced nutrient uptake supports plant immune systems, helping to combat diseases and pest infestations. To ensure optimal nutrient availability for crops, soil testing and nutrient management practices are essential. Soil testing provides insights into the nutrient status of the soil, allowing for targeted fertilizer application based on specific crop requirements. Adopting precision nutrient management strategies can help prevent nutrient deficiencies or excesses, optimizing crop quality and minimizing environmental impacts (Silver *et al.,* 2021).

Soil Management Practices for Sustainable Agriculture

Sustainable soil management practices are essential for maintaining soil health, improving agricultural productivity, and preserving natural resources. These practices aim to optimize soil functions while minimizing negative environmental impacts (Powlson*et al.,* 2011).Crop rotation involves the systematic rotation of different crops on the same piece of land over time. This practice helps break disease and pest cycles, enhances soil structure, and improves nutrient availability. Diversification of crops also promotes biodiversity, reduces the reliance on chemical inputs, and enhances overall ecosystem resilience (Powlson*et al.,* 2011; Tugrul, 2019).Cover cropping involves planting specific crops during fallow periods or between main crops. They also contribute to weed suppression, pest control, and nutrient cycling (Lal*et al.*, 1997).Effective nutrient management is crucial for sustainable soil fertility and crop productivity. It involves optimizing the application of organic and inorganic fertilizers based on soil nutrient testing and crop nutrient requirements. Balancing nutrient inputs with crop uptake minimizes nutrient losses, reduces environmental pollution, and improves nutrient use efficiency (Earles and Williams, 2005). Integrated Pest Managementcombines various pest control strategies to minimize the use of chemical pesticides while effectively managing pests. This approach integrates cultural practices, biological control agents, and targeted pesticide application. By minimizing pesticide use, Integrated Pest Management helps protect beneficial soil organisms, pollinators, and overall ecosystem health (Reganold*et al*., 1990; Powlson*et al.*, 2014). Sustainable water management practices, such as precision irrigation, help optimize water use efficiency and conserve water resources.

Soil Microbiome and Food Safety

Soil microorganisms play a critical role in maintaining food safety throughout the agricultural production chain and have a significant impact on food safety. While beneficial soil microorganisms contribute to nutrient cycling and plant health, soil-borne pathogens pose risks to human health when transmitted to crops and consumed. Beneficial soil bacteria and fungi, such as *rhizobia* and *mycorrhizal fungi*form symbiotic relationships with plants, enhancing nutrient uptake and promoting plant health. These microorganisms contribute to sustainable agriculture practices by reducing the need for chemical fertilizers and pesticides (Altomare, and Tringovska, 2011).Soil can also harbor pathogenic microorganisms, including bacteria, viruses, and parasites, which can contaminate crops and pose risks to human health. Pathogens such as *Salmonella, Escherichia coli (E. coli), Listeria monocytogenes*, and various parasites can be present in soil and be transferred to food crops through contaminated irrigation water, contaminated manure or compost, or poor hygiene practices during harvesting and processing (Qian*et al.*, 2021). Soil contamination can occur due to various factors, including improper handling and application of manure or sewage sludge, runoff from animal production facilities, polluted irrigation water, and the use of contaminated agricultural inputs. These contaminated soils can introduce pathogenic microorganisms into the food production system, increasing the risk of foodborne illnesses(Sethi and Gupta, 2020).Implementing Good Agricultural Practices is essential for reducing the risk of soil microbial contamination in food production include measures such as proper composting techniques, appropriate use of manure and irrigation water, regular monitoring and testing of soil and water sources, and adequate hygiene practices during crop handling and processing.

Soil Contamination and Food Quality

Various contaminants, such as heavy metals, pesticide residues, and pollutants, can accumulate in soil and affect the quality and nutritional value of crops. Heavy metals, including lead, cadmium, mercury and arsenic, can accumulate in soil due to human activities such as industrial processes, mining, and the use of contaminated fertilizers or irrigation water. These heavy metals can be taken up by plants and accumulate in their tissues, affecting crop quality (Golia, 2023). High levels of heavy metal contamination in soil can lead to reduced crop yield, decreased nutrient uptake, altered nutrient composition, and compromised food safety (Lewin *et al.,* 2018).Chronic exposure to pesticide residues in food can have adverse effects, including neurotoxicity, endocrine disruption, and increased cancer risk. To mitigate these risks, proper pesticide application techniques, adherence to recommended safety intervals, and compliance with maximum residue limits are essential (Van Boxstael *et al.,* 2013).Soil pollution, resulting from the release of pollutants such as industrial chemicals, heavy metals, and persistent organic pollutants, can impact food nutritional value (Mishra *et al.,* 2016). Pollutants can affect the soil's fertility, nutrient cycling processes, and microbial activity, thereby influencing the availability and uptake of nutrients by plants (Oves *et al.,* 2012). Soil pollution can lead to nutrient imbalances, reduced crop quality, and compromised nutritional value of food, potentially affecting human health and well-being.

Soil Health and Nutritional Quality of Crops

Soil health indicators provide valuable insights into the overall condition and functionality of the soil ecosystem (Weil, 2004). These indicators include physical, chemical, and biological properties that influence nutrient availability and uptake by plants. For example, soil organic matter content is closely related to nutrient cycling and can enhance nutrient retention and release in the soil (El-Ramady*et al.,* 2014). Other indicators, such as pH, nutrient levels, microbial activity, and soil structure, also impact crop nutrition. Assessing these soil health indicators helps identify potential nutrient limitations or imbalances, guiding appropriate management strategies to optimize crop nutrition (Karlen*et al.,* 1999).Organic amendments, such as compost and manure, enrich the soil with nutrients and enhance soil microbial activity, ultimately benefiting crop nutrition. On the other hand, inappropriate use of fertilizers, excessive tillage, or improper irrigation practices can negatively impact soil health and subsequently affect crop nutrient content (Ghorbani *et al.,* 2008). Soil characteristics, including texture, pH, and mineral content, addition of fertilizer can affect nutrient availability and uptake by plants. For instance, acidic soils may limit the availability of certain nutrients, while alkaline soils can affect nutrient uptake due to ion imbalances (Lehmann *et al*., 2020). Additionally, soils with varying mineral compositions can influence the nutrient content of crops. Understanding these soil-crop interactions can help identify potential nutritional variations and guide targeted agricultural practices to address specific nutrient deficiencies or imbalances.

Future Perspectives and Innovations

In recent years, there has been growing interest in exploring emerging technologies and approaches to enhance soil and food systems (Caliman *et al*., 2011). Advancements in technology are revolutionizing the way we understand and interact with soil and food production. Several emerging technologies and approaches hold tremendous promise for improving soil health and food systems (Giller*et al.,* 2004). Nanoparticles, such as nano-fertilizers and nano-pesticides, offer targeted and controlled delivery of nutrients and pest management agents to plants. These nanomaterials can improve nutrient uptake efficiency, reduce chemical usage, and mitigate environmental impacts (Manjunatha *et al.,* 2016). This approach emphasizes the use of beneficial microorganisms and organic amendments to enhance soil fertility, suppress diseases, and promote plant growth. Harnessing the power of microbial communities can result in improved nutrient cycling, reduced reliance on synthetic inputs, and increased soil biodiversity (Giller*et al.,* 2004). As urbanization continues to increase, vertical farming presents a sustainable solution for cultivating food in limited spaces. By utilizing advanced lighting systems, hydroponics, and aeroponics, vertical farms can optimize resource utilization, minimize water usage, and reduce transportation costs(Al-Kodmany, 2018).Some notable innovations include remote sensing and satellite imagery (Yang *et al*., 2012), sensor-based soil monitoring

(Bogue, 2017). These data enable farmers to implement precise irrigation and nutrient management strategies, reducing resource wastage and optimizing crop productivity. Farmerscan detect early signs of stress or diseases and take prompt corrective actions(Robert, 2002). This holistic approach promotes adaptive management strategies, leading to improved productivity, profitability, and environmental stewardship (Glover *et al*., 2000).

CONCLUSION

The relationship between soil and food is crucial for sustainable agriculture and food security. This article explores emerging technologies and approaches in soil and food, precision agriculture, and soil monitoring techniques, emphasizing the integration of soil health assessments into food production systems. Adoption of innovative technologies can enhance sustainability by optimizing resource use, reducing chemical inputs, and improving soil health, leading to resilient and productive agricultural systems. Precision agriculture minimizes waste, conserves water, and boosts crop productivity while reducing environmental pollution. However, further research and collaboration are needed to understand the impact of changing climatic conditions on soil fertility and crop performance, and to explore regenerative agriculture practices for enhancing ecosystem services and biodiversity. Integrating soil health assessments into food production empowers farmers to implement targeted management practices for sustainable outcomes, paving the way for a more resilient and productive future in soil and food production.

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Morphology, Physico-Chemical Properties and Classification of Soils of Coastal Plain Sands in Owerri, Imo State, Southeastern Nigeria

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ABSTRACT

Assessment of soil health and fertility depends on the understanding of properties and classifications of soils. In this study, soils from Obinze, Avu, Irete, and Amakohia were examined for morphology, physical, chemical properties, and classification. Target sampling technique was used and two profiles each dug across the four study sites. A total of 37 soil samples were collected according to horizon differentiation, and analyzed in the laboratory using standard procedures. Results showed that soils were well drained, colour matrix varied from brown (2.5 YR 3/2) to red (2.5 YR 5/8), sand dominated the fine earth materials (> 600 g/kg) with clay content (109 – 308 g/kg) irregularly distributed due to eluviation. Textural classes ranged from sandy loam to sandy clay loam, bulk density ranged from 1.0 – 1.77 Mg/cm^3 with high values recorded in Amakohia. Silt/clay ratio indicated advanced weathering (< 1.0), while moisture retention capacity was low. Soil pH was moderately acidic (5.22 – 6.16), and organic carbon, nitrogen, and phosphorus levels were generally low and irregularly distributed. Exchangeable cations and cation exchange capacity varied irregularly down horizons, with low base saturation indicating low soil fertility. Soils were classified using USDA Soil Taxonomy and correlated with World Reference Base for Soil Resources. Obinze, Avu, and Amakohia soils were classified as Grossarenic Kandiudult, while Irete was Typic Kandiudult, and translates to Dystric Nitisols (World Reference Base). It is recommended that; the incorporation of crop residues and addition of organic manures will improve the properties of the soils for sustainable crop production.

INTRODUCTION

Soils of Owerri are predominantly derived from Coastal Plain Sands parent material, shaped by nearby rivers such as Nworie and Otamiri. The geological formation is Oligocene-Miocene formations, comprising acid crystalline rocks like granites, gneisses, and quartzite of the Benin formation. The characteristics of these soils in a given location are greatly influenced by its parent material (Nsor, 2017). These soils typically exhibit reddish-yellow to reddish hues, sandy clay textures, and blocky structures, with low cation exchange capacity (CEC), base saturation, and free iron oxide content (Madueke *et al*., 2021). Diagnostic horizons commonly display argillic characteristics, abundant weatherable minerals, and low silt-clay ratios (Nnabuihe *et al*., 2021 and 2022). They often have deep profiles, mainly in low-lying areas, with coarse to fine sand textures and an acidic nature. The clay fraction tends to be rich in kaolinitic clay minerals, possibly due to high rainfall and soil temperatures (Nnabuihe *et al*., 2023). These soils also support diverse agricultural crops and tree plantations such as maize, yam, cassava, fluted pumpkin, oil palm, mango, avocado, kola, as well as various shrubs and grasses (Madueke *et al*., 2020). The region faces threats from rapid industrialization and population growth, leading to unsustainable land practices and environmental issues. Hence, this study aims to assess soil properties and classify them based on USDA Soil Taxonomy (Soil Survey Staff, 2014) and FAO/UNESCO World Reference Base (2014) for sustainable crop production.

MATERIALS AND METHODS

Study sites include Obinze, which is located between Lat. 05^{0} 26.804^{1} N and Long. 06^{0} 58.395^{1} E on elevation of 68 m, Avu between Lat. 05^{0} 25.663^{1} N and Long. 06^{0} 58.456^{1} E on elevation of 66 m, Amakohia between Lat. 05^{0} 30.376^{1} N and Long. 07^{0} 20.853^{1} E on elevation of 58 m, and Irete between Lat. 05^{0} 30.118^{1} N and Long. 06^{0} 59.784^{1} E on elevation of 72 m. Obinze and Avu are mainly suburbs with fast growing metropolis, Amakohia consisted of developed residential area, while Irete consisted of clusters of industries, mostly manufacturers. Mean annual temperatures ranged from 28-31°C and annual rainfall from 2500 to 3000 mm peaking between April and November (NIMET, 2023).

Target soil sampling technique was used and two profiles each dug across the four study sites. Soil sampling involved profiles as described by Food and Agriculture Organization (FAO, 2006). Thirty-seven (37) soil samples were collected, air-dried, sieved, and analyzed for physical and chemical properties. Soil particle size distribution was analyzed using hydrometer method, as described by Gee and Or (2002). Bulk density was analyzed using Core method, as described by Grossman and Reinsch (2002). Oven-drying saturated samples method was used to determine moisture content, according to Obi (1990). pH meter was used as described by Thomas (1996) to determine soil pH. Total nitrogen was based on micro Kjeldahl digestion method (Bremmer,1996). Organic carbon was analyzed using the wet digestion method (Walkley and Black, 1934). Available phosphorus was analyzed using Bray I method (Bray and Kurtz, 1945). Exchangeable acidity was based on (Mclean, 1982) and exchangeable bases (Ca, Mg, K and Na) were extracted in 1N NH_4OAc at pH 7. Sodium and K were determined with a flame photometer while Ca and Mg were determined with atomic absorption spectrophotometer (Jackson, 1962). Cation exchange capacity was analyzed using aluminum acetate leaching at pH 7 (Blackermore *et al*., 1987). Base saturation, aluminum saturation and exchangeable sodium percent were calculated.

STATISTICAL ANALYSIS

Variability amongst soil properties of different profiles were estimated using the method proposed by Wilding (1994). In this, a coefficient of variability (CV), less than 15 represents low variation,16-30 (moderate variability) and greater than 30 represents high variation (Wilding *et al*.;1994).

RESULTS AND DISCUSSION

Soil morphological properties (Table 1) revealed darker surface (0-15 cm) compared to subsurface (15-200 cm) horizons. Avu soils exhibit brownish surface and reddish-brown argillic horizons, likely influenced by organic matter. Obinze soils are reddish-brown, while Irete and Amakohia vary, possibly due to material movement from drainage. Soil structure ranges from weak to strong, with Amakohia having high compaction in A horizon. Good drainage, as attributed to more macropores, was observed. Avu shows dense plant roots, especially in argillic horizons, due to perennial crop dominance. The high root concentration in Obinze could be the abundance of trees as reported by other researchers (Esu, 2010; Madueke *et al.*, 2021, Nnabuihe *et al.*, 2022).

Table 1: Morphological properties of soils of the study sites

Horizon	Depth	Matrix colour (moist)	Texture	Structure	Consistence	Boundary form	Roots	Drainage
				OBINZE I				
A	0 – 16	2.5 YR 3/3	SL	1fg	st/sp fr	Cw	m-vf, m-f, c-m	Wd
AB	16 – 41	2.5 YR 3/4	SCL	1 msbk	st/sp fi	Gs	c-vf, c-f, m-m	Wd
Bt_1	41 – 70	2.5 YR 4/6	SCL	1 csbk	st/sp, fi	Ds	f-vf , f- f, m-f	Wd
Bt_2	70 – 122	2.5 YR 4/8	SCL	1 csbk	st/sp fi	Ds	f-vf, f-f, m-m	Wd
Bt_3	122 – 200	2.5 YR 5/8	SCL	1 csbk	st/sp fi		f-vf , f-f,c- m	Wd
				OBINZE II				
A	0 – 18	2.5 YR 3/2	SL	1fg	st/sp ,fr	Cs	m-vf, m-f,c-m	Wd
AB	18 – 42	2.5 YR 3/3	SCL	1 msbk	st/sp, fi	Gw	c-vf,c-f,	Wd
Bt_1	42 – 75	2.5 YR 4/4	SCL	1 msbk	st/sp fi	Ds	f-vf,f-f,f-c	Wd
Bt_2	75 – 128	2.5 YR 4/6	SCL	1 msbk	st/sp, fi	Ds	f-vf,f-f,m-c	Wd
Bt_3	128 – 200	2.5 YR 5/6	SCL	1 csbk	st/sp,fi		f-vf,c-m	Wd
				AVU I				
A	0 – 17	2.5 YR 3/3	SCL	1fg	slp/sls, fr	Gw	m-vf,m-f,m-m,c-f	Wd
AB	17 – 53	2.5 YR 3/4	SCL	2 msbk	slp/sls fi	Cw	m-vf,m-f,m-m,f-c	Wd
Bt_1	53 – 88	2.5 YR 4/4	SCL	1 msbk	st/sls fi	Ds	m-vf,m-f,m-c	Wd
Bt_2	88 – 134	2.5 YR 4/6	SCL	1 msbk	slp/sls fi	Ds	c-vf,c-f,c-m	Wd
Bt_3	134 – 200	2.5 YR 5/6	SCL	2 msbk	slp/sls fi		f-vf,vf-f	Wd
				AVU II				
A	0 – 14	2.5 YR 3/2	SCL	1fg	slp/sls fr	Gs	m-vf,m-f,m-m,vf-c	Wd
AB	14 – 36	2.5 YR 3/3	SCL	1 msbk	slp/sls fr	Cs	m-vf,m-f,c-m,vf-c	Wd
Bt_1	36 – 67	2.5 YR 3/4	SCL	2 msbk	slp/sls,fi	Cs	f-vf,c-f,m-m,c-c	Wd
Bt_2	67 – 94	2.5 YR 4/4	SCL	1 msbk	slp/sls,fi	Ds	m-vf,m-f,m-m	Wd
Bt_3	94 – 148	2.5 YR 4/6	SCL	2 msbk	slp/sls,fi	Ds	c-vf,c-f,c-m,vf-c	Wd
Bt_4	148 – 200	2.5 YR 5/6	SCL	2 msbk	slp/sls,fi		f-vf,vf-f,vf-m	Wd
				IRETE I				
A	0 – 60	2.5 YR 4/6	SCL	2 cg	slp/sls, fi	Cs	f-c	Wd
AB	60 – 122	2.5 YR 4/8	SCL	2 msbk	slp/sls, fi	Gs	-	Wd
Bt_1	122 – 166	2.5 YR 5/6	SCL	2 msbk	slp/sls, fi	Ds	-	Wd
Bt_2	166 – 200	2.5 YR 5/8	SCL	2 msbk	slp/sls, fi		-	Wd
				IRETE II				
A	0 – 56	2.5 YR 4/6	SCL	2 msbk	slp/sls, fi	Cs	-	Wd
AB	56 – 130	2.5 YR 4/7	SCL	2 msbk	stp/p, fi	Gw	-	Wd
Bt_1	130 – 170	2.5 YR 5/6	SCL	2 msbk	slp/sls, fi	Ds	-	Wd
Bt_2	170 – 200	2.5 YR 5/9	SCL	2 msbk	slp/sls, fi		-	Wd
				AMAKOHIA I				
A	0 – 29	2.5 YR 3/2	SCL	3 msbk	slp/sls, fr	Cw	m-vf,m-f	Wd
AB	29 – 68	2.5 YR 3/6	SCL	2 fsbk	stp/slp, fi	Ds	f-vf	Wd
Bt_1	68 – 141	2.5 YR 4/6	SCL	2 msbk	slp/sls, fi	Dw	f-vf,f-f	Wd
Bt_2	141 – 200	2.5 YR 5/8	SCL	2 msbk	slp/sls, fi		f-vf,f-f	Wd
				AMAKOHIA II				
A	0 – 25	2.5 YR 3/3	SCL	2 msbk	slp/sls fr	Cs	m-f	Wd
AB	25 – 76	2.5 YR 3/6	SCL	2 msbk	st/p,fi	Ds	f-vf	Wd
Bt_1	76 – 153	2.5 YR 4/7	SCL	2 msbk	sp/sls,fi	Dw	f-vf,f-f	Wd
Bt_2	153 – 200	2.5 YR 5/8	SCL	2 csbk	sp/sls,fi		f-vf	D

Key: Texture:-SL= sandy loam, SCL:- sandy clay loam, Structure:-1= weak, 2 = moderate, 3 = strong, f = fine, m = medium, c = coarse, g = granular, sbk = sub angular blocky, Consistence:- fr=friable, fi = firm, st = sticky, sls=slightly sticky, sp=slightly plastic, p=plastic, Boundary form:- c = clear, w = wavy, d = diffuse, s = smooth, g = gradual Roots:- (number): m = many, c = common, f = few, vf = very few.(size): vf = very fine, f = fine, m = medium, c = coarse, Drainage : wd=well drained

Table 2: Physical properties of soils of the study sites

Horizon	**Depth (cm)**	**Sand**	**Silt**	**Clay**	**TC**	**SCR**	**BD**	**MC**	**Porosity**
		g/kg			**%**		**Mg/cm^3**	**%**	
				OBINZE I					
Ap	0-16	762	60	178	SL	0.34	1.23	4.58	53.58
AB	16-41	772	20	208	SCL	0.10	1.41	4.98	46.80
Bt1	41-70	752	20	228	SCL	0.10	1.56	5.14	41.13
Bt2	70-122	752	20	228	SCL	0.10	1.41	5.23	46.80
Bt3	122-200	752	20	228	SCL	0.10	1.41	6.18	46.80
	Mean	758	28	214		0.15	1.40	5.22	47.02
	CV (%)	**1.06**	**57.14**	**9.16**		**64.00**	**7.47**	**10.12**	**8.39**
				OBINZE II					
Ap	0-19	741	50	109	SL	0.24	1.19	4.55	55.09
AB	19-46	782	20	202	SCL	0.10	1.38	4.23	47.92
Bt1	46-75	743	39	218	SCL	0.18	1.58	5.00	40.38
Bt2	75-128	742	30	228	SCL	0.13	1.45	6.50	45.28
Bt3	128-200	732	40	228	SCL	0.18	1.40	6.28	47.17
	Mean	748	36	217		0.17	1.40	5.31	47.17
	CV (%)	**2.33**	**28.13**	**20.74**		**28.24**	**9.00**	**17.25**	**10.08**
				AVU I					
Ap	0-17	752	20	228	SCL	0.10	1.00	5.02	62.26
AB	17-53	772	40	188	SCL	0.21	1.31	5.31	50.57
Bt1	53-88	752	20	228	SCL	0.10	1.46	5.20	44.91
Bt2	88-134	752	20	228	SCL	0.10	1.56	6.64	41.13
Bt3	134-200	692	20	228	SCL	0.10	1.60	7.50	39.62
	Mean	744	24	220		0.12	1.39	5.93	47.70
	CV (%)	**3.65**	**33.33**	**7.27**		**36.67**	**15.64**	**16.37**	**17.20**
				AVU II					
Ap	0-14	772	20	208	SCL	0.10	1.20	5.16	54.72
AB	14-36	762	30	208	SCL	0.14	1.36	5.38	48.68
Bt1	36-67	742	30	228	SCL	0.14	1.41	6.18	46.79
Bt2	67-94	742	30	228	SCL	0.14	1.48	6.72	44.15
Bt3	94-148	722	30	248	SCL	0.12	1.42	7.70	46.42
Bt4	148-200	702	50	248	SCL	0.21	1.50	8.82	43.40
	Mean	740	32	228		0.14	1.40	6.66	47.36
	CV (%)	**3.16**	**28.05**	**7.16**		**24.19**	**7.04**	**19.26**	**7.86**
				IRETE I					
Ap	0-60	782	30	188	SCL	0.16	1.72	2.68	35.09
AB	60-122	774	50	176	SCL	0.28	1.54	3.18	41.89
Bt1	122-166	756	30	214	SCL	0.14	1.70	3.29	35.85
Bt2	166-200	752	30	218	SCL	0.16	1.58	4.08	40.38
	Mean	766	35	199		0.19	1.64	3.31	38.30
	CV (%)	**1.62**	**24.74**	**8.83**		**29.19**	**4.67**	**15.16**	**7.56**
				IRETE II					
Ap	0 – 56	766	80	154	SCL	0.52	1.68	2.72	36.60

AB	56 – 130	706	60	234	SCL	0.26	1.71	3.22	35.47
Bt1	130 – 170	726	40	234	SCL	0.17	1.76	3.43	33.58
Bt2	170 – 200	706	60	234	SCL	0.26	1.60	4.12	39.62
	Mean	726	60	214		0.30	1.69	3.38	36.32
	CV (%)	**3.37**	**23.57**	**16.19**		**43.61**	**3.43**	**14.87**	**6.03**
				AMAKOHIA I					
Ap	0-29	772	80	148	SCL	0.54	1.70	3.70	35.85
AB	29-68	632	60	308	SCL	0.19	1.73	4.16	34.72
Bt1	68-141	692	40	268	SCL	0.15	1.65	4.72	37.73
Bt2	141-200	672	20	308	SCL	0.06	1.68	5.13	36.60
	Mean	692	50	258		0.23	1.69	4.43	36.23
	CV (%)	**7.37**	**44.72**	**25.42**		**79.25**	**1.73**	**12.26**	**3.03**
				AMAKOHIA II					
Ap	0 -25	726	40	234	SCL	0.17	1.68	2.98	36.60
AB	25 – 76	666	40	294	SCL	0.14	1.74	3.20	35.34
Bt1	76 – 153	706	60	234	SCL	0.26	1.77	3.80	33.21
Bt2	153 – 200	646	60	294	SCL	0.20	1.71	4.88	35.47
	Mean	686	50	264		0.19	1.73	3.73	35.16
	CV (%)	**4.61**	**20.00**	**11.36**		**23.35**	**1.94**	**19.75**	**3.48**

Key: TC=textural class, BD=bulk density, SCR=silt clay ratio, MC=moisture content

Table 2 shows that soil physical properties were predominantly sandy in texture across various pedons, ranging from sandy loam to sandy clay loam (632 – 782 g/kg). This sandiness, was influenced by Coastal Plain Sands, land management, and climate, and suggested low CEC, high infiltration, and low moisture (Esu, 2010). Rapid nutrient leaching beyond rooting zones was anticipated. Increase clay content with depth resulted from soil sorting, clay migration, or erosion (argillation or lessivage). Silt/clay content (< 1.0) indicated highly weathered, ferraltic soils. Amakohia exhibited highest bulk density (1.70 - 1.77 Mg/cm³), possibly due to low organic carbon, clay accumulation, compaction from traffic / buildings, and rain impact. High moisture content in Avu may stem from organic carbon content (Anikwe, 2010).

Table 3 displayed results of chemical properties at the study sites. Soil pH ranged from 5.22 to 6.16 which is moderately acidic, due to leaching of basic cations and presence of iron and aluminum ions. Organic carbon values were generally low, with highest values in Avu and Obinze, attributed to tree litter and rapid decomposition, contrasting with lower values in Amakohia and Irete due to intense land use and leaching. Avu had the highest mean total nitrogen, followed by Obinze, while Amakohia and Irete had lower values due to high mineralization, leaching, and erosion. Available phosphorus was generally low (< 1.5 mg/kg) (Landon, 1991) due to colloidal particle loss. Exchangeable bases showed low levels of Na and K compared to Ca and Mg (Kyuma *et al*., 1986; Landon, 1991). Cation Exchange Capacity (CEC) was generally low (6 - 12 cmol/kg), typical of Coastal Plain Sands (Landon, 1991), affecting nutrient retention. Percentage base saturation was low (< 60 %) (FDALR, 1990), indicating high aluminum saturation especially in Irete and Amakohia. Low Ca/Mg ratios indicated soil infertility, requiring liming to reduce acidity and replenish calcium. High aluminum saturation (< 50 %) in Irete and Obinze soils may affect plant growth. Low exchangeable sodium percent (< 2 cmol/100g soil) was attributed to intense rainfall leaching (Ogg *et al*., 2017). The USDA soil taxonomy (2006) was used to classify these soils, and correlating it with World Reference Base (WRB, 2014). Obinze, Avu, and Amakohia soils were Grossarenic Kandiudult, while Irete was Typic Kandiudult, and translates to Dystric Nitisols (World Reference Base, 2014), due to isohyperthermic temperature regime, predominant argillic and kandic horizons, low base saturation (< 35%), sandy texture, and absence of lithic contacts within 150 cm, moderately to slightly acidic (pH 5.62–6.35), with low activity clay (13.35 – 65.26%), and mixed clay mineralogy.

Table 3: Chemical Properties of Soils of the study sites

Horizon	Depth	pH H_2O	OC	TN	A P	Ca^+	Mg+	Na^+	K^+	TEB	Ca: Mg	H^+	Al^{3+}	CEC	B.sat	Al^{3+} sat	ESP
			(gkg^{-1})	%	(mgkg^{-1})	→	Cmol /100g		←			→	Cmol/100g	←	→	%	←
								OBINZE I									
Ap	0-16	5.61	0.89	0.12	0.53	1.40	0.74	0.07	0.12	2.33	1.89	0.06	0.05	6.69	34.83	2.05	1.05
AB	16-41	5.35	0.76	0.08	0.47	1.18	0.68	0.17	0.14	2.17	1.74	0.08	0.12	6.31	34.39	5.06	2.69
Bt1	41-70	5.69	0.67	0.06	0.61	1.08	1.02	0.16	0.11	2.37	1.06	0.11	0.13	5.80	40.86	4.98	2.76
Bt2	70-122	5.54	0.57	0.08	0.63	1.06	0.77	0.18	0.17	2.18	1.38	0.15	0.16	5.35	40.75	6.73	3.36
Bt3	122-200	5.44	0.28	0.04	0.71	1.12	0.86	0.12	0.19	2.29	1.30	0.13	0.21	5.47	41.86	7.98	2.19
	Mean	5.53	0.63	0.08	0.59	1.17	0.81	0.14	0.15	2.27	1.47	0.11	0.13	5.92	34.54	5.30	2.41
	CV (%)	**2.18**	**32.69**	**33.17**	**14.06**	**10.52**	**14.60**	**28.93**	**20.04**	**3.53**	**20.51**	**29.65**	**40.29**	**8.57**	**9.36**	**37.67**	**32.15**
								OBINZE II									
Ap	0-19	5.40	0.78	0.10	0.44	1.54	0.68	0.05	0.14	2.41	2.26	0.08	0.07	5.79	41.62	2.73	0.86
AB	19-46	5.64	0.72	0.07	0.48	1.13	1.04	0.12	0.10	2.39	1.07	0.08	0.05	5.85	40.85	1.98	2.05
Bt1	46-75	5.62	0.60	0.05	0.42	1.12	1.58	0.10	0.18	1.98	1.93	0.14	0.10	4.52	43.81	4.50	2.21
Bt2	75-128	5.67	0.40	0.06	0.75	1.60	0.62	0.13	0.12	2.47	2.58	0.12	0.18	5.21	47.41	6.50	2.50
Bt3	128-200	5.61	0.31	0.03	0.54	1.70	0.60	0.15	0.11	2.03	1.95	0.18	0.26	5.16	39.34	10.53	2.59
	Mean	5.59	0.58	0.06	0.53	1.31	0.70	0.11	0.13	2.26	1.96	0.12	0.13	5.31	42.61	5.25	2.11
	CV (%)	**1.72**	**31.19**	**38.59**	**22.50**	**18.68**	**53.40**	**30.96**	**21.76**	**9.17**	**25.69**	**31.62**	**59.86**	**9.14**	**6.58**	**58.43**	**29.49**
								AVU I									
Ap	0-17	5.67	1.41	0.16	0.71	1.67	0.72	0.15	0.12	2.66	2.32	0.14	0.22	6.05	43.97	7.28	2.48
AB	17-53	5.26	1.21	0.10	0.47	1.50	0.56	0.18	0.16	2.40	2.68	0.18	0.42	5.23	45.89	14.0	3.44
Bt1	53-88	5.68	0.98	0.12	0.55	1.64	0.54	0.15	0.15	2.48	3.04	0.22	0.74	5.89	42.11	21,51	2.55
Bt2	88-134	5.35	0.81	0.08	0.64	1.70	0.92	0.17	0.15	2.94	1.85	0.28	0.83	6.07	48.44	20.40	2.80
Bt3	134-200	5.22	0.63	0.06	0.63	1.68	0.43	0.21	0.17	2.40	3.91	0.31	0.86	6.12	40.67	23.50	3.43
	Mean	5. 44	1.01	0.10	0.60	1.64	0.63	0.17	0.15	2.59	2.76	0.23	0.61	5.87	44.22	17.36	2.94
	CV (%)	-	**27.48**	**34.41**	**13.74**	**4.37**	**27.04**	**13.10**	**11.16**	**7.93**	**25.25**	**27.17**	**41.21**	**5.62**	**6.21**	**35.89**	**14.22**
								AVU II									
Ap	0-14	5.71	1.52	0.18	0.51	1.74	0.81	0.12	0.14	2.81	2.15	0.16	0.24	6.04	46.52	7.48	1.99
AB	14-36	5.79	1.22	0.14	0.41	1.62	0.58	0.14	0.11	2.45	2.79	0.14	0.50	5.42	45.20	16.18	2.58
Bt1	36-67	5.63	1.00	0.16	0.52	1.65	0.64	0.52	0.11	2.92	2.58	0.31	0.78	6.14	47.56	19.45	8.47
Bt2	67-94	5.76	0.92	0.14	0.58	1.43	0.62	0.21	0.18	2.44	2.31	0.38	0.96	5.75	42.43	25.40	3.65
Bt3	94-148	5.68	0.75	0.09	0.66	1.38	0.73	0.28	0.12	2.51	1.89	0.41	0.98	5.80	43.28	25.13	4.83
Bt4	148-200	5.65	0.58	0.07	0.58	1.40	0.70	0.24	0.10	2.44	2.0	0.48	1.02	5.36	45.52	25.89	4.48
	Mean	5.70	1.0	0.13	0.54	1.54	0.68	0.25	0.13	2.60	2.29	0.31	0.75	5.75	45.09	19.92	4.33
	CV (%)	**1.00**	**30.66**	**29.46**	**14.29**	**9.02**	**11.23**	**52.78**	**20.67**	**7.50**	**13.79**	**40.62**	**38.23**	**5.02**	**3.91**	**33.16**	**48.46**
								IRETE I									
A	0 – 60	5.80	0.48	0.03	0.32	1.07	0.60	0.14	0.18	1.99	1.78	0.42	0.52	6.23	31.94	17.75	2.25
AB	60 – 122	5.90	0.41	0.01	0.25	1.14	0.73	0.15	0.18	2.20	1.56	0.18	0.60	4.91	44.81	20.13	3.05
Bt1	122 – 166	5.69	0.38	0.03	0.28	1.04	0.53	0.09	0.14	1.80	1.96	0.82	0.87	4.89	36.81	24.93	1.84
Bt2	166 – 200	5.76	0.30	0.03	0.24	1.11	0.53	0.17	0.12	1.93	2.09	0.66	1.30	5.08	37.99	33.42	3.35
	Mean	5.79	0.39	0.03	0.27	1.09	0.60	0.14	0.16	1.98	1.85	0.52	0.82	5.28	37.89	24.06	2.62
	CV (%)	**1.31**	**16.56**	**28.87**	**11.53**	**3.49**	**13.61**	**21.05**	**16.24**	**7.29**	**10.77**	**46.63**	**37.15**	**10.51**	**12.13**	**24.91**	**23.08**
								IRETE II									
A	0 – 56	5.70	0.41	0.03	0.41	1.06	0.56	0.16	0.10	1.88	1.89	0.38	0.54	4.70	40.00	19.29	3.40
AB	56 – 130	5.74	0.35	0.01	0.37	1.42	0.62	0.18	0.13	2.35	2.29	0.23	0.66	5.52	42.57	20.37	3.26
Bt1	130 – 170	5.60	0.30	0.03	0.39	1.38	0.50	0.14	0.17	2.19	2.76	0.92	0.78	5.35	40.93	21.14	2.62
Bt2	170 – 200	5.78	0.28	0.03	0.30	1.04	0.73	0.24	0.15	2.16	1.42	0.80	0.96	5.56	38.85	24.49	4.32
	Mean	5.71	0.34	0.03	0.37	1.23	0.60	0.18	0.14	2.15	2.09	0.53	0.74	5.28	40.59	21.32	3.40
	CV (%)	**1.17**	**14.78**	**28.87**	**11.20**	**14.29**	**14.16**	**20.79**	**18.47**	**7.87**	**23.66**	**53.90**	**20.97**	**6.54**	**3.35**	**9.11**	**17.86**
								AMAKOHIA I									
A	0 -29	5.96	0.66	0.04	0.38	1.28	0.48	0.19	0.18	2.13	2.67	0.66	0.74	4.74	44.94	20.96	4.00
AB	29 – 68	5.80	0.53	0.01	0.45	1.31	0.53	0.15	0.11	2.10	2.47	0.82	0.83	4.54	46.26	22.13	3.30
Bt1	68 – 141	5.87	0.50	0.04	0.37	1.08	0.64	0.26	0.14	2.12	1.69	0.94	0.98	5.23	40.54	24.26	4.97
Bt2	141 – 200	5.76	0.47	0.04	0.33	1.34	0.56	0.21	0.19	2.30	2.39	0.80	0.94	4.96	46.37	23.27	4.23
	Mean	5.85	0.54	0.03	0.38	1.25	0.55	0.20	0.16	2.16	2.31	0.81	0.87	4.87	44.53	22.66	4.14
	CV (%)	**1.30**	**13.42**	**43.30**	**11.38**	**8.15**	**10.55**	**19.80**	**20.01**	**3.71**	**15.99**	**12.27**	**10.82**	**5.27**	**5.32**	**5.45**	**14.40**
								AMAKOHIA II									
A	0 – 25	5.32	0.70	0.03	0.42	1.22	0.38	0.11	0.13	1.84	3.21	0.60	0.80	4.57	40.26	24.69	2.41
AB	25 – 76	6.08	0.48	0.03	0.48	1.40	0.41	0.13	0.12	2.06	3.41	0.82	0.87	4.38	47.03	23.20	2.97
Bt1	76 – 153	6.16	0.39	0.02	0.39	1.30	0.44	0.11	0.16	2.01	2.95	0.77	0.96	4.45	45.19	24.00	2.47
Bt2	153 - 200	6.09	0.35	0.02	0.41	1.46	0.52	0.15	0.18	2.31	2.81	0.85	0.98	4.88	47.34	23.67	3.07
	Mean	5.91	0.48	0.03	0.43	1.35	0.44	0.13	0.15	2.06	3.10	0.81	0.90	4.57	44.95	23.89	2.73
	CV (%)	**5.81**	**28.22**	**16.67**	**7.80**	**6.82**	**11.85**	**12.76**	**15.90**	**8.17**	**7.47**	**11.94**	**8.03**	**4.19**	**6.30**	**2.27**	**10.73**

CONCLUSION

Soils derived from Coastal Plain Sands are predominantly sandy, ranging from sandy loam to sandy clay loam. Soil reaction was moderately acidic; organic matter, total nitrogen, base saturation and CEC were low; aluminum saturation and exchangeable sodium percent were low. The soils of Obinze, Avu, and Amakohia were classified as Grossarenic Kandiudult, while Irete was Typic Kandiudult, and translates to Dystric Nitisols (World Reference Base). The soils of Obinze and Avu can support agricultural production if properly managed, while soils of Amakohia and Irete can support limited range of crops due to their properties and will require sustainable land management to avoid degradation. It is recommended that; the incorporation of crop residues and addition of organic manures will improve the properties of the soils for sustainable crop production.

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SUB-THEME SIX

PRECISION FARMING: USING DIGITAL TECHNOLOGIES FOR ANIMAL MANAGEMENT

Prevalent Livestock Diseases in South East Nigeria and their Control Measures: A Review

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ABSTRACT

Globally, livestock diseases are major constraints to animal production and management, usually resulting in economic losses, reduced productivity and quality of livestock products. The livestock diseases prevalent in south east Nigeria were evaluated based on data collected between January 2010- June 2023 from the epidemiology unit of the Federal Department of Veterinary and Pest control services, Federal Ministry of Agriculture and Rural Development Abuja, Nigeria. Diseases of cattle reported ranging from the highest to the least occurrence included, Contagious Bovine Pleuropneumonia (CBPP), Bovine Tuberculosis, Brucellosis, Fascioliasis and Mastitis. Major disease of small ruminants (sheep and goats) was Pests des Petits ruminants (PPR). Diseases of pigs reported included: African swine fever, Swine Erysipelas and piglet anaemia. Poultry diseases were New Castle Disease (NCD), Infectious Bursal Disease (IBD), Coccidiosis, Fowl typhoid, Fowl pox and Highly Pathogenic Avian influenza (HPAI). The article also reviewed the notifiable diseases reported by Nigeria Center for Disease Control through its Integrated Disease Surveillance and Response system (IDSR) known to be zoonotic. Diseases in this category were Tuberculosis, Anthrax, Rabies, HPAI, Food and water borne diseases such as Brucellosis, Colibacillosis, Cysticercosis. Control programmes included; Biosecurity measures, disease surveillance in flocks and farms, seromonitoring of animals, routine vaccination, accurate diagnosis and treatment of sick animals, stamping out flocks once disease is detected as in the control of HPAI and CBPP. The evaluation of the disease prevalence, economic and public health effects of these diseases could not be accomplished in the course of this review as a result of underreporting and inaccurate disease identification due to lack of basic veterinary diagnostic facilities. It was therefore recommended that developing an operational digital livestock information system for livestock farmers, disease surveillance and reporting will be needful. Decentralizing the National Veterinary Research Institute Vom function of disease diagnosis/surveillance to the six geopolitical regions in Nigeria as well as employing the one health approach to livestock disease control and management would also be apposite in unlocking the livestock potentials of Southeast Nigeria.

INTRODUCTION

Agriculture was the main stay of Nigeria's economy as it was the highest earner of foreign exchange for Nigeria which was also largely sufficient in food production. Revenue from agriculture was deployed to develop the crude oil sector. Today agriculture is playing second fiddle to oil and contributing only about 30% to 40% of Nigeria's Gross Domestic Product(GDP) and employing about 70% of the population mainly at subsistence level (Ikponmwosa 2017). Nigeria's GDP from Agriculture decreased from N5,456,895.81 (fourth quarter 2021) to N387,973.92 (first quarter 2022) (National Bureau of statistics, Nigeria)

Recent events in the global oil industry and their drastic effects on Nigeria's economy coupled with the effects of COVID-19 pandemic and Russian-Ukrainian war have driven home the fact that we have to diversify and take agriculture more seriously than we are currently doing.Nigeria has a very high rate of youth unemployment and this is the root of the security challenge in the country. Agriculture has the potential to rescue Nigeria from this major challenge.

Livestock farming also known as animal husbandry is the management and breeding of domestic or farm animals for the purpose of obtaining their meat and other products which include milk, eggs and leather. Some animals are grouped as micro-livestock and they include rabbits, giant rats, guinea pigs, grass cutters, snails and various edible insects. (Akinbobola 2022).

Livestock or farm animals constitute a major component of the agricultural economy and a source of animal protein. Nigeria's negative balance of trade is evidenced by a condition referred to as a "diary dilemma" which implies that Nigeria imports over two thirds of its milk, a sign that local production cannot meet up with demand (Vanessa and Ciara 2019). Currently, Nigeria's per capita animal protein intake is 10g per day and despite over sixty years of Nigeria's existence as a nation, we are yet to meet the minimum per capitaanimal protein requirement of 35g per day (FAO WHO 2020).Africa is 11g per day. Eastern Europe 33g per day, Western Europe 39g per day while North America is 66g.For chicken,Nigeria lags behind in its per capita protein consumption among its African peers. Nigeria is 1.9kg, Ghana is 7kg, South Africa 32kg and USA is 49kg (John Coumantaros 2022).

Animal production has remained underexploited. Livestock mostly reared by farm families in Nigeria are the small ruminants like goats (76 million), sheep (43.4 million) and cattle (18.4 million). The ecology in northern Nigeria makes it famous for livestock keeping. In addition to small and large ruminants, poultry population stands at 180 million (FMARD 2017). Domestic demand outweighs production despite several interventions by development partners to improve production and safeguard against diseases including Trans-boundary animal diseases (TADs) (FAO 2022).

The reasons for this deficiency are partly due to the fact that the growth rate of human population is not commensurate with the growth in livestock population and in part to the economic down turn in Nigeria which has made the conventional and regular sources of animal protein (beef, pork, goat meat, mutton, milk, fish, poultry meat and eggs) an exclusive reserve of the rich (Athanasius 2018).This means that we are unable to produce enough animal products to meet the demand by Nigerians for their wellbeing.

Certain factors areresponsiblefor this shortfall and they include;

- Improper implementation of government policies
- Lack of easily accessible funds (grants and loans)
- Poor infrastructure / modern technology for commercial, largescale production.
- Poor foundation stocks
- High cost of animal feeds
- Poor access to markets
- Disease outbreaks
- Lack of extension
- Insecurity
- Lack of proper training of livestock farmers
- Nonfunctional farmers' associations
- Inadequate veterinary services
- Climate change (Athanasius 2018, FAO 2022)

The Potentials of Livestock Production in South East Nigeria.

South East Nigeria is one of the six geopolitical zones in Nigeria consisting of five states namely Abia, Anambra, Ebonyi, Enugu and Imo.

South East Nigeria borders with Cross river state to the east, River Niger to the West, Kogi/Benue states to the North and Rivers/Akwaibom states to the south.

99.9% of the population are Igbos. Therefore S.E. region of Nigeria is known as Igbo land. Southeast Nigeria is endowed with numerous opportunities for livestock production such as;

a) Terrestrial resources: Land suitable for cultivation of crops and grasses for ruminants is known as arable land. About 80% of the land mass in Nigeria is considered to be arable land, which is equivalent to 82 million hectares. Currently about half of this arable land mass is being cultivated. (Ikponmwosa, 2017).

b) Aquatic resources are also highly required for livestock production and include:

- River Niger and its tributary, Anambra River traditionally known as Omambala River flows through parts of Anambra state (Anambra east and west, Ayamelum LGAs) and Enugu state (UzoUwani LGA).
- Imo River in Imo and Abia states. Abia state also has Aba River.
- Enugu state has Ekulu, Idaw, Asata and Ogbete rivers
- Ebonyi state has Iyioka, Idima and Ubei rivers.
- Other aquatic resources include lakes, streams, springs, ground waters and rain water.

a) High demand of livestock products by households, restaurants, events, hotels etc.
b) Marketing opportunities: South East Nigeria is a hub for marketing livestock products from Northern Nigeria (cattle, sheep and goats including meat, hides and skin), Pig and Poultry products (meat and eggs) from South west Nigeria, and a variety ofcanned meat, milk and pork products imported from various countries (China, Finland, Thailand, Norway, England etc.). The peculiar marketing structure in South East Nigeria is of strategic importance; the fourIgbo market days namely Eke, Oye, Afor and Nkwo. These markets connect the mega commercial centers with rural markets. This structure encourages profitable and sustainable marketing of livestock products in South East Nigeria, making livestock production and marketing attractive for wealth and employment generation. (Athanasius 2018). The marketing potentials in the SE Nigeria made the SE Nigeria evolve into a consumption region rather than productive. The livestock production potentials of the SE region should be unlocked by gearing efforts towards maximizing the opportunities and minimizing the factors responsible for the short fall in livestock production in SE Nigeria.

The Prevailing Livestock Diseases in South East Nigeria.

Livestock diseases are ailments or disorders affecting livestock animals usually resulting to economic losses,reduced productivity and quality of livestock products. Livestock diseases are major constraints to animal husbandry in all the regions of the world.

Reported Livestock Diseases from South East Nigeria:

Based on information sourced from the epidemiology unit of the Federal Department of Veterinary and Pest Control Services, Federal Ministry of Agriculture and Rural Development Abuja, the following livestock diseases are prevalent in South East Nigeria from year 2010-2023.

1. Diseases of cattle:

Contagious Bovine Pleuropneumonia
Bovine tuberculosis
Brucellosis
Fascioliasis
Mastitis

2. Diseases of Sheep and Goats
Pests des Petits ruminants (PPR)

3. Diseases of Pigs
African swine fever
Swine Erysipelas
Piglet Anemia

4. Diseases of Poultry
New Castle Disease (NCD)
Infectious Bursal Disease (IBD)
Coccidiosis
Fowl typhoid
Fowl pox
Chronic respiratory disease (CRD)
Infectious coryza
Avian influenza (HPAI)
Colibacillosis

Diseases of Cattle

Contagious Bovine Pleuropneumonia (CBPP) is an infectious and contagious disease of cattle caused by *Mycoplasma mycoides* subspecies*mycoides*. It attacks the lungs and the Pleura (membranes lining the thoracic cavity) causing fever and respiratory signs; labored or rapid respiration, cough and nasal discharges.

Contagious Bovine Pleuropneumonia is a prominent cattle disease in South East Nigeria and Africa at large. CBPP is highly contagious with a mortality rate of up to 50%. It causes significant losses. CBPP is one of the diseases for which the World Organization of Animal Health (WOAH) has established an official procedure for recognition of status. The Terrestrial Animal Health code specifies the procedure a country must follow in order to be officially recognized by the WOAH as free of CBPP. This disease has no public health risk and has been eradicated in Europe and America where control programs were: Detection of carriers, early detection of outbreaks, control of animal movement (movement restriction). In Africa control is currently based on vaccination campaigns. National Veterinary Research Institute (NVRI) produces CBPP vaccine. Treatment with antibiotics is not recommended as it results in healthy looking animals that are carriers. (WOAH 2022).

Bovine tuberculosis (TB) is a chronic bacterial disease of cattle and all mammals caused by *Mycobacterium tuberculosis*. The disease is zoonotic and humans get infected by drinking raw milk of affected cows. The clinical signs are weakness, debility, formation of a tuberculous nodule in the affected organs, cachexia and death. The disease is identified by a simple tuberculin test. Long term antibiotic treatment may cure Bovine TB. Prevention is by culling positive cases from the herd due to public health significance.

Brucellosis is a highly contagious, economic and reproductive important disease of cattle, buffalo, sheep, goats and other mammals. The causative agent is *Brucellaabortus, B.ovis, B.suis, B.canis and B.melintesis*. The clinical signs in cows are abortion, still birth, orchitis, reduced milk production and producing weak calves. The bulls are normally carriers of brucellosis and transmit organisms through semen during breeding. There is no specific treatment for Brucellosis. Culling of positive cases from the herd is helpful in the control of Brucellosis.

Bovine Fascioliasis (Liver fluke): A disease of ruminants caused by *Fasciola hepatica* and *Fasciolagigantica* which affects the liver parenchyma and bile ducts of ruminants including humans which causes economic losses and threatens public health. In ruminants the liver is damaged and clinical cases usually result in decreased production of meat and milk, secondary bacterial infections, fertility problems, loss of weight, poor carcass quality and high expenditure on anthelmintics. Fascioliasis is a zoonotic disease of public health importance. Man becomes infected when infective stages of the fluke are ingested along with vegetables grown along banks of water reservoirs inhabited by potential snail hosts. (Kalu 2015). Treatment is by administering fasciolicides e.g., triclabendazole. Prevalence of fascioliasis is 23% in Abia state (Onyeabor and Wosu 2014).

Mastitis is the inflammation of the udder (mammary) tissue and causes physical and chemical changes of milk. It is the most deadly and costly bacterial disease of dairy cattle, caused by several bacteria including *Pseudomonas,Streptococcus,Staphylococcus, E. coli, Pseudomonas, Mycoplasma* etc. The clinical signs are swelling, redness of the udder, reduced milk production, and blindness of the udder. The treatment of mastitis is with antibiotics, anti-inflammatory, and antihistaminic drugs. Prevention of mastitis is by improving milking hygiene, cow management and adequate nutrition.

Diseases of sheep and goats (Small ruminants).

Pests de Petits Ruminants (PPR) also known as sheep and goat plague is a viral disease caused by a Morbillivirus closely related to Rinderpest virus, which affects goats, sheep and some wild relatives of domesticated small ruminants as well as camels. It is characterized by severe morbidity and mortality rates (90%) and has a high economic impact in Africa, Middle East and Asia, where small ruminants contribute to sustainable livelihoods.

PPR is aWOAH – listed disease and must be reported to the WOAH according to the Terrestrial Animal Health Code. WOAH and FAO have developed the Global Control and Eradication Strategy of PPR by 2030. NVRI Vom has produced efficient PPR vaccine for the control of thedisease (WOAH 2018). PPR is the most prevalent livestock disease in SE Nigeria (FMARD 2022). Clinical signs include catarrh, diarrhea, weakness and death.

Diseases of Pigs

African Swine Fever (ASF): ASF is a highly contagious viral and economically devastating swine disease that can affect both farm-raised and feral pigs. ASF is not zoonotic but it readily passes from one pig to another by direct contact with body fluids from infected pigs (U.S Food and Drug Administration 2022). African swine fever has had significant economic and social impacts in Nigeria since 1997. There is no effective treatment and national response to control ASF. Significant reduction of ASF prevalence in Nigeria can be achieved through routine surveillance,reorganizing the market and transportation systems for pigs, on farm biosecurity protocols and consideration of the option of compensation. (Fasina *et al* 2010).

Swine Erysipelas: Swine Erysipelas is caused primarily by *Erysipelothrix rhusiopathiae*, Gram positive bacteria carried by up to 50% of pigs. Clinical manifestations are cutaneous erythema, including characteristic diamond-shaped lesions, septicaemia, arthritis and endocarditis. Erysipelas is a common cause of carcass condemnation at meat inspection. *Erysipelothrix rhusiopathiae* is susceptible to Penicillin (Forde, 2020).

Piglet Anaemia: The main cause of Piglet Anaemiais iron deficiency. Usually piglets are born with levels of iron (about 50mg) that will last them a few days of life. Naturally piglet source iron from the soil and that explains why the scavenging piglets survive piglet anaemia, but in the commercial farms, natural source is very limited. Piglets suffering from this iron deficiency anaemia show tachypnoea (fast breathing), rough hair, wrinkled skin, pale mucous membrane, poor weight gain etc. They are susceptible to other infections and are likely to develop diarrhea. Treatment is by supplementation of iron(150-200mg Iron dextran) through subcutaneous injection by the third day postnatal to ensure the piglet gets the required dose needed to overwhelm this condition (CEVA, 2021).

Poultry Diseases

The list of prevalent poultry diseases in South East Nigeria from the most prevalent to the least are: New Castle Disease (NCD), Infectious Bursal Disease (Gumboro), Coccidiosis, Fowl Typhoid, Fowl Pox, Colibacillosis, Highly Pathogenic Avian Influenza and Infectious Coryza.

According to Nwanta *et al* (2011), there is a high prevalence of gastrointestinal helminths, coccidia and ectoparasites in livestock farms in southeast Nigeria and this suggests the endemic nature of these diseases as contributing to major economic losses in livestock production in southeast, Nigeria.

Disease	Aetiology	Status	Clinical Signs	Treatment	Control	Mode of transmission
New Castle Disease	NCD Virus Paramyxo virus	Endemic, highly contagious. Greatest constraint of poultry production in Nigeria	Decreased feed and water consumption, drastically reduced egg production, Twisting of the neck (torticollis), water discharge from the nostrils	Nil Antibiotics for secondary bacterial infections	Vaccination and stamping out. Consult your local veterinarian	Direct contact with bodily fluids of infected birds especially faeces. Also, through people and objects in contact with infected birds.
Infectious Bursal disease	IBD virus Avibirnav irus (RNA virus)	Endemic contagious immunosup pressive diseases of chickens	Sleeping with their beaks touching the ground, Viscous diarrhea	Nil Antibiotics for secondary bacterial infections	Vaccination	Fecal- oral route through ingestion of contaminated feed and water Ingestion of agents from infected litter.
Coccidiosis	Eimeria species (Protozoan)	One of the most devastating diseases with substantial economic losses to poultry industry	Scuffled feathers Blood-stained diarrhea inappetence depression	Anticoccidial Drugs	Avoid wet litter. Avoid overcrowding. use of anticoccidial drugs. Vaccination	Ingestion of coccidia oocysts from infected litter.
Fowl Typhoid	*Salmonella gallinarum*	Endemic in Nigeria	Yellowish diarrhoea, Ruffled feathers	Antibiotics: AmoxycillinTetracyclinesand Fluoroquinolones	Vaccination	Transovarian (vertical) or faecal-oral contamination (Horizontal)
Fowl Pox	Fowl Pox virus (Avipoxvirus)	Prevalent in rainy season. virus can strive in the environment for months	Vesicular lesions or wartlike nodules in the month, Combs and throat, Decreased egg production	No specific treatment Antibiotics against secondary bacterial infection	Vaccination Vector control	Transmitted by mosquitoes and other blood sucking insects. By direct contact with infectious wounds.

Colibacillosis	(E. coli)	Triggered by stress	Greenish diarrhea, Droopy wings, Respiratory distress	Antibiotics	Isolation of sick birds. Avoid stress	Normal microflora disease is triggered by stress and unhygienic pens
Highly PathogenicAvian Influenza.	HPAI H5NI strain	Outbreak 2006-2008. Reemerged in 2015 and recorded till 2022	Hemorrhages in the combs, wattles and shanks.	Nil	Stamping out/ compensation. No vaccination in Nigeria	Directly from infected birds or AI virus Contaminated environments through other animals e.g., migratory birds
Infectious Coryza	*Avibacterium Paragallinarum*	Endemic in Nigeria	Swelling of the face, Drop in egg production, reduced feed and water consumption, eye and nasal discharge	Antibiotics	Vaccination Disinfection and no replacement of shock until after 3 weeks of disinfection	Carrier birds Chicken to chicken indirectly through aerosol or contaminated feed, water equipment and clothing.

Table 1. Prevalent Poultry Diseases in South East Nigeria (FMARD 2022)

Public Health Aspects of Some Animal Diseases

The Nigerian Center for Disease Control (NCDC) list of notifiable diseases show a list of diseases that have public health implications. Zoonoses are diseases that are transmitted from animals to human and vice versa. Notifiable diseases are human and animal diseases that ought to be reported to government authorities by law. Nigeria has been collecting information on epidemic-prone and other infectious diseases that can concern the populace through the Integrated Disease Surveillance and Response System (IDSR) since 2001. The IDSR system helps to identify notifiable diseases at all public primary, secondary and tertiary healthcare facilities in Nigeria.

The list of notifiable diseases in Nigeria (Collins 2021)

Cholera
Diphtheria
Leprosy
Meningococcal meningitis
Adverse effects following immunization
Diarrhoea with blood (Shigellosis)
Acquired Immunodeficiency Syndrome (AIDS)
Buruli ulcer (*Mycobacterium ulcerans* diseases)
Pertussis (Whooping cough)
Dengue fever
Hepatitis A, B, C, D and E
Human Immunodeficiency Virus (HIV)
Lassa fever
Zika virus*
Small pox
Rubella

Ebola*
Dracunculiasis
Water borne diseases outbreak*
Anthrax (human)*
Typhoid fever
Tetanus
Chicken pox
Poliomyelitis
Tuberculosis *
Rabies (human)*
Lymphatic Filariasis
Food borne Diseases outbreak*
Avian Influenza (Bird flu).*
Onchocerciasis
West Nile fever
Measles

The diseases marked * are zoonotic.The likes of Covid-19 and Monkey Pox are supposed to be on the list. Their control programmesare professionally handled to achieve measurable success.It is important to note that some food and water borne diseases like Colibacillosis, Brucellosis, Cysticercosisetc are also zoonotic and could be contacted through livestock.NCD is a mild zoonosis causing conjunctivitis in human. (DAERA 2018).

Control of Livestock Diseases

The control measures put in place against the spread of livestock diseases in order to reduce their health and socio-economic impacts include

1. Biosecurity programmes:

Biosecurity means the prevention of diseaseagents from entering or leaving any place where they can pose a risk to farm animals, other animals and humans. Biosecurity measures include

- Washing and disinfection of equipment, foot baths, cages, pens etc.
- Use of protective clothing
- Strict quarantine programmes
- Water quality management
- Movement restrictions or traffic control
- Isolation of sick animals
- Proper disposal of wastes and mortalities.

2. Disease surveillance in flocks and farm to check for contaminants of animals intended for human consumption. Such contaminants include disease pathogens, drug residues, heavy metals, pesticides, microplastics etc.
3. Seromonitoring of animals to detect antibodies in their blood to identify carriers and regulate vaccination.
4. Routine Vaccination programmes
5. Accurate diagnosis and treatment of sick animals
6. Proper feeding and management to maintain adequate immune status of animals in order to reduce predisposition to diseases.
7. Purchase of replacement stock and breeders from reputable pathogen free sources.
8. Regular deworming and control of ectoparasites with anthelminthics and acaricides
9. Addition of feed additives such ascoccidiostats, antifungals, vitaminsetc
10. Stamping out flocks once disease is detected: effective for the control of HPAI and CBPP.

It is important to mention that the NVRI Vom is the only Veterinary research institute in Nigeria, presently a parastatal under FMARD and was established with the mandate to conduct research into all aspects of animal diseases, develop and produce animal vaccines, provide surveillance and diagnosis of animal diseases as well as provide extension services to poultry and livestock farmers.

CONCLUSION

The actual economic and public health impact of livestock diseases are underestimated due mainly to under reporting or being unaware of these diseases. It is therefore very important to update information on these diseases so as to improve their awareness and facilitate prompt disease diagnosis and reporting. Future outbreaks are controlled by routine surveillance of livestock diseases as a means of developing early warning and emergency preparedness. (Oluwayelu *et al* 2018, Nwokolo 2022).

The following recommendations will help to achieve the desired objectives of controlling livestock diseases in South East Nigeria,

- Developing a comprehensive data base of livestock farmers, disease surveillance and reporting through an operational Livestock Information System.
- Decentralization of the NVRI to every region in Nigeria and improvement of veterinary services to effectively improve on prompt disease diagnosis as a major component of disease reporting and surveillance.
- Enlightenment campaigns and training of livestock farmers, livestock extension officers and animal health service providers.
- Expansion of livestock production from backyard to commercial status through importation of knowledge from western and northern Nigeria.
- Mechanization and digitization of processes.

- One health approach to livestock production and disease management.

Finally, we wish to affirm that adaptation of digital technologies and innovations are necessary to ensure food security and nutrition safety through livestock production in South East Nigeria.

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Ecological, Behavioural and Morphometric Characteristics of the Giant Cricket (*Brachytrupes membranaceus* L.) in Oji River LGA, Enugu State, South East, Nigeria: A Prelude to Semi-intensive Rearing Technique

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ABSTRACT

Ecological, behavioural and morphometric characteristics of the giant cricket (Brachytrupes membranaceus L.) in two towns (Awlaw and Achi) within Oji River Local Government Area of Enugu State, South east, Nigeria was investigated as a prelude to develop useful technique for semi- intensive rearing of the insect in simulated environment. Five hundred metres land area was marked out around the locations where the index trees were found in the two localities using line transect and the sites were used as study sites and visited once every week for three months Mid-March to June ending. The result showed ten species of trees that act as indicators of the presence of the cricket in the two towns. The burrows for male Brachytrupes membranaceus cricket were significantly higher in number and more in depth compared to that of females, but there was no significant difference on the burrow width for male and female burrows. The female though more robust in appearance, did not show any significant difference (P>0.05) in the body weight when compared to males. Of all the morphometric parameters assessed, only the pronotum length and femur length showed significance differences (P<0.05) between the male and female records. The ecological studies showed the possibility of rearing the cricket by simulating its natural milieu of Brachytrupes membranaceus in a netted outdoor environment (enclosing male and female) under laid with sandy soil at enough depth to give room for burrowing activities of Brachytrupes membranaceus and surrounded with its cherished tree species.

INTRODUCTION

The shortage of animal protein in the diet of Nigerians and other developing countries necessitates a search for alternative animal protein sources (Ebenebe, 2005) to augment the conventional meat proteins in meeting the animal protein needs of the populace. This paucity of animal protein in many developing countries and associated nutritional deficiency disease has prompted FAO and WUR (2013)collaborative effort in promoting entomophagy as a measure to improve animal protein consumption and prevent deficiency diseases such as Kwashiokor in Sub-Saharan Africa (van Huis 2013). van Huis (2003) listed about 250 edible insect species from Africa. Seventy-eight percent of which are Lepidoptera, (30%), Orthoptera (29%) and Coleoptera (19%), and 22 percent Isoptera, Homoptera, Hymenoptera, Heteroptera, Diptera and Odonota. DeFoliart (1997) estimated the number of insect species eaten worldwide to be about 1000, of which in African countries: 30 species are consumed in Congo, 22 in Madagascar, 36 in South Africa, 62 in the Democratic Republic of Congo (D.R. Congo), and 32 in Zimbabwe. In the same vein, Ramos-Elorduy (1997) compiled about 1391 insect species eaten worldwide, of which 524 are eaten in 34 countries of Africa representing 38% of all species consumed. Nutritional and other health benefits of edible insect have also been documented by many authors (Ekpo and Onigbinde (2004), Banjo *et al.* (2006), Ebenebe *et al.*, (2007), Edijala *et al*. (2009), Braide *et al*. (2010) and Nzikou *et al*.(2010). Amadi (2016) showed that the nutritional value of edible insect compared favourably with that of conventional meat proteins.Van Huis (2016) and Blasquez *et al*. (2012) showed that edible insects are richer in protein (60%) compared to beans (23.5%), lentils (23.5%) or soybean (41.1%). Blasquez *et al.* (2012) also showed that edible insects are higher in protein content compared to chicken (43%), egg (46%) or beef (54%), so according to them only fish (81%) surpass insects in protein content. Of the edible insects consumed in Nigeria, Ebenebe (2016) reported that *B. membranaceus* is the most preferred edible insects in Nigeria. According to them, while the Giant cricket (*B. membranaceus*) is the most preferred edible insect in the south east Nigeria, they are seasonal and mostly unavailable in some areas as the population has continued to decline due to farming practices especially tillage and use of agrochemicals. Miantsia *et al.* (2018) also observed that the population of *B. membranaceus* is declining in the wild for the same reason.

The house cricket mostly farmed by many big farms in Europe, America and Asia is not consumed in Nigeria (Pers. Obs) but *Brachytrupes membranaceus* is cherished as food in various parts of Nigeria both by young and old people. Besides, while the house cricket *Acheta domesticus* captive rearing is well documented in literature (Miech *et al*. 2016, Ayieko *et al.* 2016, Halloran *et al.* 2018), *Brachytrupes membranaceus* has not been amenable to captive management due to its unique ecological needs and behavioural characteristics. Cricket is not uncommon in the sand soil along the bank of River Niger where it burrows to the depth up to 2 m (Pers. Obs 2012 in our first Preliminary Studies). Burrows in this sandy soil are recognized by the presence of a small sandy mound. The burrows are not just vertical but involve a lot of diversion before the main gallery where one cricket lives. Büttiker and Bünzil (1958) reported that *B. membranaceus* are nocturnal and digs burrows of 50 to 80cm (20 -30 inches) deep, the burrows are dug with their mandibles and fore legs while the dug-out sand is usually pushed out in a heap at the entrance of the burrow, such mound or heap of sand might be up to 30cm in height.

There are four subspecies of *B. membranaceus* in Africa: *B. membranaceus* Colosseus, Sausure1899 (Madagascar), *Brachytrupes membranaceus* hoggarensus1941 Chopard (Algeria), 1952 (Mauritania), B.*Brachytrupes membranaceus* Drurry1770 (Kenya and Tanzania and other East African countries). *Brachytrupes membranaceus* has also been reported in Nigeria (Agbidye *et al* (2009), Okore (2014) and Ebenebe (2017)). In Nigeria the giant cricket *Brachytrupes membranaceus* is known by different names in different dialects: Apina (Eleme, Port Harcourt), Pina (Ogoni), Ediang (Ibibio), Gyare (Hausa) (Amadi *et al*. 2016) and Abuzu (Igbo) (Ebenebe, 2015).

The giant cricket (*Brachytrupes membranaceus*) has a plump brown body with a broad head, long antennae and very powerful legs (Hill, 2008). The head and body length is about 4 to 5 cm (Hill 2008) and body weight of 4.54g (Amadi 2016). Lakhdari *et al*. (2015a) reported that the weight of cricket of *Brachytrupes megacephalus* species varies with season, with the adults weighing 2.63g and in summer it weighs 3.54g. According to them, the head length of adult is 13 to 14mm and femur length17 to 22mm. Lakhdari *et al*. (2015b) observed significant difference in the head and protonium length of male and female cricket of the *Brachytrupes megacephalus.*

With regards to the nutrient composition of *Brachytrupes membranaceus*, Adeyeye and Awokunmi (2010) noted that *Brachytrupes membranaceus*is a good source of protein, carbohydrate and energy. Amadi *et al*. (2016) reported that protein content of 20.22% in *Brachytrupes membranaceus* compares favourably with that of chicken (19.80%) and lean meat (21.71%), while its fat content of 18.10% is quite higher than what obtains in chicken (7.23%) and lean meat3.80%. Agbidiye *et al.* (2009) reported protein content 35.06% and fat content of 53.05% while Adeyeye and Awokunmi (2010) reported protein content of 29.10% and Fat of 4.20%. Okweche *et al.* (2023) reported that cricket and fish recorded higher amount of protein compared with other nutrient sources. Sere *et al*. (2022) compared nutritional composition of *Brachytrupes membranaceus* and *Macrotermes subhyalinus* from Burkina Faso and showed that the two insect defatted isolates were alternative sources of minerals, proteins and essential fatty acids and so could be used to combat protein deficiency.

There is need to undertake a thorough study of the insect in their natural milieu. Such a field study should investigate the ecological, morphometric and behavioural characteristics of the giant cricket *B. membranaceus* as a prelude to simulating its natural habitat in semi- intensive enclosures so as to lure it into breeding in such enclosures.

This study was therefore aimed at discovering the ecological, behavioural and morphometrics characteristics of the giant cricket (*Brachytrupes membranaceus*) in three towns in Oji River LGA where *Brachytrupes membranaceus* is consumed in large quantities and also sold in large numbers in their local markets

Materials and Methods

***i.* Experimental Site**

The experiment was carried out in two localities: Awlaw and Achi town, both in Oji River Local Government Area of Enugu State, Nigeria (Fig 1). Oji River is located at Latitude $06^0$16N and longitude $07^0$16 E, with altitude of 140m above sea level. The mean annual rainfall is 2000mm, while the annual temperature ranged between 26.8^0C to 32.5^0C; the average Relative Humidity is 84%. The Local government (Oji River) (Fig 2) has an area of 403km and a population of 126,587 at the last 2006 census. The major water body in the area is a fast flowing Oji river, a tributary of Anambra River which itself is a major tributary of the River Niger (Ugwuanyi. 2015). The choice of these towns as study sites was based on the fact that while the cricket is rarely seen in many localities, large quantities of *Brachytrupes membranaceus* are sold in their local markets, besides the people in the community use the crickets for special dishes on their festive occasion and in welcoming important guests.

Fig 1: Map of Enugu State Showing the Study Area (Oji River LGA)

Fig 2: Map of Oji River LGA showing the Study sites (Awlaw and Achi)

ii. Ecological Studies

a). Locating the Burrows and Harvesting of the Cricket (*Brachytrupes membranaceus)*

About 500m^2 was mapped around areas with a number of the index trees in each site using line transect. The sites were visited once every week and the number of burrows in each site recorded. On each visitation to the sites, the natives chosen as guides used the presence of identified tree species as indicators of the presence of the cricket. The burrows are usually found under such trees. Visible, unhidden burrows which the natives believed to be occupied by snakes and other burrowing animals were avoided, while burrows found by gentle scrapping of top soil with cutlass and hoe harbouring *Brachytrupes membranaceus* were counted and their depth and width measured by use of twine and measuring tape to trace the tunnel to the gallery from which *Brachytrupes membranaceus* was harvested. The method did not involve flooding of the burrow with water as described by Lakhdari *et al.* (2015c).

b). Identification of tree species

The tree species which the natives used as indicators of the cricket's presence were taken alongside with their fruits to the experts at the Department of Botany, Nnamdi Azikiwe University, Awka, Anambra State and Horticultural Department, Federal College of Agriculture Ishiagu, Ebonyi State as well as Department of Forestry and Wildlife, Nnamdi Azikiwe University, Awka. The choice of the two institutions was for confirmation of the botanical names. The natives belief were not superstitious or presumptions rather based on their indigenous knowledge that the cricket (*Brachytrupes membranaceus*) feeds on these plant species.

c). Characteristics of Male and Female Burrows

The number of burrows of male and female burrows in each site was counted and recorded. The depth and width of each burrow from which male or female cricket was harvested was measured. The measurements were also recorded and later used for computation.

iii. Morphometric Study

Upon capture, the *Brachytrupes membranaceus* were taken to Physics Laboratory at Nnamdi Azikiwe University, Awka for various morphometric measurements using a paper, Venier caliper and Sensitive scale (Camry EK 5055). The sensitive weighing scale (Camry EK 5055) was used in taking the weight of individual cricket to the nearest0.01grams. Of all the crickets cut, weight of 100 randomly selected adults which had all their parts intact were used in the statistical analysis. Linear body measurements of the 100 adult crickets taken included:

- Body length
- Width of the head
- Length of pronotum
- Femur length
- Inner wing length
- Outer wing length

All linear measurements were taken in centimeter to the nearest 0.01cm using Venier caliper

(Plate 10 -13).

iv). Behavioural Characteristics

a). Morphological features of Male and Female

The morphological features by which the male and female crickets were differentiated was also noted by visual examination of all parts of the body.

b). Noise from Male Cricket

The cricket responsible for the chirping sound in their burrow was monitored by night marking of the burrows using stuck in peg beside the burrows. The marked burrows were dug the following morning to harvest the occupant. The season of the noise was also noted.

v. Socioeconomic Studies

Oral interview was used to assess the socioeconomic values of the cricket trade as it affects household incomes. About 10 families were randomly selected in the two communities and were queried on the economic value of the business to their family life. Members of the research team also visited the local markets to interview buyers and sellers regarding the socioeconomic values of the cricket in the two communities.

vi). Oral Interview

Twenty elderly men and women were selected from the two communities and interviewed orally to elucidate information on the season of harvest of matured cricket and the nymph, behavioural characteristics of the matured cricket and nymph, uses of the cricket and nymph, exact localities of the cricket in the two communities and the reason.

RESULTS

i. **Identification of Host Plant species**

The trees identified to be associated with giant field cricket (*Brachytrupes membranaceus)* are presented in Table 1. Ten species of trees were observed in this study to be consumed by the cricket and the villagers used their presence to denote presence or absence of the cricket (Plate 1 – 6). Lakhdari (2015c) using feacal analysis reported on eight species of plants belonging to eight different families consumed by the cricket *Brachytrupes megacephalus* (*Phoenix dactylifera*, *Nerium oleander*, *Chrysanthemium*, *Myoporumsandwicense*, *Armenia maritama*, *Prunus armeniaca*, *Solanum lycopersicumm* and *Cherry fantasia*). None of the plants reported in their study was observed in this study, while *Phoenix dactylifer* (Date palm) was the only big tree they observed, all the plants recorded in this study are big trees with fruits, two of which are edible, the rest are not edible fruits.

Table1: Host Plant Species

S/N	Local Name	English Name	Botanical Name
i		Cashew	*Anacardium occidentale*
ii	Okpokolo	?	*Anthocleista vogelii*
iii	Nka/Oka/ Ahaba	?	*Achio batari*
iv	Ubele		*Mesobeteri batari*
v.	Icheku/ Cheleku/ MbaCheleku	Velvet Black berry	*Dalium guineensis*
vi.	UtoMpoma	?	?
vii	Ogodo	?	?
viii	Ububo	?	?
ix	Utu	?	?
x	Ikemuoji	?	?

? The information is still awaiting consensus agreement by experts

ii. Number of Male and Female Burrows

The total number of burrows recorded in each town and the frequency of male and female burrows recorded in the study areas are presented in Table 2. The highest number of burrows was recorded in Awlaw and the least in Achi. There was significant difference (P< 0.05) between the frequency of male burrows in comparison with that of females. More male burrows were recorded in the three towns investigated. Many authors are of the view that mating takes place in the male burrow, so the female leaves her burrow to that of the males following the males characteristic attracting chirping sound.

Table 2: Total Number of Burrows in Each locality and Frequency of Male and Female Burrows

Towns	No of Burrows	Frequency of Male Burrows	Frequency of Female Burrows	SS
Awlaw	110	59	51	
Achi	84	47	37	
∑ X	194	106	88	
X	92	53	44	SS

*Statistical Significance (**SS**): There is significant difference in the frequency of male burrows compared to female, with male cricket occurring most

iii. Mean of Burrow Dimensions

The means of burrow dimensions (width and depth) recorded in the three towns are presented in Table 3. There was no significant difference (P>0.05) in the width of male and female burrow but the male burrows were significantly (P<0.05) deeper than that of the females in all the sites. The burrow depth range of 28.62± 0.11to 40.78± 0.21 and 25.66±0.17 to36.77±0.24 for males and female (Plate 7 and 8) respectively is lower than the burrow depth range of 50 to 80 cm reported by Büttiker and Bünzil (1958) and 60 to 80cm reported by Hills (2008). Accumulation of litter made up of the leaves of their cherished vegetation in the study sites may have resulted to this shallower depth of their habitation in these three sites.

Table 3: Means of Burrow width and depth in the Three Towns (cm)

	Burrow width		*S/NS	Burrow depth		
Towns	**Male**	**Female**		**Male**	**Female**	***S/NS**
Awlaw	9.17±0 .22	9.56 ±0.12	NS	28.62 ± 0.11	25.81± 0.12	S
Achi	10.02 + 0.10	9.79+ 0.24	NS	31.41 + 0.30	25.66+ 0.17	S

S = Significant, NS= Not Significant

iv. Body Weight and Morphometric Characteristics of the Cricket (*Brachytrupes membranaceus)*

The body weight and morphometric characteristics of the male and female crickets in the three sites are presented in Table 4. Although physically, the female appeared more robust, with fattier abdomen than the male, there was no significant difference (P>0.05) in the body weight of male and female crickets, but numerical value of female 3.82 ±0.66g was higher than that of males 3.66 ±0.22g. The body weight recorded is within the range of 3.54g reported by Amadi (2016) for *B. membranaceus* and 4.54g reported by Lakhdari (2015a) for *B. megacephalus.* Of all the morphometric parameters assessed, only the pronotum length and femur length showed significance difference (P<0.05) between the male and female records. Lakhdari *et al*. (2015b) also observed significant difference in the protonium length of male and female cricket of the *Brachytrupes megacephalus* species. Lakhdari *et al*. (2015ba) also reported, the head width of 1.3 to 1.4cm which is similar to 1.10 ± 0.22 and 0.90 ± 0.17cm recorded for male and female respectively but femur length of 2.76 ± 0.24 and 2.56 ± 0.20cm is somewhat higher than their record of 1.7 to 2.2cm for adult *Brachytrupes megacephalus* species of cricket.

Table 4: Body Weight and Morphometric Characteristics of the Cricket (*Brachytrupes membranaceus*

Parameter	Male	Female	S.S/NS.
Body weight (g)	3.66 ±0.22	3.82 ±0.66	N.S.
Body length (cm)	5.70 ±0.60	5.60 ± 0.60	N.S.
Head width (cm)	1.10 ± 0.22	0.90 ± 0.17	N.S.
Length of prontonium (cm)	0.74 ±0.08	0.66 ± 0.08	S
Femur length (cm)	2.76 ± 0.24	2.56 ± 0.20	S
Inner wing length (cm)	4.32 ±0.26	4.43 ±0.28	N.S.
Outer wing length (cm)	3.50 + 0.32	3.76 + 0.41	N.S.

v. Morphological and Behavioural characteristics

The male cricket has a patchy design on its wings while the female wings are smooth. The female on the other hand has a spine like stud extending from the ventral side of the abdomen, this is absent in the male (Plate 14 and 15). The crickets dug out of the burrows where chirping sound was heard at night were all male cricket. The chirping sound was made as attraction to the female.

Table 5: Socioeconomic values of cricket (*Brachytrupes membranaceus*)

Parameters	Male	Female	Remark
Cost	6-7@ N50 ($0.13)	4 - 5 @ N50 ($0.13)	Female has fatty abdomen that makes them tastier
Preference	Less preferred	Highly preferred	More flavor in the fatty abdomen of females
Average quantity caught/ Person/ Day	4- 5kg	1- 2kg	?
Ratio of Male to Female in a daily catch	2-3	1	
Mean contribution to family income	Variable , more costly towards the end of the rains, contributes more to protein needs than monetary gains		
Usage : Nymph	Caught between February to March: The nymph called “Mbisi” is mostly used for two highly cherished traditional soup “ Ora and Egusi (Melon) soup		The nymph are usually found in the sandy/sandy loam soil but not under tree litter
Usage: Adult	Caught between May to early July. The matured one is called “ Ebio” mainly used in eating a local dish of tapioca “Abacha” (African Salad)		Adult are usually found in the soil under the tree litter of the listed choice foods. The adult are not found under Cashew

		tree even though the cricket drags cashew leaves and fruit into its burrow
Exact Areas of Harvest	In Oji River Local Government- Akpugoeze, Inyi and Ugwuoba clayey soil and so the crickets are not found in the towns even though they cherish the cricket. People from these town purchase from local markets in Achi and Awlaw	In Awlaw three villages have crickets in large numbers because of the sandy loam and very sandy soils (AwlawIsiama, AwlawEtiti and Awlaw), In Achi the major village where crickets are found is Isikwe


Plate 1: OgodoPlate


Plate 2: Oka /NkaPlate


Plate 3:Okpokolo


Plate 4: Ubele


Plate 5: Ububo


Plate 6: Ikemoji


Plate 7: Burrow the gallery


8: Tracing the Burrow


Plate 9: Interview with a Family in cricket business

Plate 10: Femur length

Plate 11: Head width

Plate 12: Protonum length

Plate 13: Body length

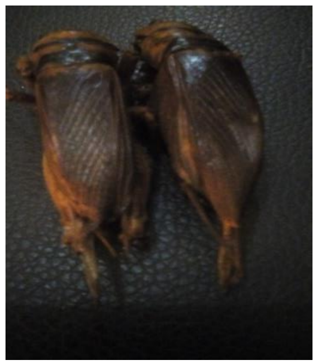

Plate 14: Female Wing with smooth vein

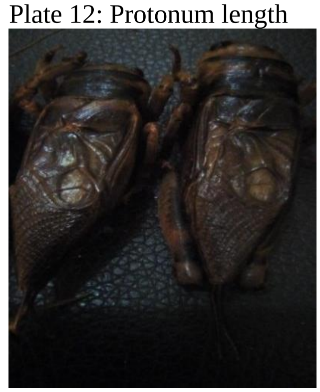

Plate 15 : Male Wing with patchy designed wing

Plate 14: Bowl of cricket for sale

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Nanotechnology in Livestock Production: A Review

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ABSTRACT

Nanotechnology , a technology that involves reduction of materials and structures into miniature/minute sizes that perform their functions accurately and better than the bulk size, has its usage in every aspect of life but the use in agriculture remain unharnessed especially in Africa and other developing countries. The areas of use of nanotechnology in the field of livestock production is reviewed in this paper alongside with the challenges and prospects with a view of motivating animal scientists , livestock farmers and other practitioners to adopt the technology in improving livestock productivity, animal health care management and husbandry practices that improve yield and efficiency,

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INTRODUCTION

The word "Nano" is from the Latin word "Nanus" meaning dwarf and thus nanotechnology is defined as the technology of materials and structures where size is measured in nanometers with application in diverse areas as physics, chemistry and biology (Buzea *et al*., 2007). Wang *et al*., (2007) defined nanotechnology as manipulation of (designing, synthesis) particle with dimension less than a micron to that of individual atom. Nanotechnology is therefore an aspect of science that studies, designs, creates, synthesizes, manipulates and also applies functional materials, devices and systems through control of matter at nanometer scale (1-100nm: one nanometer is equal to 1 x 10^{-9}, one billionth of a meter (i.e., at atomic molecular and supramolecular (NSTC, 2004) and the exploitation of novel phenomena and properties of matter and structure at that level. Nanoparticles present a higher surface volume with decreasing size of the particle; they also exhibit unique chemical, physical, photo-electrochemical and electronic properties when compared to their respective bulk materials.

History of Nanotechnology

The term nanotechnology was first used by the late Norio Taniguchi in 1974, while the concept was developed Nobel Laureate and physicist Richard P. Feynman in south California in 1952 (Kakade, 2003), but it was popularized by Eric Drexler in 1980s. Mannino and Scapicchio (2007) defined nanotechnology as a study of phenomena and manipulations in atomic, molecular and macromolecular scales where properties differ from those on a larger scale. Nanotechnology is a technology that deals with experimenting and manipulating with particles, called nano-particles that are demonstrated in the scale of nanometers (Chaudhary *et al*., 2005). Food and Drug Administration (FDA) in 2006 defined nanomaterials as particles smaller than micrometric scales, which exhibit specific properties. Thus, by exploitation of the concept of nanotechnology, miniature sized structures, materials, devises. Mannino and Scapicchio (2007) stated United States Department of Agriculture (USDA) was the first to discuss nanotechnology in Agriculture and Food industry in their action plan published in September, 2003. Joseph and Morrison (2006). According to Scott and Chen (2002) nanotechnology is useful in applied science and engineering of agriculture, animal and food systems. Kalil *et al*., (2023) noted that four generations of nanomaterials have emerged: active and passive nano assemblies, general nanosystems and small-scale molecular nanosystems. The first generation include passive nanostructures that maintain steady structures and functions during their use like dispersed and contact nanostructures like aerosols, colloids, those with products incorporating nanostructures in coatings, nanoparticle reinforced composites. Second generations makes use of active nanostructures that provide for specificity of target cell or organs,e.g. Bioactive structures that target drugs. Third generation include 3D networking, robotics, while the fourth generations which is molecular include molecular devices by design, atomic designs and other emerging functions.

APPLICATIONS OF NANOTECHNOLOGY TO LIVESTOCK PRODUCTION

Improvement of Livestock Growth/Reproduction Performance and Immunity by Use of Nanoparticles

Nanoparticles are of four different types: metals, polymers, natural compounds and nanostructured materials. Metal nanoparticles are powdery form of the solid minerals, after the large pieces have been ground to nano-versions, thus changing its physical properties (Praharee 2021). According to him, polymer nanoparticles are polymers that have been synthesized or fragmented into nanometers long, while nano particles made of natural compounds are materials that come from nature with limited manipulations such as natural polymers and proteins. Nonstructured materials are synthesized nanoparticles that originate from many sources including natural compounds such as lipid and protein- based nanoparticles. Nanoparticles in feed and water administered to livestock have yielded remarkable positive results. Wang and Xu cited in (Praharee 2021) reported that 200μg in the feed of pigs produced pigs that are 14.06% leaner at slaughter, increased skeletal muscle mass and improved pork quality. Praharee (2021) also reported that nano Chromium when added to poultry feed positively improved the breast and thigh muscles and at the same time lowered cholesterol, but raised average daily gain feed efficiency. Other nanoparticles have been reported to have many nutritional and health benefits especially nano zinc. Swain *et al*., (2016) reported on the growth promoting, antibacterial, immuno-modulatory and many more effects of nano zinc on animals. Lane and Andre (2012) similarly reported that feeding nano Zn to larger livestock and poultry produced encouraging results in terms of growth, immunity and reproduction. Nano-Selenium is another very important nano mineral with tremendous positive impact on semen quality . Shi *et al*., (2010) reported that nano selenium enhanced testis selenium content of goats, improved testicular and semen GSH-Px activity, protected the membranes system integrity and tight arrangement of mid-piece of the mitochondria.

ii. Nanoparticle as Biocides

Hill and Li (2017) discussed extensively the biocidal properties of nanoparticles and stated that. nano-particles present a feasible alternative to antibiotics. Drug resistance due to continuous use of antibiotics has remained a big challenge in the livestock industries worldwide, thus the emergence of legislations to control for prophylactic antibiotics use in agriculture. Limiting antibiotic use necessitates the search for alternatives, however, metal nano-particles with net positive charges according to Gahlawat *et al.,* (2019) are drawn to negatively charged bacterial membranes resulting in leakage and bacterial lysis. Kim *et al.,* (2007) cited in Hill and Li (2017) reported that silver nanoparticles can inhibit the growth of hemorrhagic enteritis-inciting E. coli. Gonzales-Eguia *et al*., (2009) demonstrated that nano form of copper could improve piglet through augmentation of lipase and phospholipase A activity in the small intestine compared to a basal diet supplemented with copper sulphate.

iii. Nano Meat Production

Nanotechnology is a promising technology that has applications in almost all fields. The technology has opened the path to an unexplored science for studying individual nanoparticles and their unique application to poultry and meat industry ranging from meat design, meat safety, overcoming food allergies, eliminating pesticide use and residues, meat packaging, restoring meat damage and sensory evaluation to processes such as filtration, separation, encapsulation. Nano-technology can make poultry and meat products cost-effective with the natural properties (Singh *et al*., 2011). Production may be carried out by self- replicating nano-devices using small assent of material, energy, low capacity, less labour and land. Thus, production is more efficient (Rajkumar *et al.*, 2006). For quality meat products development, nanotechnology based diagnostic techniques may replace ultrasound-like existing technique, besides is naturally composed of nano-fibres. It is the nano-fibres that undergo changes during cooking or processing leading to changes in taste, texture and flavour. Singh and Neelam (2011) noted that differentiation in quality of products can be made using nanotechnology- based techniques. Many of the molecular structure that affect the meat quality are in the nanometer range, so information on the source can play a significant role in poultry meat design. Mastering the characteristic of meat components and the knowledge of nanotechnology approach to manipulating of individual atoms and placing them where they are needed are the two basic requirements for producing meat of desired flavor, texture and taste (Chaudhary *et al.* 2005).

Recently, nanotechnology is being utilized in the development of vegetarian meat as well as cultured meat. The power of nanotechnology here lies on the fact that everything is made of basic atoms, but simply arranged in different ways, thus rearranging the atoms at the nano- levels will give desired molecules. This is the basis for laboratory meat synthesis referred to as cultured meat. Moraru *et al.* (2003) predicted the creation of unlimited amount of meat by synthesis at atomic level which eradicates animal protein deficiencies and hunger. Cultured meat will reduce level of animal production drastically while fulfilling all the nutritional and hedonic requirement of meat eaters. Marquez (2004) stated that the more futuristic applications of nanotechnology lie in the production of 'interactive' poultry meat that change colour, flavour or nutrrients depending on the consumer's taste or health.

iv. Nanotechnology Based Meat Packaging

In many developed countries, there has been increasing competition between suppliers and government regulations regarding meat packaging materials. Generally, the consumers demand to have their meat fresh for longer period or safe meat products prepared with environmentally friendly packaging materials. Andersen (2007) noted that nanotechnology innovations has produced films that enhance products and packaging performance and at the same time addressed worldwide concerns with packaging waste. Nanotechnology provides food scientists with a quantity of ways to make novel laminate films suitable for use in the food industry. A nanolaminate consists of two or more layers of material with nanometer size that are physically or chemically bonded to each other. Nanolaminates can provide food scientists some advantages for the preparation of edible coatings. Edible coatings according to Morillon *et al*., (2002) and Cagri *et al*., (2004), these coatings or films could serve, lipid and gas barriers. Edible coatings can also be made to improve textural properties of food or serve as carriers of functional agents such as colours, flavours, antioxidants, nutrients and antimicrobials.

v. Nanotechnology Applications in Egg Production

The role of nanotecnology in designer egg production is now a well- known fact. Scientists are of the opinion that in the near future the share of designer eggs in the egg production will be more than 30% and similarly supply of cholesterol free eggs, yolkless or reduced egg yolk, immune boosting eggs (which enhance production of predetermined antibodies), increased albumen eggs will be in the market. These egg qualities according to Kannaki and Verma (2006) can only be met by the emerging nanotechnology.

Furthermore, through nanotechnology, there is possibility of advanced detection of sources of pathogens in eggs and poultry meat. Such early detection of food borne pathogenesis is critical in prevention of disease outbreak and safeguarding public health. Though numerous methods have evolved over the years for this purpose, however the biggest challenges remain the speed of detection and sensitivity. Presently, novel nanotechnology-based biosensor is showing great potential for food borne pathogenic bacteria detection with high precision.

vi. Nanotechnology Applications in Milk Production

Many research has been carried out on the improvement of composition and quality of milk by the use of nanominerals. Mohamed *et al.*, (2022) reported that Chitosan nanoparticles and Selenium nanoparticles showed high antimicrobial activity against milk microorganisms that deteriorate milk quality. Rajendran *et al*., (2013) reported on the effect of feeding of dairy cattle with nano ZnO and posited that nano ZnO fed to dairy cattle increased milk production, immunity and suppressed subclinical mastitis (reduction in SCC values). Cai *et al.*, (2021) also reported that nano Zn supplementation in dairy cattle feed improved Zn availability without impairing lactation performance, health status and mammary gland permeability.

vii. Nanotechnology Use in Controlling of Piglet Weaning Challenges

Diarrhoea is a common intestinal disease of piglet, often resulting in high morbidity and mortality of piglets (You *et al*., 2012). For long, microelements like Selenium and Zinc are the essential additives required in the treatment of such diseases in piglets (Bian *et a.l*, 2010). Zinc added in feed dietarily often occur in high dosage resulting in zinc toxicity in pigs, besides; a greater proportion of the Zinc is discharged via feaces resulting in environmental pollution. Kociova *et al* (2020) cited in Baholet *et al*., (2023) showed that there was increase in piglet weight in all supplementation with nano Zinc from 500mg/kg to 2000mg/kg of Zn in enhancing growth performance and preventing diarrhoea in piglets. Pan *et al*., (2005) earlier noted that nano Zn has unique advantage of being highly effective at dosages far lower than that of the quantity of Zn) it replaces.

CHALLENGES OF NANOTECHNOLOGY

The challenges of nanotechnology are categorized into four: philosophical, ethical and societal issues. Of all these, one major challenge of nanotechnology is that, a lot of prospective adopters of the technology are ignorant of the happenings in the nanoworld. People need to understand how atoms fix up to become large structures and materials except this knowledge is available, adoption of nanotechnology will be low. Bonsor and Strickland (2007) stated that the most immediate challenge of nanotechnology is that people need to learn more about the properties of materials at the nanoscale. This is because elements at nanoscale behave differently from their bulk size. According to them, there fears about nanoparticles being toxic .

Secondly, in the human health parlance , doctors are worried that nanoparticles are so small and capable of crossing the blood-brain barrier, a membrane that protects the brain from harmful chemical in the bloodstream. This is a serious issue that is also applicable to livestocks.

Another concern of scientists is ethical issues, nanotechnology appear to take away science from nature, if nanoparticles increases sperm motility, dairy production. Nanotechnology practices may appear pervasive against societal norms and cultural beliefs and in Africa this poses a major hindrance to adoption of innovations. However , serious extension services is required if this novel discovery is to be adopted by farmers; such extension services must use native language and easily comprehensible teaching aids to bring the teaching to the farmers level of understanding.

CONCLUSION

Nanotechnology is touching every facet of life, its application in the field of animal science provides an outlook of unimaginable possibilities. It is therefore imperative for animal scientists in Nigeria to begin to appreciate the outlook of its possibilities and harness the ones that can fit into our peculiarities and utilize it to move animal production forwards,

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SUB-THEME SEVEN

TRENDS, CHALLENGES AND PROSPECTS OF DIGITALIZING EXTENSION SERVICES AND AGRICULTURAL ECONOMY

Contribution of Catfish Farming to Household Income in Ukwuani Local Government Area, Delta State, Nigeria

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KEYWORDS

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ABSTRACT

This study investigated the contribution of catfish farming to household income in Ukwuani Local Government Area (LGA), Delta State, Nigeria. The study involved 120 catfish farmers selected through a two-step sampling process. Data were analysed using descriptive statistics and Gross Margin analysis. Results indicated a male-dominated demographic in catfish farming, with males constituting 70.8%. The study emphasised diverse age groups, marital statuses, and educational backgrounds of catfish farmers, stressing the sector's inclusivity. Catfish farming emerged as a primary contributor to household income, constituting ₦1,008,403.53 (42.2%) of the total annual household income. Diversification of income sources, including crop farming and other economic activities, showcased the resilience of households. The study further revealed that catfish farming income significantly contributed to food (38.2%), education (20.8%), healthcare (8.0%), housing (19.7%), and savings (13.3%). Profitability analysis demonstrated that catfish farming was financially viable, with a Benefit Cost Ratio of 1.54. Challenges such as high input costs ($\bar{x}$ = 2.8), market fluctuations ($\bar{x}$ = 2.9), and limited access to credit ($\bar{x}$ = 2.8) were identified, necessitating targeted interventions. The findings provided valuable insights for policymakers, practitioners, and researchers to enhance the sustainability and socio-economic impact of catfish farming in Ukwuani LGA.

INTRODUCTION

Aquaculture has emerged as one of the fastest growing food production sectors globally, with an average annual growth rate of 5.8% since 2001 (FAO, 2020). In Nigeria, fish farming is increasingly being promoted as a strategy for enhancing domestic food and nutrition security, and raising incomes for smallholder farmers (Ume *et al*., 2016). Of the various farmed fish species, African catfish (*Clarias gariepinus* and *Heterobranchus species*) are the most predominant, constituting over 80% of total aquaculture production (Azra *et al*., 2022). Catfish is favoured by Nigerian farmers and consumers due to its resistance to disease and environmental stress, quick growth rate, and marketability (Dienye *et al*., 2021). Furthermore, African catfish can survive and grow well on affordable diets made from agricultural by-products and household wastes, making it suitable for small-scale rural aquaculture systems (Isyaku and Solomon, 2016). Consequently, catfish farming has been promoted by developmental programs as a means for rural farmers to productively utilize indigenous resources for income generation and poverty alleviation (Emmanuel *et al*., 2014).

Delta state, located in the oil-rich Niger Delta region of Nigeria, has enormous potential for aquaculture growth and productivity, given its extensive river systems, floodplains, and swampy terrains (Obiam and Amadi, 2022). Smallholder catfish farming has particularly thrived as a profitable enterprise and source of livelihood for rural households across the State (Inoni *et al*., 2017). Despite governmental and donor efforts to promote the growth of small-scale aquaculture in rural Nigeria, there is limited empirical evidence on the actual scale and magnitude of impacts on household incomes and poverty alleviation. Previous studies have focused more on the technical and agronomic aspects of catfish production at the smallholder level rather product marketing factors that could enhance the poverty alleviation impacts of catfish farming (Nkamigbo *et al*., 2014; Inoni *et al*., 2017;Idris-Adeniyi *et al*., 2018; Arimiche and Ukaro, 2020). Furthermore, the few economic analyses have majorly examined profitability metrics rather than assessing actual income accrued to households from catfish farming and how this translates to rural welfare improvements (Ume *et al*., 2016; Onyekuru *et al*., 2019).

In the context of Delta state, empirical inquiries into small-scale aquaculture have cantered on determinants of catfish production trends, productivity and intensity (Kadurumba *et al*., 2021; Esiobu *et al*., 2022; Ogunji and Wuertz, 2023). Quantitative evidence is lacking on the relative scale of household dependence on income from catfish farming, as well as consequent effects on poverty and wellbeing compared to other livelihood activities. As Iruo *et al*. (2018) observe, most household income studies in Nigeria exclude aquaculture earnings or lack robust data capture and analytical methodologies to reliably quantify actual contributions. This significantly limits policy insights on the effectiveness of smallholder catfish promotion initiatives towards ameliorating rural poverty and vulnerabilities in Delta state.

This study seeks to address this knowledge gap by holistically assessing income contribution, profitability metrics as well as welfare impacts of African catfish farming in Ukwuani Local Government Area (LGA), Delta state, Nigeria. Findings will guide future research and development efforts aimed at enhancing productivity and returns in small-scale aquaculture enterprises within poor marginalized rural communities.

MATERIALS AND METHODS

The study focused on Ukwuani Local Government Area (LGA), located in Delta State, Nigeria. Ukwuani LGA is located at Latitude 5°50′41″ North (5.8447°North) and Longitude 6°14′15″ East (6.2375°East) and it is characterized by its diverse landscape and is known for its agricultural activities. The area's economy is influenced by farming practices, including catfish farming, making it an ideal location to investigate the contribution of catfish farming to household income. All the fish farmers in Ukwuani LGA of Delta State served as the population of the study. A two-step sampling procedure was adopted in the selection of respondents. The first step involved the purposive selection of eight communities out of the twenty communities in the LGA with high level of fish farming. These communities include Akoku, Umutu, Ebedei-Uno, Owah Abbi, Umuoshi, Ezionum, Umuebu and Amai. In the second step, 15 fish farmers were randomly selected from each of the eight communities using a list of fish farmers obtained from the extension agents covering the communities. This gave a total of 120 respondents that were involved in this study. Data for the study were collected using a structured interview schedule. Data collect were analysed using descriptive statistics and Gross Margin analysis.

MODEL SPECIFICATION

Gross Margin Analysis model that was used to estimate the profitability of catfish farming is stated as follows;

GM = TR – TVC ………………………………….… (eqn. 1)

TC = TVC + TFC …………………………………… (eqn. 2)

NR = GM – TFC …………………………………….. (eqn. 3)

BCR = TR/TC ……………………………………….. (eqn. 4)

Where: GM = Gross margin, TVC = Total variables cost, TC = Total cost, TFC = Total fixed cost, NR = Net Returns, BCR = Benefit cost ratio

RESULTS AND DISCUSSIONS

Socioeconomic characteristics of catfish farmers in the study area

In the study area, catfish farmers were primarily comprised of males (70.8%) aligning with Nigeria's agricultural gender norms, where men traditionally take on more active roles in farming operations (Deji and Koledoye, 2013). Women constituted 29.2%, playing crucial roles in managing family resources, including income generated from catfish farming, and contributing significantly to the overall success of the enterprise (FAO, 2021). The mean age of respondents was 36 years, with diverse age ranges contributing to the farming community's richness. Marital status varied widely: 48.3% married, 37.5% single, 7.5% widowed, and 6.7% divorced. The prevalence of married catfish farmers aligns with traditional family structures in Nigeria, where marriage often signifies increased responsibilities and shared household duties (Asadu and Egbuche, 2020). This group may benefit from additional labour resources within the household, contributing to the overall success of catfish farming operations. The presence of single individuals, comprising 37.5%, suggests a potentially distinct set of challenges and opportunities, with greater flexibility in managing time and resources for catfish farming. The study revealed that 38.3% of the fish farmers have completed secondary school, 29.2% primary school, 15.8% tertiary education, and 16.7% reporting no formal education. The dominance of secondary school education suggests a relatively high level of basic education within the catfish farming community, potentially facilitating the adoption of modern farming practices (Muhammed *et al*., 2021).

There was a prevalent medium-sized household structure, with 52.5% reporting 6 to 10 persons, and a mean household size of 7 persons. This aligns with the traditional extended family system in Nigeria, where multiple generations often contribute to agricultural activities, fostering a balance between available labour resources and the management of agricultural responsibilities (George *et al*., 2014). The average stock size of the respondents was 1,884 fishes indicating a medium-sized farms. This finding suggests a balance between efficient management practices and sustainable production, as medium-sized farms are often associated with better operational control and economic stability (Alawode and Ajagbe, 2020). The distribution of farming experience showed that 48.3% of the farmers had 6 to 10 years of experience, reflecting a substantial presence of seasoned farmers with a mean experience of 8 years. Additionally, 27.5% have above 10 years of experience, while 24.2% are in their first 5 years of farming. This diverse distribution encompasses both new and experienced farmers, suggesting a community that benefits from the innovative perspectives of those new to the field and the stability and expertise contributed by experienced farmers. The prevalence of experienced farmers aligns with the potential for in-depth knowledge and skills in catfish farming practices, contributing to the overall success and sustainability of catfish farming in the region (Inoni *et al*., 2017).

Table 1: Socioeconomic characterises of the respondents

	Variable	**Frequency**	**Percent**	**Mean**
Gender	Male	85	70.8	
	Female	35	29.2	
Age (years)	18 – 24	13	10.8	
	25 – 34	40	33.3	
	35 – 44	30	25.0	36 years
	45 – 54	23	19.2	
	Above 55	14	11.7	
Marital status	Single	45	37.5	
	Married	58	48.3	
	Widowed	9	7.5	
	Divorced	8	6.7	
Educational level	No formal education	20	16.7	
	Primary school	35	29.2	
	Secondary school	46	38.3	
	Tertiary education	19	15.8	
Household size (persons)	1 – 5	45	37.5	
	6 – 10	63	52.5	7 persons
	Above 10	12	10.0	
Stock size (fishes)	Less than 1,000	43	35.8	
	1,000 – 3,000	68	56.7	1,884 fishes
	3,100 – 5,000	7	5.8	
	Above 5,000	2	1.7	
Farming experience (years)	1 – 5	29	24.2	
	6 – 10	58	48.3	8 years
	Above 10	33	27.5	

Source: Field Survey (2023)

Economic contribution of catfish farming to household average annual income in the study area

Table 2 provides the result of the economic contributions of various income sources to the average annual income of households engaged in catfish farming in the study area. The result reveals a clear economic hierarchy, with catfish farming emerging as the primary driver, contributing ₦1,008,403.53, accounting for 42.2% of the total household average annual income. This underscores the pivotal role of catfish farming in the study area's economy, aligning with previous research highlighting the significance of aquaculture in sustaining rural livelihoods in Nigeria (Ogunjiand Wuertz, 2023). The substantial contribution from catfish farming reflects not only the economic value of the practice but also the potential to serve as a catalyst for poverty reduction and rural development. While catfish farming dominates, the study also reveals the diversification of income sources among the households. Crop farming, contributing ₦403,300.58 (16.9%), signifies the importance of agricultural diversity for income stability (Okhale, 2019). Beyond agriculture, artisan activities, trading, and employment collectively contribute ₦969,444.26, representing 40.9% of the household income. This diversified income portfolio underscores the adaptability and resilience of households, engaging in various economic activities to mitigate risks associated with dependence on a single source. The multifaceted nature of income generation observed in this study area provides a nuanced understanding of the economic landscape, essential for informed policy-making and targeted interventions that aim to enhance overall economic sustainability and well-being in the study area.

Table 2: Economic contribution of catfish farming to household average annual income in Delta State, Nigeria

Source of income	Amount (₦)	Percentage of household average income
Catfish farming	1,008,403.53	42.2
Crop farming	403,300.58	16.9
Artisan	115,228.74	4.8
Trading	253,503.22	10.6
Employment	610,712.30	25.5
Total household average annual income	**2,391,148.37**	**100**

Source: Field Survey (2023)

Utilisation of average annual income generated from catfish farming

Table 3 shows the result of how the average annual income derived from catfish farming is utilized within households in the study area. The study revealed that the highest allocation, at 38.2%, is directed towards food and groceries, emphasising the pivotal role of catfish farming income in meeting fundamental sustenance needs. This finding aligns with studies highlighting the integral link between aquaculture income and improved food security for rural households in Nigeria (Anthony and Richard, 2016). The significance of catfish farming in addressing immediate nutritional requirements reflects its crucial contribution to household well-being and underlines the importance of sustaining and enhancing catfish farming practices to ensure continued food security in the region. Education expenses receive a substantial allocation of 20.8%, indicating that catfish farming income contributes significantly to educational pursuits within these households. This finding resonates with existing research emphasizing the positive correlation between income from agricultural activities and increased investment in education (Diao *et al*., 2020). The allocation to education expenses suggests that catfish farming not only serves immediate consumption needs but also plays a crucial role in fostering human capital development, potentially leading to improved socio-economic conditions for future generations in the community. The remaining income allocations to healthcare expenses (8.0%), housing and utilities (19.7%), and savings (13.3%) highlight the diversified impact of catfish farming income. These allocations signify a balanced approach, addressing both immediate needs and long-term aspirations. The investment in healthcare and housing reflects a commitment to enhancing the overall quality of life within these households, while savings contribute to long-term resilience, potentially acting as a financial buffer during periods of economic uncertainty. This multifaceted utilization pattern highlights the importance of catfish farming income not only as a means of daily sustenance but also as a driver of holistic development and improved well-being in the studied area.

Table 3: Utilisation of average annual income generated from catfish farming

Category	Amount (₦)	Percent
Food and groceries	385,210.15	38.2
Education expenses	209,747.93	20.8
Healthcare expenses	80,672.28	8.0
Housing and utilities	198,655.50	19.7
Savings	134,117.67	13.3

Source: Field Survey (2023)

Profitability of catfish farming per cycle in the study area

The result in Table 4 shows the profitability of catfish farming per cycle in the study area. Variable costs, accounting for 78.9% of the total cost, are primarily associated with inputs that vary with the scale of production. Feeds emerge as the most significant variable cost, constituting 27.2% of the total cost. This aligns with the literature, where feed costs are often cited as a major component in aquaculture production (Hecht, 2013). Medication, veterinary services, and fuel also contribute substantially to variable costs, underscoring the importance of health management practices in catfish farming. Efficient management of these variable costs is crucial for optimizing profitability and ensuring the economic sustainability of catfish farming operations. Fixed costs, accounting for 21.1% of the total cost, encompass expenses such as rent, pond construction, and depreciation. The revenue generated from selling 1,596 fishes amounts to ₦2,872,800.00, resulting in a gross margin of ₦1,401,515.95. The net revenue, calculated as the gross margin minus the total cost, is ₦1,008,403.53. The Benefit Cost Ratio (BCR), calculated as the ratio of the net revenue to the total cost, is 1.54. A BCR greater than 1 indicates positive returns, suggesting that catfish farming in the study area is financially viable and has the potential to generate profits beyond the costs incurred.

Table 4: Profitability of catfish farming per cycle in the study area

Variable cost	Quantity	Price (₦)	Amount (₦)	Percentage of Total Cost
Fingerlings/ juveniles	1,884	55	103,620.00	5.6
Feeds	40.5 bags	12,500	506,250.00	27.2
Water			115,901.31	6.2
Fuel			186,071.73	10.0
Labour			101,103.59	5.4
Medication			211,717.26	11.4
Veterinary services			186,270.36	10.0
Miscellaneous			60,349.80	3.2
Total variable cost			**1,471,284.05**	78.9
Fixed cost				
Rent	1 year		122,000.92	6.5
Pond construction	3 ponds	82,155	246,465.00	13.2
Depreciation			24,646.50	1.3
Total fixed cost			**393,112.42**	21.1
Total cost			**1,864,396.47**	
Revenue	**1,596 fishes**	**1,800**	**2,872,800.00**	
Gross margin			**1,401,515.95**	
Net revenue			**1,008,403.53**	
Benefit Cost Ratio			**1.54**	

Source: Field Survey (2023)

Challenges affecting the profitability of catfish farming in the study area

Table 5 presents the result of the assessment of the challenges affecting the profitability of catfish farming in the study area. Several challenges receive consensus among farmers, indicated by mean scores equal to or greater than 2.5. These include high input costs ($\bar{x}$ = 2.8), market fluctuations ($\bar{x}$ = 2.9), limited access to affordable credit ($\bar{x}$ = 2.8), inadequate infrastructure ($\bar{x}$ = 2.5), unpredictable weather ($\bar{x}$ = 2.5), lack of government support ($\bar{x}$ = 2.6), competition with imported fish ($\bar{x}$ = 2.6), and environmental issues ($\bar{x}$ = 2.5). The agreement on these challenges highlights their significance in influencing the profitability of catfish farming. For instance, market fluctuations and high input costs are common concerns in agriculture globally (Mishra, Behera and Behera, 2023), emphasizing the need for adaptive strategies and targeted interventions. Challenges with mean scores below 2.5 receive disagreement among farmers. These challenges include disease outbreaks ($\bar{x}$ = 2.4), difficulty accessing reliable markets ($\bar{x}$ = 2.4), and insufficient technical knowledge ($\bar{x}$ = 2.4). While disease outbreaks are often recognized as a potential threat in aquaculture (Ina-Salwany, *et al*., 2019), farmers in this study may perceive it to be less severe compared to other challenges. The disagreement on technical knowledge and market access challenges suggests a need for targeted capacity-building initiatives and improved market linkages.

Table 5: Challenges affecting the profitability of catfish farming in the study area

Challenges	$\bar{x}$	Standard deviation	Remark
High input costs	2.8	1.1447	Agreed
Market fluctuations	2.9	1.0138	Agreed
Limited access to affordable credit	2.8	1.1530	Agreed
Disease outbreaks	2.7	1.0705	Disagreed
Inadequate infrastructure	2.5	1.1839	Agreed
Difficulty accessing reliable markets	2.4	1.1384	Disagreed
Insufficient technical knowledge	2.4	1.1378	Disagreed
Unpredictable weather	2.5	1.2256	Agreed
Lack of government support	2.6	1.0936	Agreed
Competition with imported fish	2.6	1.0447	Agreed
Environmental issues	2.5	1.1691	Agreed

Where $\bar{x}$≥2.5 is Agreed, $\bar{x}$<2.5 is Disagreed

Source: Field Survey (2023)

CONCLUSION

The study on the contribution of catfish farming to household income in Ukwuani LGA, Delta State, Nigeria, revealed important socioeconomic characteristics, economic contributions, and challenges faced by catfish farmers. The dominance of males, mid-adult age distribution, and prevalence of married individuals align with broader agricultural trends in Nigeria. Catfish farming emerged as a vital contributor to household income, constituting 42.2% of the total average annual income. The diversified income sources highlighted households' adaptability, mitigating risks associated with dependence on a single activity. The study therefore recommends the need for the following targeted interventions:

i. Fish feed companies, hatcheries and research institutes should collaborate with extension agencies to promote cost-effective feeds, ensure availability of quality fingerlings and provide customized trainings to enhance productivity of smallholder catfish farms.

ii. Government agencies should facilitate partnerships between farmer cooperatives, cold storage operators, transport companies and retailers to develop cold chain infrastructure and strengthen market linkages for smallholder catfish producers.

iii. Insurance companies supported by government agencies and development organizations should design suitable risk mitigation products to safeguard smallholder catfish farmers against climate vagaries and price volatility.

iv. Rural infrastructure authorities in coordination with electricity utilities and community organizations should improve road connectivity and electricity access in concentrated catfish farming areas to reduce transaction costs for smallholder producers.

v. Financial institutions backed by favourable policies from regulators and development banks should ease collateral conditions to facilitate formal credit access for small aquaculture enterprises.

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A Comprehensive Analysis of Market Structure-Conduct-Performance of Sugarcane (*Saccharum officinarum* L.) in North Central Nigeria

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ABSTRACT

This study investigates the market structure, conduct, and performance of sugarcane in North Central Nigeria. Employing a multi-stage sampling approach, 235 sugarcane marketers were randomly selected from a pool of 575 using the Slovin's formula. Primary data was collected through structured questionnaires and analyzed using the Gini coefficient, Lorenz curve, marketing margin, and marketing efficiency model. Market analysis reveals income inequality, with Gini coefficients ranging from 0.61 to 0.72. The closer the value of gini coefficient is to unity, the greater is the degree of income inequality and the higher is the level of concentration of sellers and vice versa. The diagonal connecting points of (0, 0) and (1, 1) on the Lorenz curve depicts the 450 line or line of perfect equality. The graph showed the cumulative percentage of sugarcane marketers against the cumulative percentage (%) of sugarcane total sales or income which reveals that the market is an imperfect market. The study identifies pricing factors influencing market conduct, with net margins and profitability ratios confirming sugarcane marketing as profitable. Sensitivity analysis suggests potential profit optimization by reducing transportation and storage costs. The study concludes that sugarcane marketing is profitable in North Central Nigeria and recommends interventions such as establishing training centers, offering capacity-building workshops, implementing flexible credit policies, and enhancing security for marketers.

INTRODUCTION

Agricultural development is one of the most effective tools for eradicating extreme poverty, boost shared prosperity, and provide sustenance for a projected 9.7 billion people by 2050 (World Bank, 2021). This is possible if industrial crops like sugarcane production and marketing can be given top priority because of its relevance in providing raw materials to our industries to achieve the sustainable development goals. Sugarcane *(Saccharum officinarum)* holds significant importance as an industrial crop on a global scale, with roughly 110 countries involved in sugar production from either sugarcane or sugar beet (ISO, 2020). Food and Agricultural Organaisation (2020), reported that sugarcane, on average, accounts for approximately 80 % of global sugar production. Sugarcane aside mainly grown for manufacturing sugar and other sweeteners, its by-products are used in chipboard and paper industries. Products derived from sugarcane also includes *falernum*, molasses, rum, *cachaça* (a traditional alcohol from Brazil), *bagasse* (cane fibres) used to produce cellulosic ethanol, a second-generation biofuel. The plant itself can be used as thatch and livestock fodder (Amita, and Sudip, 2020).

However, in Nigeria chewing cane accounts for between 55 – 65 % of the total cane production. The bulk of these are consumed raw for sweetness of the juice while some are processed into a variety of products such as sugar, molasses, bagasse, *Jaggery (Mazarkwaila)*, sweets *(Alewa)* and left – over leaves/stalks used as thatch and livestock feeds (Oni, 2016). Despite having all these importance, sugarcane production and marketing in Nigeria has not matched the sugar and sweeteners need of the country. In 2019, the amount of sugar consumption stood at over 1.4 million MT while in 2020 it was also over 1.5 million Metric Tons (MT). However, Nigerian sugar production in 2019 stood at only 38,597 MT (0.039 million MT) while importation stood at 1.4 million MT and 1.5 million MT in 2019 and 2020, respectively (ISO, 2020b). With average unit price of $283/MT, the importation cost from the deficit gap stood at over $433 million with per capita consumption of 7.6kg; (NSDC, 2020). Hence, the country depend very heavily on imports of sugarcane products thereby making the country highly vulnerable to global market and supply shocks.

Marketing of sugarcane is a very important but rather neglected aspect of agricultural development. In developing countries more emphasis is usually placed on increase sugarcane production with little or no policies to increase how to distribute the sugarcane produced efficiently and in a manner that will enhance increased productivity (Omotesho, *et al* 2013). Sugarcane marketing by farmers and traders, mostly in the immediate post-harvest period, usually involves a lot of costs and these costs are so high that lowering the costs through efficient marketing system may be as important as increasing sugarcane production. Although, Aina, *et al* (2015), Sulaiman (2015) Oni (2016), Amita and Sudip (2020), Issa, *et al* (2020) and Darika, *et al* (2021) has carried out several studies on importance and profitability of sugarcane, but little is known in terms of their marketing as such paucity and dearth of information in sugarcane marketing in Nigeria particularly North central Nigeria is the reason this research was conceived. It is also pertinent to note that Nigeria government through several policies has aimed at boosting sugarcane production in the country such as imposition of 50 % tariff on importation of white sugar, 5 % levy on imported raw sugar, 5 year tax waver for sugar refineries and privatization of the major sugar firms in Nigeria, yet domestic production of sugar and its value addition is slightly less than 3% of the country's annual requirement (CBN, 2019 and CBN, 2020) and this is the main reason this research was conceived to look at the comprehensive analysis of market structure-conduct- performance of sugarcane in North central Nigeria.

METHODOLOGY

Study Area

The study was conducted in North Central Nigeria comprises of six states namely; Benue, Kogi, Kwara, Nasarawa, Niger and Plateau, and Federal Capital Territory (Figure 3.1). The zone has a projected population of 34,334,723 constituting 16% of Nigeria population (World Meter, 2022). The region lies approximately between Latitudes 7^0.30' and 10^0.20' N and Longitude 3^0.30' and 14^0.30' E occupying a land mass of about 242,425 km^2 (26.24%) out of 923,768 km^2 of Nigeria landmass (NBS, 2020). The North central has network of drainage system forming tributaries that flow from the Benue River and river Niger making it suitable for growing sugarcane using irrigation system.

North central region is mainly influenced by the climate of the Northern and Southern regions of Nigeria giving the working population opportunity to engage in farming, fishing, livestock and poultry. The ideal climate for production of maximum sugar from sugarcane is characterized as a long, warm growing season with a high incidence of solar radiation and adequate moisture (rainfall). Warm and humid climate is favorable for its growth. A temperature range of 30^0C to 40^0C with annual rainfall ranging between 700 to 1500 mm in North central is the best for its successful cultivation (FMARD, 2019). Long duration of sunlight helps in producing thicket and short sugarcane. Warm long days produce plants with more tillers, juice and high sucrose contents (FDAE, 2019).

Sampling Procedure and Sample Size

The major actors considered in this study are the sugarcane marketers in North Central Nigeria. In addition to the major actors, information's were obtained from service providers like International Sugar Organization (ISO), National Sugar Development Council (NSDC), Federal Ministry of Industry, Trade and Investment (FMITI), Federal Ministry of Agriculture and Rural Development (FMARD) Agricultural Development Projects (ADPs) and Research Institutes. A reconnaissance survey was conducted in North central Nigeria to ascertain the population of each sugarcane producers and marketers as obtained from Kogi, Kwara, Nasarawa and Niger states Agricultural Development Projects (ADPs) respectively. This study employed a multi-stage sampling approach. The first stage involved the purposive selection of four states viz: Kogi, Kwara, Nasarawa and Niger which are predominantly engaged in sugarcane production in north central Nigeria. In the second stage, three local governments each from the states were purposively selected based on the preponderance of sugarcane production and marketing in those local governments making a total of twelve (12) LGAs. The third stage involved random selection of two hundred and thirty five (235) sugarcane marketers from a total of five hundred and seventy five (575) sample frame of marketers using the Taro Yamane formula adopted by Sani and Oladimeji (2017) with assumption of 5% expected margins of error, 95% confidence interval and applying the finite population correction factor was determined. The formula was expressed as;

$$n = \frac{N}{1} + N\ (e)^2 \tag{1}$$

$$Where, n\ = Sample\ size\ N\ =\ Total\ population\ of\ study\ 1\ =\ Constant\ e\ = limit\ of\ tolerable\ error, for\ this\ study\ (0.05)$$

$$\frac{575}{1+575(0.0025)} = \frac{575}{2.44} = n = 235\ \frac{235}{575} \times 100 = 41\%$$

Table 1: Population and sample size of sugarcane Producers and Marketers

State	**LGAs**	**Marketers SF**	**Marketers SS (41%)**
Kogi	Bassa	63	26
	Dekina	44	18
	Koton/Karfe	39	16
Kwara	Edu	42	17
	Patigi	52	21
	Moro	54	22
Nasarawa	Awe	62	25
	Lafia	59	24
	Obi	34	47
Niger	Mokwa	33	14
	Gbako	47	19
	Edati	33	14
Total		575	235

Source: Kogi, Kwara, Nasarawa and Niger State Agricultural Development Project (ADP), 2022.

Data Analytical Techniques:

Gini Coefficient, Lorenz curve and marketing Margin (MM)

Gini Coefficient was used to analyze the structure of sugarcane market. The Gini Co-efficient according to Okereke and Anthonia (1988) gives indication about competitiveness of the market. A low Gini Coefficient indicate more equal incomes/wealth or market distribution, while a high Gini Coefficient indicates more unequal distribution. (Zero) (0) corresponds to perfect equality and 1 (one) corresponds to perfect inequality (Wikipedia, 2009). Gini Co-efficient model according to (Ihenacho, 2005) can be specified as follows

$$G\ C\ =\ 1\ -\ \sum (X\ Y) \tag{2}$$

Where, G C = Gini coefficient, X = proportion of sellers, Y = cumulative/percentage proportion of sales, and

$\sum$ = summation sign

Marketing margin was adopted to analyse the market conduct while marketing efficiency model was used to analyse the performance of the market. Marketing margin according to Olukosi and Isitor, (1990) refers to the difference in prices paid for a commodity at different stages of the marketing system. It represents difference in price of a given commodity as it passes through different stages of market channel before it gets to ultimate consumer.

The model is specified as follows:-

$$MM = \frac{SP - PP}{SP} \dot{\times}\ 100 \quad (3)$$

Where

MM = marketing margin, SP = Selling price (retail price of sugarcane), PP = Purchase price

While marketing efficiency on the other hand is the maximization of the ratio of output to input in marketing. Thus, marketing inputs according to Olukosi and Isitor, (2007) are the cost of providing marketing services. Whereas the market outputs are the benefits or satisfaction created or value added to the commodity as it passes through the marketing system.

Marketing efficiency model is specified as follows:

$$ME = \frac{TSR}{TMC} \dot{\times}\ 100 \quad (4)$$

Where , ME = Marketing efficiency, TSR = Total Sales Revenue, TMC = Total Marketing Cost

RESULT AND DISCUSSION

Gini coefficient to measure the variability and the distribution of income amongst sugarcane market participants

Market structure is basically a measure of the degree of competition in a particular market and one of the ways to measure the structure of the market is the use of Gini coefficient. The Gini coefficient measure inequality in the income of different population and is used to compare income distribution across different population sectors. Another importance of the Gini coefficient is that it can be used to indicate how the distribution of income has changed within a given area. When the Lorenz curve is plotted the Gini coefficient is simply calculated as the ratio of the area between the Lorenz curve and the perfect distribution (45 degrees) and the total area below the 45-degree line. The Gini coefficient measures the equality among the values of variable. The higher the value of an index, the more dispersed is the data. Alternatively, the Gini coefficient can also be calculated as the half of the relative mean absolute difference. The point of interest here is to find out the variability of sugarcane marketers in the distribution pattern. Though there was high income inequality and level of concentration in rural buyers (0.63) than the wholesalers (0.61), retailing (0.72) and producers (0.68). The Gini co-efficient ranges from 0 to 1. The closer the value is to unity, the greater is the degree of income inequality and the higher is the level of concentration of sellers and vice versa. These results are in line with the findings of Rueben and Mshelia (2011) on Structural Analysis of Yam Markets in Southern part of Taraba State, Nigeria and that of Ada Okungbowa (1998) on the Market Structure, Conduct and Performance for Yam in Ondo State, Nigeria

Table 1: Gini-coefficient for sugarcane marketers (Farmers) in North Central Nigeria

Qty Sold/Month (Kg)	Freq	% of SC Marketers (X)	Cum. % of SC Farmers'	Total value of monthly sales (₦)	% of total sales	Cum. % of total sales (Y)	∑XY
≤30000	27	0.21	0.21	100000	0.03	0.03	0.0063
30001-40000	21	0.17	0.38	200000	0.06	0.09	0.0153
41001-50000	23	0.18	0.56	300000	0.08	0.17	0.0306
51001-60000	11	0.09	0.65	400000	0.11	0.28	0.0252
61001-70000	10	0.08	0.73	500000	0.14	0.42	0.0336
71001-80000	13	0.10	0.83	600000	0.17	0.59	0.0590
81001-90000	12	0.10	0.93	700000	0.19	0.78	0.0780
>90000	9	0.07	1.00	800000	0.22	1.00	0.0700
Total	126	1.00		3600000	1.00		0.3180

Source: Field Survey, 2022

Mean value of farmers monthly sales = N28, 571.43
GC = 1 - ΣXY
1 – 0.3180
GC = **0.68**

This result reveals that the market is an imperfect market. This finding is in agreement with Ndanitsa, Mohammed and Ndako (2017) who reported imperfect market in their work on analysis of marketing structure and net margin of fresh mango fruits in Minna Metropolis of Niger State, Nigeria and that of Apata (2003) who in the analysis of vegetable market in Ibadan Metropolis, Oyo State, Nigeria also reported imperfect competition in the market.

Table 2: Gini-coefficient for sugarcane marketers (Rural buyers)

Qty Sold/Month (Kg)	Freq	% of SC Marketers (X)	Cum. % of SC Marketers'	Total value of monthly sales (₦)	% of total sales	Cum. % of total sales (Y)	∑XY
≤30000	7	0.20	0.20	78000	0.03	0.03	0.0060
30001-40000	4	0.11	0.31	120000	0.04	0.07	0.0077
41001-50000	3	0.08	0.39	148000	0.05	0.12	0.0096
51001-60000	4	0.11	0.50	365000	0.12	0.28	0.0308
61001-70000	5	0.14	0.64	420000	0.14	0.38	0.0532
71001-80000	5	0.14	0.78	510000	0.17	0.55	0.0770
81001-90000	5	0.14	0.92	655000	0.22	0.77	0.1078
>90000	3	0.08	1.00	680000	0.23	1.00	0.0800
Total	36	1.00		2976000	1.00		0.3721

Source: Field Survey, 2022
Mean value of rural buyers monthly sales = N82, 666.67
GC = 1 - ΣXY
1 – 0.3721
GC = **0.63**

This variability may be as the result of the collusive practices in buying and selling as well as the differences in the degree of risk involved in sourcing for supplies by the different categories of the marketers. The values are evidence of high inequality and high concentration level in the markets, and that the markets were operating at an inefficient level.

Table 3: Gini-coefficient for sugarcane marketers (Wholesalers)

Qty Sold/Month (Kg)	Freq	% of SC Farmers (X)	Cum. % of SC Farmers'	Total value of monthly sales (₦)	% of total sales	Cum. % of total sales (Y)	∑XY
≤30000	2	0.11	0.11	80000	0.03	0.03	0.0033
30001-40000	3	0.17	0.28	100000	0.03	0.06	0.0102
40001-50000	1	0.06	0.34	158000	0.05	0.11	0.0066
50001-60000	3	0.17	0.51	360000	0.11	0.22	0.0374
60001-70000	3	0.17	0.68	450000	0.14	0.36	0.0612
70001-80000	1	0.05	0.73	550000	0.17	0.53	0.0265
80001-90000	2	0.11	0.84	685500	0.22	0.75	0.0825
>90000	3	0.16	1.00	800000	0.25	1.00	0.16
Total	18	1.00		3183500	1.00		0.3877

Source: Field Survey, 2022

Mean value of wholesalers monthly sales = N176, 861.11
GC = 1 - ΣXY
1 – 0.3877
GC = **0.61**
This finding is consistent with the study conducted by Ojo, Ojo, Tsado and Usman (2015) titled Marketing efficiency of rice in Kwara State, Nigeria: a structure-conduct-performance model approach with a gini-coefficient of 0.71. The elements of market structure include the number and size distribution of products, entry conditions, and extent of differentiation.

Table 4: Gini-coefficient for sugarcane marketers (Retailers) in north central Nigeria

Qty Sold/Month (Kg)	Freq	% of SC Farmers (X)	Cum. % of SC Farmers'	Total value of monthly sales (₦)	% of total sales	Cum. % of total sales (Y)	∑XY
≤1000	14	0.25	0.25	12500	0.03	0.03	0.0075
1001-2000	11	0.20	0.45	25000	0.06	0.09	0.0180
2001-3000	9	0.16	0.61	37500	0.08	0.17	0.0272
3001-4000	6	0.11	0.72	50000	0.11	0.28	0.0308
4001-5000	3	0.06	0.78	62500	0.14	0.42	0.0252
5001-6000	5	0.09	0.87	75000	0.17	0.59	0.0531
6001-7000	4	0.07	0.94	87500	0.19	0.78	0.0546
>7000	3	0.06	1.00	100000	0.22	1.00	0.0600
Total	55	1.00		450000	1.00		0.2764

Source: Field Survey, 2022

Mean value of retailers monthly sales = N8, 181.82
GC = 1 - ΣXY
1 – 0.2764
GC = **0.72**

Lorenz curve showing the cumulative percentage of income of marketers as against the cumulative percentage of total sugarcane sales

The graphical representation of gini coefficient for farmers, rural buyers, wholesalers and retailers within the study markets are depicted in figure 1. The diagonal connecting points of (0, 0) and (1, 1) on the graph depicts the 45^0 line or line of perfect equality. The graph showed the cumulative percentage of sugarcane marketers against the cumulative percentage (%) of sugarcane total sales. The graphs also confirmed the highest point where 78% amongst retailer's controls 94% of sugarcane sales, 78% amongst farmers' control 93% of total sugarcane sales and 77% of rural buyers control 92% of total sugarcane sales while 75% of wholesalers control 84% of total sale per month respectively. But generally there is no greater variability in income distribution among all the four categories of marketers. All the points indicating the cumulative percentage of marketers as against the cumulative percentage of total sugarcane sales were uniformly distributed, that is, they are not far from the 45^0 line or line of perfect equality, therefore there is no greeter divergence between the diagonal and the Lorenz curve. This implies that all the points showing the level of income distribution amongst farmers, rural buyers, wholesalers and retailers are nearer to the line of perfect equality. These tend to suggest fair competition among the marketers and an indication of income inequality as the lines does not lies on the diagonal. This study agrees with the findings of Thabbal *et al* (2023) who reported inequality in income distribution among the both out-growers and non out-growers farmers in savannah Sugar Company, Adamawa state, Nigeria.

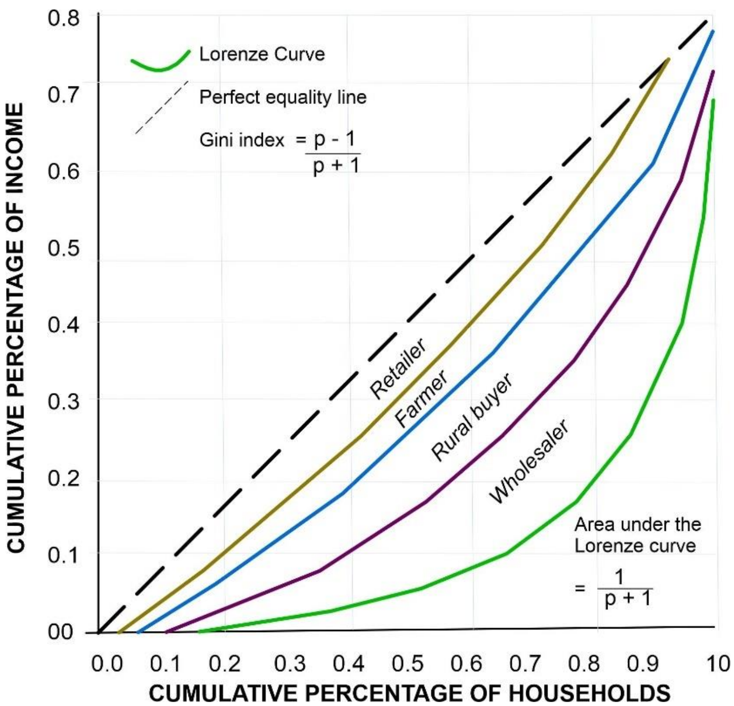

Fig. 1: Lorenz curve showing the cumulative percentage of income of marketers as against the cumulative percentage of total sugarcane sales by households

Market Conduct Analysis

Table 5 reveals that 46.38% of marketers attributed their pricing behaviour to market cost and margins, 30.64% to demand and supply forces and 22.98% to negotiation practices. These findings highlight buyers effective bargaining in price determination and the impact of marketing conduct on price outcomes. This finding is in line with that of Ojo, *et al* (2015) in their work of marketing efficiency of rice in Kwara State, Nigeria: a structure-conduct -performance model approach where they discovered 90% of the marketers indicated that their pricing behavior was determined by marketing cost and margin, while 87% indicated forces of demand and supply, and 67% indicated higgle and haggle. The result on the marketers' conduct was the evidence of buyers' ability to bargain well in price determination, and an incidence of price discrimination.

Table 5: Determinants of pricing behaviour by sugarcane marketers

Factors	Frequency	Percentage
Factors of demand and supply	72	30.64
Price bargaining (higgle and haggle)	54	22.98
Marketing cost and margin	109	46.38
TOATAL	235	100

Source: Field survey, 2022

Market performance assessment of sugarcane

Marketing margin and profitability ratios were used to determine the performance of sugarcane marketers in the study area. The cost of sugarcane purchase for wholesalers in the study area was ₦70/kg (Table 6) which was the highest share of the total cost while storage cost was ₦0.58/kg. Rural buyers' transport cost was ₦0.62/kg and the cost of sugarcane was ₦65/kg. Retailers in the study area also had the highest cost of sugarcane of ₦120/kg and highest transportation cost of ₦1.34/kg compared to wholesalers' transportation cost of ₦0.67/kg enjoying economic of scale. The operating costs for wholesalers aside cost of sugarcane was low (₦3.21/kg) when compared to farmers, rural buyers and retailers. The net margin accruing to a seller/kg was ₦20.21, ₦34.06, ₦37.11 and ₦57.54 for farmers, rural buyers, wholesalers and retailers, respectively. The profitability ratios were 0.34, 0.49, 0.50 and 0.43 for farmers, rural buyers, wholesalers and retailers, respectively. The financial efficiency ratios were 1.34, 1.49, 1.50 and 1.43 by the different categories of marketers. In analyzing the performance of the wholesalers, storage cost was small in comparison with other variable costs, this can encourage arbitraging by evening out supplies through space and time such that sugarcane is stored with minimum cost against scarcity. The low operating cost for wholesalers is an indication that they enjoyed economies of scale. Considering the profitability ratio of 0.34, 0.49, 0.50 and 0.43 for farmers, rural buyers, wholesalers and retailers, respectively, implies that for every ₦1 invested in sugarcane marketing, 1.34k, 1.49k 1.50k and 1.43k were realized as profit by market participants, respectively. The profitability ratios for all the category of marketers was a confirmation that sugarcane marketing was a profitable business in the study area. The financial efficiency ratio showed that all the marketers were financially efficient. This result is supported by a study carried out by Ademola, (2017) which revealed that the average return on investment was 1.14 and 1.85 implies that for every ₦1 invested in sugarcane marketing under rain-fed and irrigated farming system, 1.14 kobo and 1.85 was realized by the marketers.

Table 6: Market performance assessment of sugarcane

	Category of Marketers							
Items	**Farmer (n=126)**		**Rural buyer (n=36)**		**Wholesaler (n=18)**		**Retailer (n=55)**	
	Amount (₦)/kg/sale	% of Total cost	Amount (₦)/kg/sale	% of Total cost	Amount (₦)/kg/sale	% of Total cost	Amount (₦)/kg/sale	% of Total cost
Variable costs								
Cost of sugarcane	50	83.63	65	92.94	70	93.47	120	89.25
Cost of transportation	1.49	2.49	0.62	0.89	0.67	0.89	1.34	0.99
Labour cost	2.73	4.57	1.23	1.76	1.57	2.09	2.89	2.15
Storage cost	0.52	0.87	0.25	0.36	0.58	0.77	1.73	1.29
Loading and off-loading cost	0.63	1.05	0.45	0.64	0.35	0.47	1.32	0.98
Miscellaneous	0.99	1.66	0.78	1.12	0.39	0.52	2.51	1.87
Total Variable cost	**56.36**	**94.26**	**68.33**	**97.70**	**73.56**	**98.22**	**129.79**	**96.53**
Fixed cost								
Sales tools (Tie rope/wheel)	2.86	4.78	1.34	1.92	0.98	1.31	3.87	2.88
Depreciation	0.57	0.94	0.27	0.39	0.35	0.47	0.80	0.59
Total Fixed cost	**3.43**	**5.74**	**1.61**	**2.30**	**1.33**	**1.78**	**4.67**	**3.47**
Total cost (TVC+TFC)	**59.79**	**100**	**69.94**	**100**	**74.89**	**100**	**134.46**	**100**
Returns (P*Q)	**80.00**		**104**		**112**		**192**	
Net income (TR-TC)	**20.21**		**34.06**		**37.11**		**57.54**	
Profitability Ratio TR/TC	**0.34**		**0.49**		**0.50**		**0.43**	
Efficiency Ratio	**1.34**		**1.49**		**1.50**		**1.43**	

Source: Field survey, 2023

Sensitivity analysis of the performance of the marketers

In linear programming problem shadow prices help in understanding the impact of changes in constraints on the objective function value, while allowable increase and allowable decrease provide bounds on how much those constraints can change without altering the current optimal solution. The sensitivity report of the cost and return of the marketers in table 7 reveals that the rural buyers can increase their profit to ₦2 if they can reduce their transportation cost by 45k per kg. This additional profit have the potential to increase up to ₦4.02k/kg without altering the optimal solution. The wholesalers on the other hand can increase their profit to ₦2.1k if they can reduce their cost of storage by ₦32. Therefore, the rural buyers and wholesalers have the prospect to reduce their cost of marketing by ₦24.74k and ₦16.58k respectively to maximize profit.

Table 7: Cost and Return shadow Price

Actors	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
Farmers	0.3435	0	23.64	45.53	4.94
Rural buyers	0	24.74	35.67	Infinity	24.74
Wholesalers	0	16.58	38.44	Infinity	16.58
Retailers	1.1106	0	62.21	16.44	40.95
Constraints Activities	Final Value	Shadow Price	Constraints R.H. Side	Allowable Increase	Allowable Decrease
Cost of Sugarcane ₦/kg	150.45	0	150	0.45	Infinity
Cost of Transport	2	4.54	2	4.02	0.04
Labour cost	4.15	0	4	0.15	1E+30
Storage cost	2.1	32.44	2.1	0.48	0.0076
Loading and Offloading	1.68	0	1.56	0.12	1E+30
Miscellaneous	3.13	0	2.89	0.24	1E+30
Sales of tools	5.28	0	2.93	2.35	1E+30
Depreciation	1.08	0	1.03	0.05	1E+30

Source: Cost and Return Sensitive Report 2023

CONCLUSION AND RECOMMENDATIONS

The study concluded that sugarcane marketing is profitable in north central Nigeria. However, the income inequality can creates a competitive environment among marketers to strive to maximize their profits and increased economic efficiency within the market. It was suggested that the marketers can increase their profit by reducing the marketing cost particularly the cost of transportation and storage. The imperfect markets offer advantages for higher profits for sugarcane business with market power, and flexibility in pricing strategies and encourage resource allocation based on consumer preferences.

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Leveraging Precision Agriculture for Sustainable Food Security in Nigeria

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ABSTRACT

This article reviewed opportunities and challenges of emerging technologies with precision agriculture to address challenges of food security amid the growing population in Nigeria. Providing sufficient, safe and nutritious food to all people is one of the major global concerns historically and in the twenty-first century. Food security is usually framed in four dimensions, food availability, access to food, food use/utilization and food stability. The objectives of precision farming as reviewed by this study are to; optimize resource use, enhance crop yields, improve sustainability, and reduce environmental impact and are attainable. Precision farming harnesses data, technology, and innovation to transform these objectives into reality. Precision farming is a modern management strategy that employs the details of site-specific nutrient management, remote sensing, global information system, global positioning system, and variable rate application to precisely manage the farm. It was researched that they are installed on tractors and other field equipment to check or enhance equipment operations. Limitations identified were high costs of some of the technologies, other key barriers include the lack of digital infrastructure like Internet and electricity, lack of awareness and digital skills among farmers, and societal barriers like gender and cultural practices. Also, lack of digital skills and literacy among smallholder farmers remains a major barrier to leveraging the potential of digital technologies. Agriculturists are therefore encouraged to adopt precision farming to increase production efficiency, reduce cost of production/ waste and improve the quality of farm produce.

INTRODUCTION

World agriculture needs to undergo a major transformation to meet the future demands of a growing population. Over the years there have been issues surrounding food production. Global changes in population, economy, and climate continue to impose grand challenges on agriculture By 2050, the food industry will have to face the daunting challenge of feeding about 10 billion people by almost sustainably doubling its food supply (UNDP, 2021). Providing sufficient, safe and nutritious food to all people is one of the major global concerns historically and in the twenty-first century. Food security is usually framed in four dimensions food availability, access to food, food use/utilization and food stability (FAO, 2016). These dimensions build the overall framework of the definition established by the Food and Agriculture Organization of the United Nations (FAO 2016): “Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life” Across all countries, people living in rural areas are the most exposed to food insecurity, owing to limited access to food and financial resources (FAO, 2016). Among them, 50 percent are smallholder farmers, producing on marginal lands that are particularly sensitive to the adverse effects of weather extremes, such as droughts or floods (UNCTAD, 2017).

Recent developments in digital technologies and big data combined with precision agricultural strategies can enable farmers to better understand the agronomics of crop production and to vary their management practices in response to site-specific growing conditions. This can increase the efficiency of input use and reduce agricultural pollution (Finger *et al*. 2019). Gene editing provides the promise of creating crop varieties that are more robust to climatic conditions, pests, weeds, and nutrient deficiency and the potential to enhance resource use efficiency in agricultural production (Sedeek *et al*. 2019). Recent improvements in nitrate uptake, transport, and use made through gene editing demonstrate the potential of this technology to reduce nitrogen losses (Fan *et al*. 2017, Kant 2018). Precision agriculture technologies are transforming the face of modern farming. Digital advancements such as wireless communication, data analytics, and data-driven genome editing, are rapidly being applied in agriculture as they provide more accuracy in decision making and practice. Being able to accurately decrease fertilizer, herbicide or seed rates in areas where it will not be economical to utilize is one of the key benefits of precision agriculture. Increasing yields because of applying agronomic principles at a high resolution, while reducing costs increases overall profitability. Satellite and Global Positioning System (GPS) technologies, sensors, smart irrigation, drones, and automation, to list a few, provide the means for precision agriculture, which further aids in effective resource utilization.

Two key problems of food security have been identified from the 2016 agriculture promotion policy which are: the inability to meet domestic food requirements and the inability to export at quality levels required for market success (FMARD, 2023). The inability to meet the domestic food requirement is largely attributed to inefficient farming models and lack of inputs such as fertilizers, irrigation crop protection and necessary support from the agricultural communities. On the other hand, the poor knowledge of target markets and inefficient system for enforcing the food quality to meet international standards are the limiting factors to exportation and successful market. Malnourished people are less productive, hungry children get no or little education, and become less capable adults even if hunger is overcome. Even short-term food insecurity has a long-term lasting impact on growth potential for the economy. The 11th edition of the Global

Food Security Index (GFSI) published in 2023, showed that Nigeria ranked 107th (scoring 42.0 points) out of 113th countries globally in the food security index. This suggests that 12.9 per cent of the global population in extreme poverty was found in Nigeria as of 2022. Precision agriculture will enhance the sustainable development goal, SDG aims to "End hunger, achieve food security and improved nutrition and promote sustainable agriculture". Intrinsically related to society, economy, and the environment, is key to the success for food security (FAO 2016). Although poor countries tend to show greater reliance on farming activities, food production and consumption is fundamental to any economy and permeates every society. The eradication of hunger requires SDG targets and indicators aligned with the four pillars of food security: availability (having available sufficient quantities of food, whose continued production also depends on a healthy environment), access (having the economic and physical means to obtain a nutritious diet), utilization (having adequate dietary intake and the ability to absorb and use nutrients in the body), and stability (ensuring the other three pillars on a consistent basis) (FAO, 2016).

These problems can be addressed by shifting from manual driven agricultural system to a technology and data driven or smart agricultural models. This involves application of precision and smart agriculture for irrigation, water detection, soil analysis, field monitoring for pest control, tracking and monitoring of farm animals, monitoring of farm products during transportation, storage, and other farm operations. Precision agriculture (PA) can be referred to as the gathering of information dealing with spatial and temporal variation within an agricultural field and then using that information to manage inputs and farm practices efficiently. It has the potential to revolutionize agriculture and contribute to increased productivity and sustainable farming practices.

The Role of Precision in Modern Agriculture

The use of modern technology in agriculture can ensure that farmers grow large quantities of food in the shortest possible time. GPS technology has been used in the development of self-driving sprayers and tractors that do not require a driver (UNDP, 2021). These vehicles can perform tasks like planting, spraying, and harvesting with minimal human intervention. Precision agriculture reduces the need for agricultural inputs like water, fertilizers, and pesticides, thereby reducing costs and the environmental footprint of agricultural production. The use of technology also cuts down the need for physical labour and improves productivity, ultimately enhancing the profitability of farming as a source of livelihood. Digital technologies are making precision agriculture solutions increasingly affordable and accessible to even smallholder farmers in developing countries (Corallo *et al*, 2020). The adoption of these technologies is also driven by the growing mobile phone and Internet penetration and the falling costs of data worldwide. The mobile phone is perhaps the most transformative technology enabling precision agriculture for smallholder farmers. Examples of precision agriculture technologies include GPS and mapping systems, sensors, remote sensing technologies, satellite imagery, variable rate application equipment, autonomous or vehicles, and drones. Also automation technologies, such as robotics and Artificial Intelligence (AI), can improve efficiency and reduce labour costs in agro-food processing (UNDP,2019). For instance, robots can harvest crops, reducing the need for manual labour and increasing productivity (Lezoche *et al*., 2020).

Goals of Precision Agriculture in Food Production

Mobile phones enable two-way communication between farmers and experts, real-time monitoring, and the digitization and easy collection of field data. Smartphones with cameras, GPS, various sensors, and a processor offer additional capabilities. Cost-effective and scalable mobile phone-based farming advisory services are already helping millions of farmers worldwide, overcome the challenges of conventional agricultural extension. Through mobile phones, farmers can receive customised and localised advice on what, when, and how to grow, as well as alerts on weather, pests, and diseases. Remote sensing using satellites is also supporting precision agriculture (UNDP, 2019). This is made possible through the increasing availability of high-resolution imagery from satellites. Various onsite sensors can also be used to collect accurate farm-level data (e.g., soil moisture and pH, temperature, humidity) to help farmers make decisions related to sowing, irrigation, fertiliser application, and harvesting. This is enabled by advances in wireless networking technologies like Low-Power Wide Area Networks (LPWAN) and cloud computing (Lezoche *et al*., 2020. Sensors are being used to track food products, manage inventory, and reduce waste, leading to a more efficient and sustainable supply chain. Sensors can also help you track and trace your food products throughout the supply chain, ensuring traceability and accountability. Some examples of sensor technology that can improve your food quality are infrared, hyperspectral, and biosensors. Technologies can help reconcile the necessity for sustainable and profitable food production. The challenge is to identify what technologies work best in specific circumstances, and define and provide the right incentive framework, to facilitate the achievement of sustainability goals in ways that enhance global welfare, in accordance with policy principles agreed upon by United Nations Development Programme, 2012.

Reconciling food production and environmental goals can sometimes be achieved through the adoption of appropriate technologies. Sometimes those goals can be reconciled simply by changing the level, type and location of agricultural production. Reconciling those goals, however, also means that the rights and responsibilities of farmers regarding the adoption of technologies and practices need to be clearly defined and applied (taking into account the current distribution of property rights), and thus the situations under which they are entitled to remuneration (provider gets) or obliged to pay (polluter pays). The attribution of property rights has important implications for the distribution of income, wealth and equity. Technological change has been the basis for increasing agricultural productivity and promoting agricultural development. Research affects the productivity of farming systems by generating new technologies that, if appropriate to farmers' circumstances, will be rapidly adopted. Historically, researchers and extension workers have been primarily responsible for identifying and injecting economic and environmental factors into the process of developing and introducing an agricultural innovation (Devereux *et al*., 2020, Corallo *et al* .,2020, Adelaja and George, 2019). This is typically characterised as a top-down process, whereby researchers develop the innovation, extension workers promote its use, and farmers either adopt or reject the innovation based on the features important to them.

Benefits of Precision Agriculture

Precision agriculture is based on the ability to identify inter and intra-field variability and to use this information for more targeted crop management (Adelaja and George, 2019). By using resources more efficiently, precision agriculture can make agriculture more productive and sustainable. These precision agriculture sensors are used to determine the variety, distance, and height of any position within the required area (Sedeek *et al* ., 2019). They utilize the help of GPS satellites for this purpose. They are installed on tractors and other field equipment to check equipment operations as used thus:

i. Technologies that precisely target pests and diseases.

The need for medicines and pest control agents in agriculture is not likely to disappear any time soon, however, technological advances in the science of pest control are expected to continue to produce chemical control agents that over time are at least as effective in controlling pests as the ones they replace, but which are also less toxic, less persistent and less mobile through the soil. The greater application of monitoring and knowledge-based systems, aided by reductions in the costs of electronic sensors and computers, should also enable farmers to be more economical in their use of pest control agents, especially insecticides: applying them only when and where necessary, rather than according to predetermined dosages and schedules.

ii. Technologies that administer nutrients more efficiently

Farmers have traditionally relied on two main practices to supply nutrients to root zones: manuring and burning. Inorganic fertilisers allowed the separation of crop production from animal husbandry, restored fertility to depleted soils, and contributed to the development of livestock production based on grain and other feed ingredients. Research into the specific needs of particular crop-soil combinations and livestock has led over the years to more scientifically formulated fertilisers and feeds (Lezoche *et al*, 2020). Wider application of technologies that administer fertilisers only at the times and in the amounts needed can be expected to increase crop yields further while reducing the leaching and runoff of nutrients.

iii. Technologies that administer water more efficiently.

Many of the technologies still used for irrigating crops are as old as civilisation itself. The problem is that conveying water through open channels and furrows is wasteful: much of the water evaporates before it reaches the root zone. In Nigeria, much of the water used in agriculture is carried to fields by pipes; but technical efficiency could still be improved through greater application of technologies, like precision fertilisation, combine more accurate measurement of actual crop needs with means to deliver the water more accurately and in more precise dosages.

iv. Technologies that reduce wastage following harvesting.

The demand for primary agricultural commodities is a derived demand, which is determined in part by wastage between producer and final consumer. Technologies used in Organisation for Economic Cooperation and Development (OECD) countries to harvest, transport, store, process and distribute farm commodities are already highly efficient, and result in much lower levels of wastage than in countries where the requisite capital and infrastructure are in much shorter supply (Ortiz *et al*, 2019). Virtually all parts of most crops and animals are recovered for some commercial use only for feed, fertiliser or energy. Some further reduction in post-harvest losses is achievable, but the most wastage (in proportion to the quantity purchased) takes place at the point of final consumption.

v. Technologies that disseminate knowledge.

Historically farmers relied on their own experience and that of their neighbours with regard to adopting "good farming practices" (Kant, 2018). Advice and information from publicly funded agencies and agri-food industries are increasingly focused on environmental effects. The Internet provides further developments in the dissemination of information on sustainable technologies. More sophisticated medicines to some extent took pressure off from natural resistance. However, as consumers in OECD countries started demanding products that use fewer or none of these agents, a renewed stress on developing natural resistance can be expected.

Limitations of Precision Agriculture

The adoption of precision agriculture by farmers in developing countries is still at a nascent stage and is limited by several factors. High costs of some of the technology, other key barriers include the lack of digital infrastructure like Internet and electricity, lack of awareness and education, lack of data management and analytical skills among farmers, and societal barriers like gender (Kant , 2018). Also, the lack of digital skills and literacy among smallholder farmers remains a major barrier to leveraging the potential of digital technologies.

Solution

Overcoming these challenges requires cross-sector collaboration among the public and private sectors, civil society, and the academia. Solutions should be user-centred and designed considering the local context such as language, social and political barriers and inclusion challenges. An open approach (e.g., open source, open standards) to designing digital solutions will increase collaboration among stakeholders, ensure interoperability between solutions, and prevent duplication of efforts (Miao and Popp, 2014). The availability of digital infrastructure is a major bottleneck in scaling precision agriculture solutions, particularly in rural and remote areas. Public-private partnerships and technological innovation will play an important role in making available at least basic Internet coverage for all farmers.

Enabling policies addressing issues of data ownership and management, privacy and cybersecurity are essential for spurring innovation in the agritech sector and scaling the adoption of digital solutions. The public and private sectors can partner with civil society organisations (CSOs) and leverage their on-ground presence (e.g., agricultural extension workers) for delivering hands-on pieces of training and building the digital capacities of farmers.

CONCLUSION AND RECOMMENDATION

The precision agriculture relies upon specialized equipment, software and IT services. This includes accessing real-time data about the conditions of the crops, soil and ambient air, along with other relevant information such as hyperlocal weather predictions, labour costs and equipment availability. Agriculturists are encouraged to practice precision farming to increase production efficiency, reduce cost of production and improve the quality of farm produce to achieve food security. Therefore this research recommends that Government and other stakeholders should create more awareness about precision farming, provide specialized training and equipment, software and IT services at affordable prices.

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Arable Crop Farmers' Perception of Rising Food Prices in Bayelsa State, Nigeria

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KEYWORDS

Arable crop farmers,
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ABSTRACT

The study examined arable crop farmers' perception of rising food prices in Bayelsa State. The objectives were factors causing high cost of food prices, effect of food price hike and farmers' perception of rising food prices in the study area. Multi-stage random sampling technique was used to select 110 respondents from 11 communities. Data were collected using structured questionnaire. The objectives were achieved using frequency, percentages, mean and analysis of variance (ANOVA). The hypotheses were tested at 5% level of significance. Findings showed that transportation cost ($\bar{x}$ = 4.68), high cost of inputs ($\bar{x}$ = 4.36), climate change ($\bar{x}$ = 4.35), reduction in currency value ($\bar{x}$ = 4.24) and insufficient storage facilities ($\bar{x}$ = 3.93) were the factors causing high cost of food prices in the study area. The result also revealed that food insecurity ($\bar{x}$ = 4.25), increased debt ($\bar{x}$ = 4.11), hunger and malnutrition ($\bar{x}$ = 4.06) and reduced profit ($\bar{x}$ = 3.45) were the effect of food price hike on the living conditions of arable crop farm households. Majority of the respondents had a very negative perception ($\bar{x}$ = 4.44) of rising food prices. It was concluded that majority of the respondents had a very negative perception of rising food prices. Hence, the study recommends that government should provide adequate infrastructure such as good roads in order to reduce the high transportation costs that constituted a major cause of high food prices in the study area.

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INTRODUCTION

Nigeria has experienced a historically unprecedented increase in food prices recently. Several factors are attributed to the recent price shock by arable crop farmers which combined effect has led to an upward price movement (Food and Agriculture Organisation (FAO, 2019). Several studies have highlighted the negative impact of food price hike on households such as reduced food access and consumption, increased food insecurity, and reduced purchasing power (Nkegbe, Kuunibe and Abdul-Rahim, 2020; Ayinde, Otekunrin, Akinbode and Otekunrin 2020; Chen, Bowen and Nelson, 2019).

The cost of transporting the materials and commodities from the point of purchase to the place of business has increased; the increase in prices has made the patronage of food to dwindle. Increase in the price of fuel has made transport operators all over Nigeria to increase the cost of transporting goods and passengers in order to meet up with their operational and maintenance cost (Abimbola, 2022; Bolaji, 2022). This leads to poor distribution of food items all over the country; thus, compelling food vendors to increase the prices of available food items.

Moreover, most of the roads connecting rural to urban or rural to rural areas are in poor conditions. Farmers and food item vendors find it very difficult to get their goods to the markets and other destinations. For instance, almost all major roads in the South-East, South-South and Southwest of Nigeria are in very poor conditions. Food vendors find it difficult to convey their goods from the Northern to the Southern part of the country. This has discouraged the smooth movement and distribution of food items to places where their demand is high, and thus has led to limited supply of food and therefore a corresponding increase in prices.

Price fluctuations are not new in the global and local food markets. In 2015 and 2016, there was an upsurge of food prices and what distinguished it from the upsurge of 2003 and 2004, and 2007 and 2008 was that the hike in prices was not only for a selected crops but nearly all major food including livestock feed commodities (World Food Program -WFP, 2017). Several factors are attributed to the recent price shocks whose combined effect has led to an upward price movement (FAO, 2017). Firstly, low stock levels to complement food consumption and secondly, oil prices and food prices are highly correlated (Ahmadi, Behmiri, and Manera 2020).

The negative consequences of the continuous rise in food prices in recent years have become increasingly important, particularly for the poor who spend a considerable portion of their income on food. Food price volatility has resulted in increased hunger and food insecurity among the poor, low investment, and the potential for social upheaval in most emerging countries (Ahmadi, Behmiri, and Manera 2020). Individual factors such as the exchange rate, loan rate, money supply, real GDP per capita, stocks, and oil price have all been blamed for the sudden and substantial spikes in food prices. Studies have found a link between these individual elements and variations in food prices over the last few years (Ahmadi, 2015).

In Nigeria, arable farming is the dominant agricultural practice in rural areas, and it is the major source of livelihood for rural households in Bayelsa State. However, food price hike may limit the production capacity of arable farming households, leading to decreased income and poverty (Omobowale, Ogunniyi and Akintola, 2020). Furthermore, studies have also shown that food price hike affects agricultural productivity and income. For example, (Obalola, Likita, Abaoba and Olabode, 2020) find that high food prices reduce farmers' profitability and may lead to a decrease in their production. Similarly, another study observed that high food prices negatively affect the welfare of farming households and their ability to invest in their farms (Omobowale *et al*., 2020). These studies suggest that food price hike may have adverse effects on the arable farming household in Bayelsa State. Thus, there is a need to investigate the effect of food price hike on arable farming households in Bayelsa State. Against these backdrops, this study seeks to investigate the perception of arable crop farmers on the rising prices of food. The specific objectives are to:

i. ascertain the perception of rising food prices by arable farmers in the study area;
ii. ascertain the factors causing high cost of food prices in the study area
iii. examine the effect of food price hike on the living condition of arable farming household in Bayelsa State

This study was be guided by the following null hypotheses

HO_1. There is no significant difference in the causes of the rising food prices by arable farmers

HO_2. There is no significant effect of food price hike on the living conditions of arable crop farming household in the study area.

MATERIALS AND METHODS

Study Area

The study was carried out in Bayelsa State. Bayelsa is geographically located approximately within Latitude $4°15^1$ South and $5°23^1$ North, and Longitude 5°West and 6°45 East (NPC, 2006). . It is bordered by Delta State to the West, Rivers State to the East, the Atlantic Ocean to the South and both Rivers and Delta States to the North. The State is made up of eight Local Government Areas, namely: Brass, Ekeremor, Kolokuma/Opokuma, Nembe, Ogbia, Sagbama, Southern Ijaw and Yenagoa. The major occupation of the people is farming and fishing, Olaniyi, Nwokocha and Anyaegbunam ,(2020).

The main language is Izon, with other dialects such as Nembe, Ogbia and Epie/Atissa. ~~B~~ayelsa State has one of the largest crude oil and natural gas deposits in Nigeria. Bayelsa is often described as the cradle of Ijaw culture and tradition because of its rich culture and tradition that dates back to so many centuries.

Food crops grown in the state include yam, cocoyam, banana, pineapple and plantain. Cash crops grown in the state include coconut, pears, oil palm and raffia palm. The potentials for the development of these crops to feed local industries are very good. Technologies are being developed to reclaim land from mangrove swamps in order to cultivate food, especially lowland rice and the cash crops identified above on a large, commercial scale.

Method of Sampling Technique

The study adopted a multi stage random sampling technique. The first stage involved the random selection of three Local Government Areas (LGAs) out of the eight LGAs in the State. These LGAs were Sagbama, Yenagoa and Southern Ijaw LGA. The second stage involved the random selection of five communities from each of the three LGAs making a total of 15 communities. Thereafter, eight crop farmers were randomly selected from each of the 15 communities making a total of 120 respondents for the study.

Method of Data Analysis

Data generated from this study was analysed by the use of descriptive tools such as percentage, and mean rating. ANOVA was employed to test the hypotheses. The objectives were achieved using five points' likert-type scale

RESULTS AND DISCUSSIONS

Factors Causing High Cost of Food Prices

The result in Table 1 reveals that transportation cost ($\bar{x}$ = 4.68), high cost of inputs ($\bar{x}$ = 4.36), climate change ($\bar{x}$ = 4.35), reduction in currency value ($\bar{x}$ = 4.24) and insufficient storage facilities ($\bar{x}$ = 3.93) were the factors causing high cost of food prices in the study area. These mean ratings were above the bench mark mean score of 3.00. This implies that transportation cost, high cost of inputs, climate change, reduced profit, reduction in currency value and insufficient storage facilities were the factors causing high cost of food prices in the study area. High transportation costs of agricultural commodities will likely lead to high cost of food prices which in turn leads to less profit for farm households due to the high cost of the transportation of agricultural produce. High costs of farm inputs will also lead to the high cost of crop production and subsequently, high food prices. Agbarevo and Ukagha (2018) noted that rural farmers in Nigeria usually find it difficult to purchase farm inputs and obtain the required quantities at the right time which grossly affect their productivity and income, this is in consonance with this result which stated that cost of inputs is one of the causes of hike in food prices

Table 1: Factors causing high cost of food prices

S/N	Factors	SA	A	U	D	SD	Mean	Remarks
1	Transportation cost	83	20	6	1	-	4.68	Agree
2	High cost of inputs	59	39	5	7	-	4.36	Agree
3	Insufficient storage facilities	47	28	17	16	2	3.93	Agree
4	Climate change	66	24	13	7	-	4.35	Agree
5	Reduction in currency value	57	28	21	2	2	4.24	Agree
	Grand mean score						4.31	Agree

Source: Field survey data, 2023

Note: SA = Strongly agree; A = Agree; U = Undecided; D = Disagree; SD = Strongly disagree

Effect of Food Price Hike on the Living Conditions of Arable Crop Farm Households

The result in Table 2 reveals that food insecurity ($\bar{x}$ = 4.25), increased debt ($\bar{x}$ = 4.11), hunger and malnutrition ($\bar{x}$ = 4.06) and reduced profit ($\bar{x}$ = 3.45) were the effect of food price hike on the living conditions of arable crop farm households in the study area. These mean ratings were above the bench mark mean score of 3.00. This implies that food insecurity, increased debt, hunger and malnutrition and reduced profit were the negative effect of food price hike on the living conditions of arable crop farm households in the study area. This is in conformity with those of Nkegbe, Kuunibe and Abdul-Rahim (2020) and Omobowale, Ogunniyi and Akintola (2020) who reported that reduced food access and consumption, increased food insecurity, and reduced purchasing power were the negative impact of food price hike on households.

Table 2: Effect of food price hike on the living conditions of arable crop farm households

S/N	Effect of food price hike	SA	A	U	D	SD	Mean	Remarks
1	Increased debt	55	32	4	18	1	4.11	Agree
2	Reduced profit	34	30	9	25	12	3.45	Agree
3	Reduced crop production	15	26	24	25	20	2.92	Disagree
4	Food insecurity	54	38	10	8	-	4.25	Agree
5	Hunger and malnutrition	53	33	9	8	7	4.06	Agree
	Grand mean score						3.76	Agree

Source: Field survey data, 2023

Note: SA = strongly agree; A = agree; U = undecided; D = Disagree; SD = strongly disagree

Perception of Rising Food Prices by the Respondents

The result in Table 3 indicates that the majority of the respondents had a very negative perception (x = 4.44) of rising food prices in the study area. This is because the mean response was greater than the bench mark mean score of 3.00. This is expected as rising food prices have huge implications for the livelihood of arable crop farm households. The majority of rural farm households who still operate on subsistent basis would aside coping with low food production have to deal with the negative effects of rising food prices on their households. Rising food prices could also reduce farmers' profitability and may lead to a decrease in their production.

Table 3: Perception of rising food prices by the respondents in the study area

S/N	Perception	VSE	A	U	D	SD	Mean	Remarks
1	Very positive	6	4	7	36	57	1.78	Disagree
2	Positive	4	7	11	47	41	2.75	Disagree
3	Very negative	72	23	8	5	2	4.44	Agree
4	Negative	54	42	6	5	3	4.26	Agree
	Grand mean score						3.31	Agree

Source: Field survey data, 2023

Note:VGE =Very Great Extent (5); Great Extent = (4); U = Moderate Extent (3); D = Small Extent (2); NE = No Extent (1).

Result of hypothesis test 1

Test of significant difference in the effect of food price hike on the living conditions of arable crop farm households

The result of the Analysis of Variance (ANOVA) f-test used to test for significant difference in the effect of food price hike on the living conditions of arable crop farm households in the study area is presented in Table 4. The result in Table 4 shows that the calculated Anova f-value of 2.08 was significantly higher than the tabulated Anova f-value of 1.97 at $P \leq 0.05$, suggesting that there was significant difference in the effect of food price hike on the living conditions of arable crop farm households across the selected communities in the study area. This implies that the hike of food prices is significantly affecting living conditions of arable crop farm households across the sampled communities in the study area. This also has an impact on the cost of house rents, cost of transportation and general cost of living.

Table 4: Analysis of variance results showing difference in the effect of food price hike on the living conditions of arable crop farm households across the selected communities

Variable		Sum of Squares	Df	Mean Square	F-cal	F-tab
Effect of food price hike	Between Groups	8.473	9	.941	2.08	1.97
	Within Groups	55.135	100	.551		
	Total	63.608	109			

Source: Field survey data, 2023

Ho_1: accepted at 5% level

Result of hypothesis test 2

Test of significant difference in the perception of arable crop farmers on the causes of rising food prices

The result of the Analysis of Variance (ANOVA) f-test used to test for significant difference in the perception of arable crop farm households on the causes of rising food prices in the study area is presented in Table 5. The result in Table 5 shows that the calculated Anova f-value was lower than the tabulated Anova f-value of 1.97 at ($P \leq 0.05$), for high cost of input, cost of transportation and currency devaluation. Suggesting that there was no significant difference in the causes of rising food prices by arable crop farm households across the selected communities in the study area. This implies that the causes of rising food prices by arable crop farm households did not differ significantly across the sampled communities in the study area.

Table 5: Analysis of variance results showing difference in the perception of rising food prices by arable crop farm households across the selected communities in the study area

Variable		Sum of Squares	Df	Mean Square	F-cal	F-tab
	Between Groups	2.119	9	.235	1.817	1.97
High cost of inputs	Within Groups	12.955	100	.130		
Cost of transportation	Between Groups	6.846	9		1.689	1.97
	Within Groups	16.222	100			
Devaluation of currency	Between Groups	4.134	9		1.628	1.97
	Within Groups	19.202	100			

Source: Field survey data, 2023

Ho_2: accepted at 5% level

CONCLUSION

The study concluded that arable crop farmers perceived that the rising prices of food stuffs is caused by high cost of inputs (seeds, fertilizers, agro chemicals, land and labour etc), general rise in the cost of transportation due to the removal of fuel subsidy and the low exchange value of the Nigerian Naira. Arable farmers incur high cost of production and as a result there is a reduction in production activities. The high demand for food amidst low production explains the hike in food prices.

RECOMMENDATIONS

i. The study recommends that government should provide adequate infrastructure such as good roads and also an efficient transport system in order to reduce the high transportation costs that constituted a major cause of high food prices in the study area.
ii. Government and other stakeholders should provide subsidies to farmers to reduce the cost of inputs.
iii. A stable exchange rate should be maintained to reduce the general rise in prices of commodities.

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A Review of the Awareness of Climate Smart Agricultural Practices by Potato Farmers in Ayamelum Local Government, Anambra State

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KEYWORDS

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ABSTRACT

The study reviewed the awareness of climate smart agricultural practices by potato farmers in Ayamelum local government, Anambra state. The study looks at the, current level of climate smart practices, demography and challenges of farmers in these particular areas with a view to providing critical information on climate smart awareness on sustainable farming development in the study area. Data were collected from 50 respondents who were selected through multi-stage procedure. In the first stage one (1) Local government area (Ayamelum LGA) was purposively selected from the 6 Local government areas that make up Anambra agricultural zone. In the second stage two (2) communities from the chosen local government area was randomly selected. Stage three twenty five (25) potato farmers from each of the selected communities was randomly selected and this gave a total of 50 respondents. The data were analysed using descriptive statistics and a four scale likert type. The survey reveals a balanced gender distribution (46% male, 54% female) and a predominantly young farming population, with the majority aged 31 to 40 years. The level of education varies and emphasises the need to develop targeted programmes in order to close knowledge gaps. Challenges such as reduced access to information, financial constraints and lack of infrastructure are faced by farmers. Targeted education programmes, financial support initiatives, enhanced information dissemination channels are recommended in order to deal with these issues. There is a widespread climate smart agricultural practice, in particular improved water use and management, integrated pest management, use of quality seeds and planting materials and Biodiversity management. These findings have laid the foundations for information and policy adjustments, as well as a community driven initiative aimed at raising local farmers' resilience and wealth.

INTRODUCTION

Climate change is a worldwide event that poses one of the most serious risks mankind has ever faced, generating floods and droughts and hurting farmers' livelihoods by influencing ecosystems, water supplies, food security, settlements, and human health (Food and Agriculture Organization of the United Nations, 2016). Climate and agriculture are strongly interrelated universal processes and thus variations in climate influence agricultural activities. Improving the accumulations of carbon dioxide (CO2) will have a lot of prospective effects on plants and may also have a lot of indirect threats on herbivores and all other food chain members. Climate conditions such as influential rainstorms, high wind pressures, and high temperatures have much influence on agricultural activities (JAT *et al*., 2019). This is not least in developing countries where unsustainable land management, land degradation and greenhouse gas fluxes in terrestrial ecosystems have all been linked to climate change; resulting in decreased agricultural production which pose a threat to food security (IPCC, 2019). Similarly, climate change, reflected in more irregular and inconsistent rainfall patterns, severe floods, frequent droughts, increased insect and disease rates and irregular agricultural planting seasons have resulted in higher production costs Van Dijk *et al*., (2018). which have adversely affected crop and livestock output Van Dijk *et al*., (2018).

Potato cultivation experienced a number of difficulties due to the environment, pests, and illnesses before the advent of climate-smart agriculture. Traditional agricultural techniques frequently relied on conventional procedures that weren't always long-term sustainable. In particular, climate change caused challenges because variable weather patterns reduced agriculture output.

Climate-smart agriculture is an approach that aims to enhance food security, adaptation, and mitigation in the face of climate change. It involves the use of innovative techniques and technologies to make agriculture more resilient to climate variations. For potato production, climate-smart practices may include the use of drought-resistant varieties, improved irrigation systems, soil conservation, and integrated pest management.

This climate-smart approach has significantly impacted potato production by making it more sustainable and adaptive. It allows farmers to be better prepared for changing climatic conditions, leading to improved yields and reduced environmental impact.

In Ayamelum local government agriculture is the major occupation of its inhabitants. The awareness of climate problems and the potential benefits of taking action is an important determinant of adoption of climate change mitigating measures. Archie *et al*, (2022) argued that farmer's awareness of change in climate attributes (temperature and precipitation) is important to adaptation and decision making. Innovation adoption is the key to increasing farm productivity. There is, therefore the need to examine the review of the awareness of climate smart agricultural practices on potatoes farmers in Ayamelum L.G.A Anambra State, Nigeria.

Concept of climate smart agriculture

Climate-smart agriculture (CSA) is a comprehensive approach that addresses the pressing challenges of food security and agricultural sustainability in the face of climate change. It encompasses a range of practices and strategies aimed at enhancing productivity, building resilience, and reducing greenhouse gas emissions in agricultural systems. The various approaches of climate smart agriculture:

1. Sustainable Intensification:

Sustainable intensification is a key principle of CSA that focuses on increasing agricultural productivity without compromising the environment. By optimizing resource use, such as water, fertilizers, and energy, farmers can produce higher yields while minimizing negative impacts on natural ecosystems. This approach was highlighted by the Food and Agriculture Organization (FAO) in their report on "Climate-Smart Agriculture Sourcebook" (FAO, 2013), which emphasizes the importance of integrating sustainable practices in farming systems.

2. Adaptation:

Climate change poses significant challenges to agriculture, including increased frequency and intensity of extreme weather events, shifts in precipitation patterns, and rising temperatures. CSA promotes adaptation strategies to help farmers cope with these impacts and maintain agricultural productivity. A study by Anarah *et al*. (2019) discusses various adaptation options for agriculture in the context of climate change, such as the use of drought-resistant crop varieties and improved water management techniques.

3. Mitigation:

Agriculture is a significant contributor to greenhouse gas emissions, mainly through methane from livestock and nitrous oxide from fertilizer use. CSA seeks to mitigate these emissions by adopting practices that reduce the carbon footprint of agriculture. Thornton *et al*. (2015) highlight the role of climate-smart practices in reducing emissions while ensuring food security.

4. Resilience:

Building resilience in agricultural systems is crucial to withstand climate-related shocks and stresses. Climate-smart agriculture emphasizes the integration of adaptive and risk management strategies to enhance the resilience of farming communities. The study by Thornton *et al*. (2017) discusses the importance of mixed crop-livestock systems as a means to enhance resilience in agriculture.

5. Social Equity:

Ensuring that CSA benefits smallholder farmers, women, and marginalized communities is a fundamental aspect of this approach. Social equity in CSA is about empowering vulnerable groups to participate in decision-making processes and gain access to resources and knowledge. FAO's Climate-Smart Agriculture Sourcebook (2013) discusses the importance of social inclusion in implementing climate-smart practices.

6. Knowledge Transfer:

Effective knowledge transfer is critical for the successful awareness of climate-smart agricultural practices. Farmer extension programs, capacity building, and the sharing of best practices play a crucial role in disseminating knowledge about CSA. Anarah *et al*. (2019) discuss the significance of proper education on climate variability should be made available to farmers through environmental experts and extension agencies to curtail various effects of these vagaries of weather on production potentials.

Statement of problem

The awareness of climate-smart agricultural (CSA) practices by potato farmers in Ayamelum Local Government, Anambra State, Nigeria, is crucial for enhancing agricultural productivity, reducing climate change vulnerability, and ensuring sustainable food security. However, despite the potential benefits of CSA practices, their awareness rate among potato farmers in the study area is reviewed. The department of Agricultural economics and extension department over the years through the technical and research team organizes a yearly out reach on the farmers to sensitizes the communities on the issues of climate change, adaptation method and mitigation . This research aim to review the awareness of climate smart agricultural practices in Ayamelum local government area.

Objectives of the research;

i. assess the current level of awareness of climate smart agricultural practice;

ii. examine socio-economic factors influencing the awareness of climate smart agricultural practices and

iii. identify the barriers faced by potato farmers in Ayamelum Local government.

Sampling and sampling procedure

Purposive sampling methods were employed for the selection of the respondents from the major farming location in the local government of the selected study area. Purposive sampling is a valuable tool for researchers who are interested in understanding the experiences and perspectives of a particular group of people.

A multi stage selection procedure was used to select the respondent.

Stage one: In the selected agricultural zone, one (1) Local government area (Ayamelum LGA) was purposively selected from the 6 Local government areas that makes up Anambra agricultural zone

Stage two: two (2) communities from the chosen local government area were randomly selected.

Stage three: twenty five (25) potato farmers from each of the selected communities were randomly selected and this gave a total of 50 respondents that was serving as the sample size for this study.

Data collection

Primary data that was used for the study was collected with well validated open and close ended questionnaire and personal observation by the researcher.

Data analysis

The tools of analysis that was used in this study are; descriptive statistics such as the mean, frequency distribution and percentages.

The Likert scale which gives the average mean score from a four-point was used to analyse the constraints faced by Potato farmers.

Objective (1) and (2) were achieved using descriptive statistics such as mean, frequency, distribution and percentage. Objective (3) was achieved by using the Likert scale which gives the average mean score from a four-point scale which was used to analyse the constraints of potato farmers. A four-point Likert type of scale is specified as follows:

Strongly agree (SA) 4-point; Agree (A) 3-point; Disagree (D) 2-point and strongly disagree (SD) 1-point.

The mean response to each item will be interpreted using the concept of point. The numerical value of the scale points will be as follows:

- Strongly Disagree (SD) =1point
- Disagree (D) = 2points
- Agree (A) =3points
- Strongly Agree (SA) = 4points 4+3+2+1=2.5

Therefore, any constraint with a mean score greater than 2.5 is significant while the one less than 2.5 are not significant.

RESULTS AND DISCUSSION

Data in Table 1 revealed that use of animal manure is mostly used and aware off by respondent in the study area with 90% followed by inter cropping 80%, organic farming practiced 76% , crop rotation and Drought-resistant crop varieties 70% respectively. Use of crop- livestock integration shows 68%, Soil conservation techniques 60% and Weather forecasting 60%. These are level of awareness in the study area. The result shows the respondents are fully aware of climate smart agricultural practices in the area.

Table 1. Level of awareness of climate smart agriculture in the study area.

S/N	Level of awareness (CSA practices)	Frequency	%
1.	Drought-resistant crop varieties	35	70
2.	Rainwater harvesting	25	50
3.	Crop rotation	35	70
4.	Intercropping	40	80
5.	Soil conservation techniques	30	60
6.	Organic farming practice	38	76
7.	Irrigation	28	56
8.	Weather forecasting	30	60
9.	Use of animal manure	45	90
10.	Agro forestry	26	52
11.	Soil water conservation	31	62
12	Crop diversification	28	56
13	Crop-livestock integration	34	68

Source: Field survey, 2023. Multiple response**

Table 2 showed that 46% of respondents in the area are male and 54% are female. The majority of the farmers' age range from 31 to 40 years (40%), followed by those from 41 to 50 years (30%), those above 51 years (20%). The mean age of 25.00 implies that the farmers are young. On marital status, 40% of respondents are married while 28% are single. Their level of education showed that 52% attended secondary school, 24% attended primary school, and 16% obtained tertiary education while only 8% attended postgraduate studies. The household size of majority of respondents is 0 to 5 persons (56%), followed by those having 6 to 10 persons (28%) and those having 11 to 15 persons (16%) in their household. The mean household size of 5 implies that the respondents have no large family size. Those that have 6 to 11 years farming experience are 44%, those that are 11 to 15 years are 30% while those above 0-5 years are 16% with mean of 5.5.

Table .2 Demographic characteristics of the respondents in Ayamelum LGA.

Socioeconomic characteristics	Frequency (n = 50)	Percentage	Mean
Sex			
Male	23	46.00	
Female	27	54.00	
Age			
21-30yrs.	5	10.00	25.00
31-40yrs.	20	40.00	
41-50yrs.	15	30.00	
51 yrs.and above	10	20.00	
Marital status			
Single	14	28.00	
Married	20	40.00	
Divorced	6	12.00	
Widow/widower	10	20.00	
Level of education			
Primary	12	24.00	
Secondary	26	52.00	
Tertiary	8	16.00	
PGD	4	8.00	
Farming experience (yrs.)			
0-5	8	16.00	5.50
6-10	15	30.00	
11-15	22	44.00	
16 andabove	5	10.00	
Household size			
0-5	28	56.00	5
6-10	14	28.00	
11-15	8	16.00	

Source: Field Survey, 2023

Constraints faced by farmers in the study area.

Most constraints faced by farmers in Ayamelum L.G.A are shown in Table 3. A number of variables identified to be highly used by the respondents are ranked from the greatest to the least. Those with are Limited access to information ($\bar{X}$ = 4.90), Financial constraint ($\bar{X}$ = 4.72), Lack of infrastructure ($\bar{X}$ = 4.65), Limited access to credit ($\bar{X}$ = 4.37), Sticking traditional practices ($\bar{X}$ = 4.31) and the least Others ($\bar{X}$ = 1.80).

Table 3 constraints faced by potatoes farmers in Ayamelum L.G.A

S/N	Constraint	SD	A	D	SD	$\bar{X}$	Std.	Rank
1	Limited access to information	25.00	10.00	5.00	10.00	4.90	2.887	1st
2	Financial constraint	35.00	5.00	10.00	5.00	4.72	2.696	2nd
3	Lack of infrastructure	20.00	20.00	1.00	9.00	4.65	2.084	3rd
4	Limited access to credit	40.00	3.00	7.00	0.00	4.37	1.549	4th
5	Sticking traditional practices	31.00	5.00	9.00	5.00	4.31	0.837	5th
6	Pest and disease	20.00	10.00	10.00	20.00	4.26	0.564	6th
7	Market access	23.00	10.00	6.00	11.00	3.56	0.695	7th
8	Social and gender barrier	10.00	23.00	10.00	7.00	2.28	0.586	8th
9	Climate change	0.00	10.00	8.00	32.00	1.97	0.682	9th
10	Others	10.00	10.00	5.00	25.00	1.80	0.231	10th

Source: Field Survey, 2023

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATION

This chapter summarized the findings of the study. Conclusions and recommendations based on the findings made.

Summary of findings

Major findings of the study show that 46% of respondents in the area are male and 54% are female. The majority of the farmers' age range from 31 to 40 years (40%), followed by those from 41 to 50 years (30%), those above 51 years (20%). Animal manure is mostly used and aware off by respondent in the study area with 90% followed by inter cropping 80%, organic farming practiced 76% , crop rotation and Drought-resistant crop varieties 70% respectively. Use of crop- livestock integration shows 68%, Soil conservation techniques 60% and Weather forecasting 60% respectively. Result showed the level of awareness of the climate smart practice is high in the study area, and this is as result of the yearly outreach by the fourth year students and technical staff of the department of agricultural economics and extension in Ayamelum L.G.A

Conclusion

They presence of faculty of Agriculture in Ayamelum L.G.A has a significant effects on the populace and the community through the industrial training done by the student in the study area. The climate change awareness and climate smart agricultural practices awareness through the outreach, demonstration farm and rural development have help the potatoes farmers in the study area.

Recommendations

The following recommendations are made based on the findings of this study:

1. Addressing the limited access to information could involve creating and promoting effective channels for disseminating agricultural knowledge. This might include workshops, community meetings, or utilizing technology such as mobile apps for easy access to relevant information.
2. The community should have a synergy with the University for Collaboration.
3. Climate smart agricultural should be encourage through incentive by the government. Since financial constraints were identified as a significant challenge, efforts can be made to provide financial support and improve access to credit for farmers. This could involve collaborations with financial institutions, government agencies, or NGOs to create tailored financial solutions for the agricultural community.
4. Considering that a significant percentage attended only secondary or primary school, there is an opportunity for educational and training programs to enhance farmers' knowledge and skills. This could cover aspects such as sustainable farming practices, improved water management, and advanced agricultural techniques.
5. Given the evolving nature of agriculture and climate challenges, continuous research and innovation are crucial. Support for research initiatives and the development of new technologies tailored to the local context could enhance the resilience and productivity of farmers.

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Analysis of marketing margin and marketing efficiency of fresh coconut (*Cocos nucifera*) marketing in Onitsha North South LGA, Anambra State, Nigeria

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K E Y W O R D S

Channels,
Fresh coconut
Marketing conduct,
Marketing efficiency,
Net returns

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A B S T R A C T

The study examined analysis of marketing margin and marketing efficiency of fresh coconut marketing in Onitsha South LGA, Anambra State, Nigeria. The study specifically described socioeconomic characteristics of coconut marketers, marketing channels and volume of trade among the channels, net returns, marketing conduct and constraints associated with coconut marketing in the study area. Multistage sampling procedures involving purposive and random sampling methods were used to select respondents (marketers) for the study. Findings from socioeconomic characteristics showed that female 63.75% are more in coconut marketing. This implies that the enterprise is gender based in the study area. Findings on marketing channels and volume of trade shows that the fruits has three channel through which it reaches the consumer. The first stage is where producer/supplier sells to intermediate who sales to final consumer which recorded the highest volume of trade (43%) among the channels. Findings on net returns showed that net return per Naira invested was 1.77%. The implication of this is that for every one Naira invested in the enterprise, 1.77k was generated as profit. This implies that coconut marketing is profitable in the study area. Findings on marketing conduct shows that size of coconut (61.25%) was a criteria used as purchase strategies from suppliers. Findings on constraints showed that over stayed coconut is the major constraints. Marketing prices of certain food and fruits should be looked into by government and stakeholders and stakeholders should device a means to carry coconut to minimize wastage associated with transport e.t.c were recommended.

INTRODUCTION

Coconut is one of the most important and useful palms in the world, with Indonesia, Philippines and India respectively ranking as the Topmost producers of coconut in the world. It is fondly referred to as the “tree of life” for its important role in smallholders’ livelihoods as a direct source of cash income, nutrition, and materials Okoronji, Nwankwo and Emeghalu (2020). It adapts to many soil types and climates. It resists bad weather conditions and produce continuously from the age of 4 or 7 years to 60 years. Coconut farming is a gold mine because of its wild range of industrial application of most of the products. Coconut can be processed into various products that can be used industrially or as food. Coconut products are used by Pharmaceuticals, Cosmetics, Beverage and in the preparation of delicacies like chocolate, crepes, candy etc. Iheke and Osundu (2012) stated that the goal of marketing of any agricultural products is to ensure that consumers get satisfaction from the entire process of production as well as create benefits to the various participants in the marketing channel. Iheke and Osondu (2012) opined that, a sound and effective marketing system plays a great role in achieving economic growth and prosperous agriculture. They further stated that an efficient marketing system is the one in which the cost of marketing is minimized and wastage is eliminated and marketing is the critical link between farm production sector, the rural non-farm sector, industry and urban economy.However, despite the potential economic benefits of coconut farming and marketing, challenges abound in the marketing aspect of the coconut value chain. These challenges are diverse and multifaceted, ranging from inadequate marketing infrastructure, high transportation costs, price volatility, and limited access to markets, to name a few (Amusa, Kehinde andJegede. (2016) and Okon, Ekong, andIbok. (2018). These difficulties have led to sub optimal returns for coconut farmers and have hindered the sector's overall growth and contribution to the national economy.

MATERIALS AND METHODS

The study was was carried out in Onitsha South L.G.A, Ana^{0}mbra State, Nigeria. It has an estimated population of 561066 (NPC, 2006). It is located between latitudes 06^0,07^{1}12^{1}N and 06 ^{0} 9^{1}36^{1}N and longitude 06^0 45^{1}54^{1}E and 06^0 47^1 42^{1}E covering an area of 36.12Km^2. It is the largest urban city in Anambra State. There are numerous daily markets where agricultural produce are sold . The targeted population was fresh coconut marketers. Purposive and simple random sampling method were used to select 80 marketers namely Ogbo-Oroma market, Lafiaji market, Ose-nku market and Ochanja market due to high volume of trade from these markets. Twenty marketers (respondents) were selected using random sampling from the list of coconut marketers gotten from Local government ADP which form the sample frame. This gave a total of 80 marketers for the study which form the sample size.

Method of data analysis/collection

The objectives of the study were analyzed using descriptive statistics, net returns and relative importance index. Data used were collected through the Primary sources. Primary data were collected using structured questionnaire to the respondents from the list of coconut marketers that constituted the sampling frame for the study.

Population and sampling technique

The study population was made up of all the coconut marketers in Onitsha South LGA, Anambra State Nigeria. Multistage,purposive and simple random techniques were used to select four communities, four daily markets and 20 respondents (marketers) for the study.

Stage one : Four communities were purposive selected from the entire LGA (Woliwo, Fegge, Niger Street and Iweka Road)

Stage two: This involved purposive selection of one daily market with large number of consumers from each of the selected communities for the study (Lafiaji, Ogbo-oroma, Ose-nku, and Ochanja markets).

Stage three: This involved random selection of twenty marketers (respondents) from each of the markets selected earlier making it a total of 80 marketers for the study.

Net Returns

Marketing margin and marketing efficiency models were adopted from Mendoza (1995) as applied by Nkamigbo, Isibor, Obiekwe and Udemba (2023) and are specified as:

NR = TRS-TMC----------(1)

Where, NR= Net returns measured as the difference between the total revenue and the total cost of coconut marketing. TRS= Total Revenue sales which is obtained by calculating the total amount (₦) realized from the sales of coconut, TMC= Total marketing cost is the sum of the total cost incurred in marketing coconut. Marketing margin is one of the indicators usually identified with marketing efficiency, the formula is specified thus:

$$\boldsymbol{M_m = \frac{S_p - P_p}{S_p} \times \frac{100}{1} = (1)}$$

Where M_m= Marketing margin (₦), S_p= selling price (₦), P_p= Purchase price (₦).

Marketing efficiency describes the movement of goods from producer to consumers at lowest marketing cost consistent with the provision of the services that the consumers' desire and can afford specified as thus:

$$\text{M.E} = \frac{value\ added\ by\ marketing\ (Net\ Return)}{Total\ marketing\ (TMC)} \times \frac{100}{1} = (3)$$

For processors, cost and return analysis were used for profitability, thus NR=TRS-TMC

Constraints to coconut fruits marketing

The respondents were asked to rate the problems the face in coconut marketing from a list of problems complied by the researcher. The relative importance index was used in determining the degree of importance of the problem as follows: Very important =4, Important =3, moderately important =2, Not important = 1. The responses on constraints to coconut fruits marketing will be disaggregated as follows:

Where:

RII = ∑ W/A*N
RII = Relative importance index
W = Weighting given to each factor by the marketers (ranging from 1-4)
A = Is the highest weight
N = Is the total number of marketers.
To make inferential statement, the mean score will be compared with the critical mean, 2.5. If the calculated mean of a problem is greater than the standard critical value, then the problem is regarded as very serious.

RESULTS AND DISCUSSION

Socioeconomic Characteristics of coconut fruits marketers

Socioeconomic characteristics of coconut fruits marketers is presented in Table 1. The Table indicates that majority of the marketers are within the age limit of 40-49 (37.50%). This implies that the marketers are middle age and relatively young. The finding is in tandem with Nkamigbo, Isibor, Obiekwe and Udemba (2023) who reported that garden egg fruits marketers are relatively young and are able to handle the hustle of the marketing. The finding on gender reveals that female 51 (63.75%) are more in coconut marketing. This implies that the enterprise is gender based in the study area. This is in agreement with Nkamigbo, Chiekezie and Ozor (2019) who reported gender sensitive in tomato marketing in the study area. This varies with the report of Nkamigbo, Ugwumba and Okeke (2019) who reported male dominance in watermelon marketing at their study area. Findings from educational status revealed that majority of the marketers had one level of education or other thus making the study area a very vibrant economic hub center for business activity. The result of marital status revealed that majority of the marketers were single. This implies that most children hawk coconut both in the market and events centers. Some even sale coconut with dry bread fruits or coconut with palm kernel seed. This makes it a very movable fruits that children hawks around to make a living or help the parents. . From the result majority of the marketers kick started their enterprise with personal savings (52,50%) because a little amount of money can bring one into hawking or selling on table or combine it with other fruits. Many also sell coconut among fruits salad, while only few kick start their enterprise with help from friends and relative (27.50%). d. The result revealed a household size of 5-8 persons living and eating from same source had a percentage of (77.50%). This contradicts the report of Idris, Maurice and Ahmed (2018) who reported lesser household for onion marketing in their study area. Majority of the marketers (76.25%) belongs to their trade union (Isusu union) where they practice Isusu for their personal welfare and interest. This according to them serves as an umbrella, protection for their members and also as a welfare to carter for their own in case of any eventuality. Majority of the marketers do combine coconut fruits marketing with other enterprise (7o%) at all levels of marketing.. the marketing experience reveals that marketers are well experienced (50.83%) which is expected to enhance the efficiency with which the trading activities are performed.

Table 1: Socioeconomic characteristics of coconut fruits marketers

VARIABLES	FREQUENCY	PERCENTAGES
Age		
Less than 20	3	3.75
30-40	16	20.00
41-50	30	37.50
51-60	22	27.50
61 and above,	9	11.25
Total	80	100
Gender		
Female	51	63.75
Male	29	36.25
Total	80	100
Marital Status		
Single	39	48.75
Married	28	35.00
Widow/Divorced	13	16.25
Total	80	100
Educational Status		
0-6	18	22.50
7-12	49	61.25
13-18	13	16.26
Total	80	100
Source of Finance		
Personal savings	42	52.50
Friends and relatives	22	27.50
Cooperatives/Isusu/banks	11	13.75
Total	80	100
Household Size		
1-4	12	15.00
5-8	62	77.50
9 and above	6	7.50
Total	80	100
Trade union		
member	61	76.25
Non member	19	23.75
Total	80	100
Total	80	100
Other biz Activities		
Yes	56	70.00
No	24	30.00
Total	80	100
Marketing Experience		
3-10 years	61	50.83
11-20 years	43	35.83
Above 20 years	16	13.33
Total	80	100
Hawking		
Sales in the market	39	48.75
Sales in the market and other places	41	51.25
Total	80	100

Source, field survey, 2023.

Market channels and volume of trade among the channels

According to Isibor and Nkamigbo (2023) marketing channel refers to various ways through which products moves from producers till it gets to the hands of end users and consumers. It is a sequence of intermediaries or middlemen and marketers through which produce pass from producers to final consumers. The distribution channels of coconut fruits in the study area indicated a three channels as shown below, the marketing channels identifies were:

Producer/Supplier → intermediates → consumer (43%)
Producer/Supplier → consumers (09%)
Producers/Suppliers → wholesalers → Retailers → Consumers (28%)

Coconut is a fruit that serves many purpose in Igbo land and virtually every where. The fruit is sold as a whole or in pieces with African salad, palm kernel, fresh corn, fruits salad. The demand for the fruits for commercial, medicinal and export purposes is is gaining ground all through the year. The fruits has three channel through which it reaches the consumer. The first stage is where producer/supplier sells to intermediate who sales to final consumer which recorded the highest volume of trade (43%) among the channels. In this stage the intermediaries called locally (ndi-mgbere) buys from suppliers either from their houses or runs after them while coming to market and buy from them and sale to the final consumers. They make much profit and the suppliers receives little of the profit. The second stage is where the supplier sales directly to consumers which recorded (9%) volume of trade. The suppliers prefer this stage because they make maximum profit of their produce . the last stage of the channel is the stage where the producers/suppliers sales to the wholesalers who sales to retailers that finally sales to the consumers. This passes through a long route and the consumers and suppliers are exploited while the middlemen makes much of the profit.

Net returns of coconut marketers

Marketing margin is the difference between purchase price and price received on resale Sulumbe, Shettima and John (2015) and Nkamigbo, Isibor, Ositanwosu and Obiajulu (2023). The marketing margin reflects the effect of the product characteristics on the complexity of the marketing functions that must be performed as the product passes through the marketing system. From the result of analysis the marketing margin was 43.5% which is below 50% indicates an average return on investment in providing the marketing services. This is in agreement with the report of Nkamigbo *et al*. (2023) on garden egg leaf marketing in their study area This is at variance with Sulumbe *et al*. (2015) who reported a market margin of 27.27% which implies that the marketers gets a fair share of the profit realized in the marketing of garden egg leaf in the study area. The marketing efficiency analysis showed that the marketers had an efficiency of 149%. This implies that they are efficient in performing their marketing functions. This agrees with Nkamigbo, Isibor, Ositanwosu and Obiajulu (2023) who reported a marketing efficiency of 120% of sweet potato marketing in their study area. The net return per Naira invested was 1.77%. The implication of this is that for every one Naira invested in the enterprise, 1.77k was generated as profit. This agrees with Adinya (2009) who reported ₦0.22 for every one spent in groundnut marketing. This implies that coconut marketing is profitable in the study area.

Table 2 : Net returns of coconut fruits marketers (average quantity/month)

Variables	Quantity (I bundle/3.5 kg)	Unit cost(₦)	Total cost (₦)
Purchase	90	12,180	1,096,200
Transportation		15	182,700.00
Loading		5.00	60,900
Miscellaneous			1500
Total variable cost			**1,341,300.00**
FIXED COST			
Selling point stand/shop			240,000.00
Depreciation and Taxes			9,000.00
Total market cost			**1,590,300**
Selling price		1	**2,375,100.00**
Revenue			**2,375,100.00**
Net return (TR-TC)			
Performance indicators			
Marketing margin			43..5%
Marketing efficiency			149
Return on Naira investment (₦)			1.77

Source, field survey, 2023.

$$\boldsymbol{M_m = \frac{S_p - P_p}{S_p} \times \frac{100}{1}}$$

$$= \frac{\mathbf{2,375,100.00 -}\quad 1{,}341{,}300.00}{\mathbf{2,375,100.00}} \times \frac{100}{1} = \frac{1{,}033{,}800.00}{2,375{,}100.00}$$

$$= 43.52\%\ marketing\ margin$$

$$Marketing\ efficiency = \frac{value\ added\ by\ marketing\ (Net\ Return)}{Total\ marketing\ (TMC)} \times \frac{100}{1}$$

$$= \frac{2{,}375{,}100 \times 100}{1,590{,}000}$$

$$149\%\ marketing\ efficiency$$

Market conduct of coconut marketers

The distribution of conduct of coconut marketers is shown in Table 3. The result showed that size of the bundle of coconut fruits (40%) and freshness of coconut (26.25%) is a determining factor of criteria for purchase for marketers while taste and sweetness (13.75%) was the least in the study area . The result also revealed that marketers used common techniques of fixing prices through consideration of purchase price and other expenses incurred in marketing of garden egg leaf. This supports the findings of Nkamigbo and Isibor (2021). The findings also revealed that size of coconut (61.25%) was a criteria used as purchase strategies from marketers while freshness and good water content was a strategy used by end users in purchasing the product in the study area. This support the report of Nkamigbo, Isibor, Obiekwe and Udemba (2023) who revealed that the size of bundle of garden egg leaf is a criteria to consider during purchase.

Table 3: Market conduct of coconut marketers

VARIABLES	F	%
CRITERIA FOR PURCHASE		
Colour and specie of coconut		
Size of the bundle of coconut	32	40.00
Freshness of coconut	21	26.25
Lack of wounds/cracks	16	20.00
Taste and sweetness	11	13.75
Total	80	100
SRATEGIES OF FIXING SELLING PRICES		
Fix price as you like (Arbitrary)	21	26.25
Fix prices through consideration of purchase price and other expenses incurred.	59	73.75
Fix prices through bargaining with wholesalers, retailers and consumers (demand and supply push)	-	-
Fix price by garden egg leaf union	-	
Total	80	100
PURCHASE STRATEGIES FROM SUPPLIER		
Size of the coconut	49	61.25
Soft removal of back cover	31	38.75
Total	80	100
SELLING STRATEGIES TO BUYERS		
Good water content	29	36.00
Freshness and sweetness	20	25.00
size	31	38.75
Total	80	100
STRATEGIES USED IN ATTRACTING CUSTOMERS		
Neat environment	31	38.75
Good rapour with customers (mannerism)	49	61.25
Total	80	100

Source, field survey, 2023.

Constraints to coconut marketing

The constraints to coconut fruits marketing is presented in Table 4. From the analysis of the Table,coconut fruits which is over stayed (M=3.45) either at the place of storage or shop tends to decay from inside and the water contents starts drying up this affects the sales which also reduces the revenue. This is in tandem with the reported of Ozor, Nkamigbo and Chiekezie (2019) who reported lack of storage facilities for dry maize marketing in their study area.Another constraints of importance is breakage associated with transport (M=3.15). this affects the sales as customers detests coconut that has cracks or the are sold at a lower prices which affects the revenue of the marketers. The nature of the country now is highly unpredictable and this has affected the prices of food stuff, fruits and likes. One cant predict the price of coconut in the market. Hazards associated with hawking among children (M=2.55) is another constraint of importance. Most under-age children and even the adults in quest to sale to their customers do run into a moving vehicle which result to accident. This affects the revenue of the marketer. Other constraints of less importance are seasonality of coconut and temporal selling point of the marketers.

Table 4: Constraints to coconut fruits marketing

Constraints	Mean score	Rank
Seasonality of coconut	2.25	6th
Inadequate price control (Irregular prices)	3.05	3rd
Inappropriate storage facilities	2.50	5th
Breakage associated with transport	3.15	2nd
Over stayed nuts	3.45	1st
Hazards associated with hawking	2.55	4th
Temporal selling point	2.05	7th

Source, field survey, 2023.

SUMMARY

Findings from socioeconomic characteristics shows that majority of the marketers (76.25%) belongs to their trade union (Isusu union) where they practice Isusu for their personal welfare and interest. This according to them serves as an umbrella, protection for their members and also as a welfare to carter for their own in case of any eventuality. Findings from market channels and volume of trade among the channels revealed that the first stage is where producer/supplier sells to intermediate who sales to final consumer which recorded the highest volume of trade (43%) among the channels. In this stage the intermediaries called locally (ndi-mgbere) buys from suppliers either from their houses or runs after them while coming to market and buy from them and sale to the final consumers. They make much profit and the suppliers receives little of the profit..From the result of analysis the marketing margin was 43.5% which is below 50% indicates an average return on investment in providing the marketing services. The marketing efficiency analysis showed that the marketers had an efficiency of 149%. This implies that they are efficient in performing their marketing functions. The result of conduct showed that size of the bundle of coconut fruits (40%) and freshness of coconut (26.25%) is a determining factor of criteria for purchase for marketers while taste and sweetness (13.75%) was the least in the study area. From the analysis of the Table,coconut fruits which is over stayed (M=3.45) either at the place of storage or shop tends to decay from inside and the water contents starts drying up this affects the sales which also reduces the revenue.

CONCLUSION

Marketing of coconut fruits is a profitable enterprise in the study area considering the marketing margin and marketing efficiency. The net returns will improve in the study area if the identified constraints are given adequate attention by government and stakeholders.

RECOMMENDATION

i. Marketing prices of certain food and fruits should be looked into by government and stakeholders.
ii. Stakeholders should device a means to carry coconut to minimize wastage associated with transport.
iii. Implement a staggered planting schedule to ensure a more consistent supply of coconuts.
iv. Use appropriate packaging materials and techniques to reduce breakage during transportation.
v. Educate vendors on proper hygiene practices to ensure the safety of the product.

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Economic Analysis of Mobile Food Vendors in Nnewi Metropolitan City, Anambra State, Nigeria

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ABSTRACT

The study examined the economic analysis of mobile food vendor marketing in Nnewi metropolis, Anambra State, Nigeria. The study specifically, described the socioeconomic characteristics of mobile food vendors, various mobile food vendors prevalence in the area, profitability of mobile food vending, influence of socioeconomic characteristics on net income of mobile food vending and constraints associated with mobile food vending in the study area. Multistage sampling procedures involving purposive and random sampling methods was used to select respondents (marketers) for the study. Findings from socioeconomic characteristics shows that most of these mobile food uses wheelbarrow, bike, truck and or head to carry their product to sell to their customers. Findings on various mobile food vendors prevalence in the area showed that Abacha vendors had 25.83% which stands to be the highest mobile vending in the study area. Finding on profitability shows that marketers return 76 kobo for every 1 Naira invested in the business, a profitable enterprise. Stakeholders should work together to reduce the hike in transportation to enable these small businesses to thrive and government should formulate a programs to train these vendors to attain to world class vending business in food marketing were recommended.

INTRODUCTION

Agriculture is an engine room for sustaining growth of Nigeria economy and still remains the mainstay of our economy by providing food for the teeming population, creates jobs as well as wealth, raw material for the industrial sector and foreign earnings (Isibor and Nkamigbo, 2019). Agriculture is one of the affective ways to alleviate hunger, poverty and remained one of the top and widely profitable business sector (Amungwa and Baye, 2014 and Idu, Ajah, Alabi and Nnaji, 2021). Agriculture is a major sector of the Nigerian economy, accounting for up to 35% of total employment in 2020.

Mobile food vending are points of sale of ready-to-eat foods sold on the public roads. Mobile or street vending equally referred to as street foods are foods prepared and/or sold by vendors in street and other public places for immediate consumption or consumption at a time without further processing or preparation (Onyeka *et al*. 2023). They further stated that it have been a part of the culture of many countries throughout the globe particularly in low and middle income countries. It is regarded as a major source of income for many low income earners Vendors can also include those selling from informal sidewalk arrangements such as tables, coolers, and blankets (Lucan, 2019). It has happened for hundreds of years and is considered as a basis of many cities' historical and cultural birthright (Skinner, 2016, Agada, Fems, Duke and Okoyan, 2018).

Idiong (2022) stated the sector is a major source of employment for the poor in many cities of the developing world. This is particularly true in sub-Saharan Africa, where a significant share of the population depends on the informal economy for their livelihoods and most informal workers are concentrated in food retail. In the context of the global food system, the food vending business is considered an important economic activity in developing countries that provide diverse employment opportunities for local workforce (Adeosun, Oosterveer, Greene and Salman, 2022) ; Fusté-Forné, 2021; Newman and Burnett, 2013). It attracts foreign tourists to experience the unique culture that different food menus provide (Abrahale, Sousa and Gabrula, 2019). Food and Agriculture Organization estimated that 2.6 billion people consume vended foods on daily basis (ImathIu, 2017). The mobile food vending businesses use trucks for mobility, as they can easily move around, build customer growth, and take care of different events. This line of business helps to sustain their source of livelihood and homes as they cater to their bills while other needs are met as well . There is increasing recognition that street food vending plays an important socioeconomic role in terms of employment potential, providing special income, particularly for women and provision of food at affordable costs to mainly the lower-income groups in the cities (Ayodele, Innocent and Garba, 2019) .

In Nigeria, mobile food vending accounts for the employment of millions of people who are poor, unskilled and have limited formal education. It contributes to survival of families in financial dificulties. It has benefits for sellers and consumers as people star marketing food as a source of income that helps the home economy.

MATERIALS AND METHODS

The Study was conducted in Nnewi North Local Government Area, Anambra state. Nnewi is a metropolitan city that is made up of four autonomous communities, namely Otolo, Uruagu, Umudim and Nnewichi. It has a population of about 2 million people and land square of 2,789 Km2 with latitude 6.0167N and longitude 6.9167E (Nkamigbo, Chikezie and Ozor, 2019 and wikipedia 2022). Nnewi is the second largest city in Anambra state and is referred to as the Japan of Africa due to the presence of several large and small scaled industries, automobile and production company and automobile market (Nkamigbo, *et al*, 2019) It is widely circulated that Nnewi metropolis houses over 2 million people. The rainy season occurs from the month of March to October, the dry season occurs from the month of November to February. The annual rainfall ranges from 1400mm in the North to 2500mm in the South with temperatures of 25°c to 35°c. Geographically. The main occupation of the people of Nnewi North Local Government Area (L.G.A) is trading and farming, therefore they depend mainly on Agriculture and commerce for their daily livelihood. Industrial activities in Nnewi have indeed brought massive development into the city. This is mostly because the breakthrough in the motorcycle spare parts business has attracted a huge population to Nnewi making the city a hub for many other business activities since there is a large population to patronize the businesses.

Sampling procedure and sample size

Simple random sampling was used to select 30 respondents from each of the 4 markets (Nkwo Nnewi, Eke-Amaobi, Orie-Agbo and Afia-Okpono egbu) from the list of mobile food vendors collected from their union which formed the sample frame. This includes those selling using /wheelbarrows/trucks to sell their food and those staying under temporary structures. Descriptive statistics such as tables, means, percentages and frequency . Enterprise Budgeting, multiple regression and relative importance index were used to analyzed the objectives.

Model specification

The Budgetary Technique is expressed as:

$NER=\sum P_{yxi}Y_i-(\sum P_{xij}X_{ij} + \sum F_{ij})$
Where $\sum$ =sum

$P_{yi}Y_i$= unit price × quantity of i^{th} respondents sales = Total revenue (TR) for i^{th} respondent.

$P_{xij}X_{ij}$ = Prices X quantities of i^{th} respondents variable inputs= total variable cost (TVC) for j^{th} respondent.

F_{ij} = Depreciation values of equipment, annual rent for store, interest on loan, for j^{th} respondents = Total fixed cost (TFC) for j^{th} respondent.

TC = Total cost (TVC + TFC).

Marketing Efficiency

$$ME=\frac{TC}{TR} X \frac{100}{100}$$

where

ME = coefficient of marketing efficiency, TC = Total marketing cost incurred (Expressed in Naira), TR= Total value of product sold (Expressed in Naira)

Socioeconomic characteristics were as follows:

NMI=Net Marketing Income, AGE= Age (in years), Sex = Gender (dummy: male =0; female = 1), MRS = Marital status (married =0; single = 1, widowed = 1), EDU = Educational level (Number of years spent in School), SOF = Source of finance (dummy,: personal =0, friends =1, isusu=2, Banks=3), HOS = Household size (number of persons living together), TOU = Membership of trade union (dummy: member =0, non-member = 1), EXP = Marketing experience (in years), MKS = Marketing cost (Naira), e = Stochastic error term.

It is implicitly represented below as

$NMI = \beta\ (AGE_{1,}\ SEN_{2,}\ MRS_{3,}\ EDU_{4,\ ,}SOF_{5,}\ HOS_{6,}\ TOU_{7,}\ EXP_{8,}\ MKS_{9,}\ \ldots\ldots e_1)$

Acronyms:

NMI= Net marketing income

The explicit versions of the functional forms are stated as:

Linear form:

$NMI = \beta_0 + \beta_1AGE_1 + \beta_2SEN_2 + \beta_3MRS_3 + \beta_4EDU_4 + \beta_5SOF_5 + \beta_6HOS_6 + \beta_7TOU_7 + +\beta 8EXP8_+ + \beta_9\ MKC_9 + e_1$

Semi Log form

$NMISN = \beta_0 + \beta_1 logAGE_1 + \beta_2 logSEN_2 + \beta_3 logMRS_3 + \beta_4EDU_4 + \beta_5SOF_5 + \beta_6HOS_6 + \beta_7TOU_7 + \beta_8EXP_8 + \beta_9MKC_9 + e_1$

Double Log form:

$Log\ NMISN = \beta_0 + \beta_1 log\ AGE_1 + \beta_2 logSEN_2 + \beta_3 logMRS_3 + \beta_4 logEDU_4 + \beta_5 logSOF_5 + \beta_6 logHOS_6 + \beta_7 logTOU_7 + +\beta\ 8logEXP8 + \beta logMKC_9 + e_1$

Exponential form:

$Log\ NMISN = \beta_0 + \beta_1AGE_1 + \beta_2SEN_2 + \beta_3MRS_3 + \beta_4EDU_4 + \beta_5SOF_5 + \beta_6HOS_6 + \beta_7TOU_7 + \beta_8EXP_8 + \beta_9MKC_9 + +e_{1.}$

Constraints to mobile food vendor marketing

Where: $RII = \frac{\Sigma W}{A * N}$

Where:

RII = Relative importance index
W = Weighting given to each factor by the marketers (ranging from 1-4), A = Is the highest weight,
N = Is the total number of marketers.
To make inferential statement, the mean score will be compared with the critical mean, 2

RESULTS AND DISCUSSION

Socioeconomic Characteristics of mobile food vending
Socioeconomic characteristics of mobile food vending is presented in Table 1. The Table indicates that majority of the marketers are within the age limit of 48.33%. This implies that the marketers are middle aged and relatively young people. This is in tandem with Isibor and Nkamigbo (2023) who reported that fresh pepper marketers were relatively young and energetic marketers.The finding on gender reveals that female 81.66% are more in mobile food vending. This implies that the enterprise is gender based in the study area. This is in agreement with Nkamigbo, Isibor, Obiekwe and Udemba (2023) who reported gender sensitive in garden egg fruits marketing in their study area. This varies with the report of Ekeke, Isibor and Nkamigbo

(2021) who reported male dominance in socioeconomic determinants of farmers using social network in advancing agribusiness in Anambra State. Findings from educational status revealed that majority of the marketers had one level of education or other thus making the study area a very vibrant economic hub center for business activity. Majority of the marketers (89%) had spent 7-12 years in school , thus they can easily read and write and can also adapt to changes in marketing processes. The result of marital status revealed that majority of the marketers 65% were married. This gives the married an edge as their children are mostly used in advancing the course of their enterprise. This is in agreement with Isibor, Nkamigbo and Ekeke (2021). From the result majority of the marketers kick started their enterprise with personal savings 56.65% because a little amount of money can bring one into hawking or selling on a spot or combined, only few kick start their enterprise with help from friends and relative 32.50%. The result revealed a household size of 5-8 persons living and eating from same source had a percentage of 45.00%. Majority of the marketers 90.08% belongs to their trade union (Isusu union) where they practice Isusu for their personal welfare and interest. This according to them serves as an umbrella, protection for their members and also as a welfare to carter for their own in case of any eventuality. Marketing experience revealed that 62.4% of the vendors have spent between 6-10 years in the enterprise. This proves that many who entered the enterprise finds it difficult to stay away from it. The monthly income as reveals that those who make between ₦20,000.00-80,000.00 had a percentage of 87.5%.

Table 1: Socioeconomic characteristics of mobile food vendors marketers

VARIABLES		FREQUE+NCY	PERCENTAGES
Age	20-29	07	5.80
	30-39	13	10.83
	40-49	58	48.33
	50-59	27	22.50
	60 and above	15	12.5
	Total	120	100
Gender	Male	22	18.33
	Female	98	81.66
	Total	120	100
Marital Status	Single	31	25.83
	Married	78	65.00
	Widow/Divorced	11	9.166
	Total	120	100
Educational Status	0-6	22	18.33
	7-12	89	74.16
	13-18	09	7.50
	Total	120	100
Source of Finance	Personal savings	68	56.66
	Friends and relatives	39	32.50
	Cooperatives/Isusu	13	10.83
	Banks		-
	Total	120	100
Household Size	1-4	47	39.16
	5-8	54	45.00
	9 and above	19	15.83
	Total	100	100
Trade Union	Member	109	90.8
	Non Member	11	9.16
	Total	120	100
Market Experience	1-5	45	37.5
	6-10	75	62.4
	10 and Above		
	Total	120	100
Monthly income	20,000- 80,0000	105	87.5
	80,000 and above	15	12.4
	Total	120	100

Source, field survey, 2023.

Various mobile food vending prevalence in the study area

Various mobile food vending prevalence in the study area is shown in Table 2. From the result, Abacha vendors had 25.83% which stands to be the highest mobile vending in the study area. This is a result of the nature of the food as many of the sellers hawk the produce every where. This is is followed by those who sell swallow of all type 24.17% . Most of these swallow vendors sells in the afternoon and the study prefers it and are readily available to patronize them. The rice and beans vendors as it is popularly called with ofe akwu and or stew is 24%. They are ever ready both in the morning, afternoon and evening. Others were bread fruits which people believe is big man's food 15.83% and agadi with pepper soup (5.83%).

Table 2: Various mobile food vending prevalence in the study area.

VARIABLES	FREQUENCY (F)	PERCENTAGES (%)
Beans/rice and stew or ofe akwu	24	20.00
Swallow (Akpu/semo/garri) and soup	29	24.17
Bread fruits (Ukwa)	19	15.83
Abacha	31	25.83
Yam porridge	10	8.30
Agaidi and pepper soup	07	5.83
Total	120	100

Field survey, 2023.

Estimated monthly profitability of mobile food vendors marketing

The enterprise budgeting analysis was used to estimate the monthly profitability of mobile food vending marketing in the study area as shown in Table 3. Result of the analysis indicating total cost (TC), Total Revenue (TR), Total Variable Cost (TVC), Total Fixed Cost (TFC), Gross Margin (GM), Net marketing Income (NMI) and Net Return on Investment (NROI) is presented in Table 4.3. It could be seen from that out of the total cost of ₦5,272,110.00 spent by the marketers, purchases constituted 80.60% while the least expenses was off loading 2.1%. This is in agreement with Nkamigbo, Isibor, Ositanwosu and Obiajulu (2023) who reported that purchase of stock is the most important cost in sweet potato marketing in their study area. From the above stock purchase is the most important cost in the enterprise of mobile food vending while off loading is the least cost spent by the marketers.

On profitability of mobile food vending , after spending a total variable cost ₦4,674, 855. 00 and a total cost of ₦5,272,110.00 the marketers realized the sum of ₦6,890,000.00. This transaction generated a gross margin of ₦2,215,145.00, net marketing income of ₦1,647,890.00 and net return on investment of 0.76. The implication of the net return on investment is that the marketers return 76 kobo for every 1 Naira invested in the business. Overall, the profitability indicators (gross margin, net marketing income and net return on investment) showed that mobile food vending marketing is a profitable venture in the study area.

Influence of socioeconomic characteristics on net marketing income of mobile food vending

Table 4 shows the outputs of the four functional forms of regression model for predators of mobile food vending marketing. The result indicated that output of the Linear form gave the best result in terms of number of significant predictors, signs and sizes of predictors as well as the values of F-statistic, R^2, R^2 Adjusted and was chosen as the lead equation. Out of the nine predictors included in the model, only four were significant namely gender, household, source of finance and marketing experience others were not significant. The coefficient of gender had positive coefficient but negative significant effect on the net marketing income at 10% level of probability. This implies that gender plays a role in mobile food vending marketing with a higher presence of female marketers dominating the market. It is considered by most people that mobile food vending is mainly for female folks who derives joy in the enterprise and it readily serves as a means of survival welfare for their family.

Table 3: Estimated monthly profitability of mobile food vendors marketing

VARIABLE	Frequency	Percentage %
TOTAL REVENUE (TR)	6,890,000.00	
VARIABLE COST (VC)		
Purchase of various food items	3, 768,125.00	80.60
Transportation	209,500.00	4.48
Loading	198,000.00	4.23
Off-loading	101,230.00	2.1
Miscellaneous costs (water, nylon bag, recharge card, tarpaulin)	398,000.00	8.51
TOTAL VARIABLE COST (TVC)	4,674, 855. 00	100.00
FIXED COST (FC)		
Monthly shop rent	189,750.00	33.45
Ground levy	256,985.00	45.30
Depreciation on equipment (plates, spoons, fork, tray, bowl, greater, pots, kettles, cooking utensils)	68,960.00	12.15
Interest on loan	51,560.00	9.08
TOTAL FIXED COST (TFC)	567,255	100
TOTAL COST TC=TVC+TFC	5,272,110.00	
GROSS MARGIN: TR-TVC	2,215,145.00	
Net marketing income NMI: GM-TFC	1,647,890.00	
Return on investment: TR/TC	1.30	
Net return on investment NMI/TC	0.31	
Gross ratio: TC/TR	0.76	
Marketing efficiency: TC/TR*100/1	76.51	

Source, Field survey, 2023.

The coefficient of household size was positively related to the net marketing income and had a significant effect at 10% level of probability. This suggests that as the vendors household increases, their income from mobile food vending sales also increases. The coefficient of marital status was positively related to the net marketing income and had a significant effect at 5% level of probability. This implies that the family members will serve as a tool of improvement and advancement for the enterprise. The coefficient of marketing experience was positively related to the net marketing income and had a significant effect at 1% level of probability.

Table 4: Influence of socioeconomic characteristics on net marketing income of mobile food vending

Predictor	**Double log**	**Semi log**	**Exponential**	**Linear**
CONSTANT	-11.562 (0.000)	-2170(0.000)	2.01(0.000)	7.62(0.63)
AGE	0.10 (0.01)*	0.17(0.76)	-0.047(0.11)	1.64(0.06)
GEN	-0.01 (0.08)	-2.65(0.50)	0.03(1.61)*	-0.61(0.67)*
MRS	0.001(0.54)	11.23(0.04)*	0.02(1.45)	5.52(0.02)
EDU	0.06(0.08)*	12.32(0.08)	0.04(0.23)	7.65(0.12)
SOF	0.06(0.05)	1.11(0.67)	1.01(0.22)	5.49(0.38)***
HOS	-0.01(0.32)	0.000567(0.09)	0.04(0.17)	-164(0.06)*
TOU	0.011(0.32)	5.02(0.02)***	0.003(0.37)**	0.007965(1.43)
EXP	0.03(0.28)	0.023(0.42)	0.15(1.97)	1011(1.11)**
MKS	9.36 (0.000)	4.123(0.43)*	-4.23(0.45)	0.00064(0.75)
R^2	76.0	59.0	69.0	71.0
ADJ. R^2	0.7823	0.71	0.67	0.69
ROOT	43.69	41.90	30.09	33.98

Key Note: * = significant at p<0.10, **= significant at p<0.05, *** = significant at p<0.01. Figures in ( ) are T ratios. Source, field survey, 2023.

Constraints to mobile food vendor Marketing

The constraints associated with mobile food vending in the study area were shown in Table 5. The findings show that patronage by low and average people was perceived as the most serious challenge in mobile food vending in the study area. This is an indication that most well to do people feels that stopping to buy food from from these vendors reduces their personality and the way people view them. Another major constraints associated with the enterprise is price fluctuation. This has adversely affected their bossiness as the prices of products always varies and the prices of the mobile food vending keep changing. The change in price affects the common man who has budgeted the amount to spend on feeding knowing fully well that the vendors are always cheaper than others. Sit at home palaver is becoming another challenge these vendors are experiencing. Most of the vendors depends on the daily income generated from the enterprise to take care of their home but when emergency sit at home occurs their home of survival that day is affected. Other constraints in the enterprise were high cost of transportation which is as a result of hike in pump price of petrol.. poor storage facility and bulkiness of food materials were not considered as a major constraints to the enterprise.

Table 5: Constraints to mobile food vendor Marketing

Constraint	Mean	Rank
High cost of transportation	2.50	5th
Sit at home palaver	2.90	3rd
Poor storage facility	2.20	6th
Price fluctuations	3.10	2nd
Inadequate capital	2.75	4th
Patronage by low and average people	3.45	1st
Bulkiness	2.00	7th

Source: Field Survey; 2023.

SUMMARY

Findings from socioeconomic characteristics shows that most of these mobile food uses wheelbarrow, bike, truck and or head to carry their product to sell to their customers. Some have a joint or sale out let where they occasional stay to sell. Findings on various mobile food vendors prevalence in the area showed that Abacha vendors had 31 (25.83%) which stands to be the highest mobile vending in the study area. Finding on profitability of mobile food vending shows that after spending a total variable cost ₦4,674, 855. 00 and a total cost of ₦5,272,110.00 the marketers realized the sum of ₦6,890,000.00. Overall, the profitability indicators (gross margin, net marketing income and net return on investment) showed that mobile food vending marketing is a profitable venture in the study area. Out of the nine predictors included in the model, only four were significant namely gender, household, source of finance and marketing experience others were not significant. Findings on constraints shows that patronage by low and average people was perceived as the most serious challenge in mobile food vending in the study area. This is an indication that most well to do people feels that stopping to buy food from from these vendors reduces their personality and the way people view them.

CONCLUSION

Mobile food vending given the positive values of gross margin, marketing efficiency and prevalence various route is a profitable enterprise. The level of profitability will increase if measures are taking to address the constraints identified in the study area.

RECOMMENDATION

i. Government and stake holders should encourage the vendors to register with ministry of environment who should monitor their activities to avoid food poisoning.

ii. Stakeholders should work together to reduce the hike in transportation enable these small businesses to thrive.

iii. Government should formulate a programs to train these vendor to come to world class vending business in food marketing

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Determinants of Rural Farmers' Access to Commercial Bank Credit in Enugu State, Nigeria

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KEYWORDS

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ABSTRACT

The study analyzed access to commercial bank credit by rural farmers in Enugu State, Nigeria. Three specific objectives guided the study. Purposive and random sampling techniques were employed to select 80 rural farmers for the study. Primary data were collected with the use of well-structured questionnaire through the aid of trained data collection agents. Descriptive and inferential statistics such as Ordinary Least Square (OLS) Regression and Access Index models were used for data analysis. A greater percentage (46.9%) of the studied farmers was between 20-40 years, 35.8% was between 41 - 60 years, while 17.3% was 60 years and above. Level of education, membership of cooperative societies, farming experience and value of asset held by farmers facilitated access to credit. Also, result shows that high interest rate, inadequate collateral and communication problem between commercial banks and farmers were the major constraints hindering access to credit.

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INTRODUCTION

Agricultural funding is critical to realizing food security, poverty reduction and sustainable agriculture. The United Nation's Sustainable Development Goals (SDGs) of no poverty, zero hunger, good health and well-being hinge on the success of the agricultural sector. Agriculture can help reduce poverty, raise incomes and improve food security for 80% of the world's poor who live in rural areas and work mainly in farms (World Bank, 2023). For robust agricultural activities and sustainability, access to credit by rural farmers is of paramount importance (Akpan *et al*., 2020; Osuafor *et al*., 2018). Ibe *et al.* (2016) assert that agricultural funding and development is analogous to rural development. The agricultural sector is strategically positioned to have a high multiplier effect on the economy due to its links with other real economic sectors (Agbaeze and Onwuka, 2013; Onyekwe *et al.*, 2021). Access to credit plays a key role in achieving productivity through investment in expansions and new technologies (Osuafor and Ude, 2021). Commercial banks in Nigeria and Enugu State in particular have critical roles to play in funding agriculture. According to Ibe *et al*. (2016), Commercial Banks are a major component and hub of Nigeria's financial infrastructure. All things being equal, they have the bulk monetary facility for funding projects in the country.

Though agriculture is a major contributor to the GDP in Nigeria, smallholder farmers play a dominant role in the sector (Philip *et al.,* 2021). Despite the importance of agriculture in Nigeria, the sector experiences a serious setback in the country mainly due to paucity of funds (Obed *et al.,* 2021; Ibe *et al.*, 2016). Some previous research works have reported that many rural farmers in Nigeria do not easily obtain credit from commercial banks due to various factors such as inadequate collateral, high-interest rates, and low levels of financial literacy. Onuoha (2002) asserts that commercial banks view agriculture as bad risk, and therefore are risk averse towards the agricultural sector. Some other researchers, like Okoye and Agwu (2020); Nzomo and Muturi (2014) examined and affirmed that there are challenges faced by rural farmers in the course of accessing credit in Nigeria, but the factors determining the access have not been fully investigated in Enugu State. It is on this standpoint that this study is birthed to analyze the access to commercial bank credit by rural farmers in Enugu State, Nigeria.

Objectives of the Study

The broad objective of this study is to analyze access to commercial banks' credit by rural farmers in Enugu, Nigeria. The specific Objectives are to:

i. estimate the determinants of access to credit by the rural farmers;

ii. determine the extent of access to credit; and

iii. identify the constraints militating against access to banks' credit in Enugu State.

METHODOLOGY

The study area of this research was Enugu State, Nigeria. Enugu State is one of states that make up the Federal Republic of Nigeria and was created in 1991. It is located in South-East geo-political region of the country. Enugu State has a land area of about 8,022.95 km^2. The state has an estimated population of about 4,411,633 persons (National Bureau of Statistics, 2016). The State is known for its fertile land suitable for agricultural production and has tropical climate with two distinct seasons, the rainy and dry seasons. In order to select the appropriate respondents, this study combined purposive and random sampling techniques. In stage 1, three Local Government Areas (Nsukka, Isi-Uzo and Udenu) were purposively selected out of the seventeen Local Government Areas that make up Enugu State. This selection is based on the rural nature of the areas and the inherent dominance of farming activities as the main occupation of the vast majority of the populace, and the high density of farmers in the areas so as to have appropriate representative data for the study. In stage 2, simple random sampling technique was used to select 80 farmers from the three respective Local Government Areas. Sampling of respondents was done in the following ways, Nsukka 30 farmers, Isi-uzo 30 farmers and Udenu20 farmers. Primary data were used for data collection.

Model Specification

Objective (i) was realized using Binary logistic regression model to estimate the determinants of volume of credit accessed, Objective (ii) was achieved using access index and Objective (iii) was achieved using Likert-type rating scale.

RESULTS AND DISCUSSIONS

Determinants of access to commercial bank's credit accessed

Ordinary Least Square (OLS) regression was employed to determine the factors influencing access to credit by farmers. Educational level: the coefficient for educational level of the farmers' was positively and significantly related with determining the volume of credit accessed by the farmer at 5% level of probability. In other words, certificate was correlated to volume of credit accessed by farmers'. This implies that volume of credit accessed by the farmer when the certificate is higher invariably would be able to access large volume of credit than those with less certificate. Ugbajah (2011) found out that access to agricultural credit has been positively linked to qualification acquired by the farmer. In other words, rural farmers with high educational qualifications have more likelihood of accessing credit from formal financial institutions.

Farming years: The coefficient for farming years of the farmers' was positively and significantly related with determining the volume of credit accessed by the farmer at 10% level of probability. This implies that the higher the years of farming experience, the higher the access to large volume of credit. This findings agrees with Abu *et al*., (2011) who reported that access to agricultural credit has been positively linked to agricultural productivity as a result of farming years in several studies in Nigeria. For value of asset, the coefficient for value of asset of the farmers' was positively and significantly related with determining the volume of credit accessed by the farmer at 1% level of probability. This implies that volume of credit accessible by farmers with more value of assets is higher than those with less value of assets.

Belonging to cooperative: the coefficient for farmers' belonging to cooperative was positively and significantly related with determining the volume of credit accessed by the farmer at 5% level of probability. This implies that farmers who belong to a cooperative have higher chances of accessing bank credit.

Gender: the coefficient for farmers' gender was positively and significantly related with determining the volume of credit accessed by the farmer at 10% level of probability. In other words, the gender of the farmers was correlated to volume of credit accessed. This implies that male farmers have access to larger volume of credit than their female counterparts. The study of Asom and Ijirshar (2017) found out that gender is one of the socioeconomic factors that have significant influence on the farmers' access to loan in the study area. Sabopetji and Belete (2009) argued that over 90% of rural women had not accessed formal financial services in rural South Africa. Ololade and Olagunju, (2013) discovered a significant relationship between farmers' sex and access to credit. It has been argued that, access to finance has the capacity to change women positively thereby enabling them to possess and control over their assets (Umejiaku, 2020; Akpan *et al*., 2020; Osuafor *et al*., 2018). Also, the result is consistent with the finding of Magaji and Aliyu (2007) which shows that over 90% of women in rural Bauchi State have no access to institutional (formal) credit.

Average annual income: the coefficient for average annual income of the farmers' was positively and significantly related with determining the volume of credit accessed by the farmer at 10% level of probability. This implies that farmers who earn higher annual income access higher volume of credit than those with low annual income. This result is in line with the finding of Ijirshar, Ker and Terlumun (2015) and Ibrahim and Aliero (2012). On minimum acoount balance: the coefficient for minimum acoount balanceof the farmers' was positively and significantly related with determining the volume of credit accessed by the farmer at 10% level of probability. In other words, farmers' minimum acoount balancewas correlated to volume of credit accessed. This implies that volume of credit accessed by the farmer who meets up with the minimum acoount balance is invariably able to access large volume of credit than those below the minimum acoount balance requirements. These findings are in line with Akpan *et al*., (2013) who reported that farmers' age, gender, farm size, membership of social organization, extension agent visits, distance from the borrower's (farmer's) residence to lending source, years of formal education and household size are important determinants of access to credit among poultry farmers.

Table 1: Factors Influencing Access to Credit by Farmers

Variable	Coef.	Std. Err.	Z – Value	Prob.
Educational Level	0.40027	0.239056	1.674387**	0.0487
Farming experience	0.000675	0.006925	0.097465*	0.0922
Ageof farmer	-0.002831	0.005859	-0.483166	0.6306
Value of asset holding	4.90E-07	1.71E-07	2.863037***	0.0056
Amount borrowed	-3.10E-07	4.76E-07	-0.651311	0.5171
Membership of Cooperative	0.278564	0.111379	2.501038**	0.0148
Gender	0.149873	0.102440	1.463029*	0.0948
Interest rate	-0.023416	0.015445	-1.516116	0.1342
Average annual income	4.89E-08	1.25E-07	0.390852*	0.0697
Collateral	-7.20E-09	6.70E-09	-1.074683	0.2864
Minimum account balance	6.06E-07	4.19E-07	1.447167**	0.0152
Length in days	-0.000596	0.001061	-0.562085	0.5759
Number of Documents required	-0.019477	0.054737	-0.355818	0.7231
Statistics: No. of observations =	180			
R-squared =	0.438298			
Adjusted R-squared =	0.337694			
F-statistic =	4.356688			
Prob(F-statistic) =	0.000043			

Source: field Survey, 2023, *, **, *** indicates significant at 10%, 5% and 1% respectively.

Volume and Extent of Access to Credit

Binary Logit Regression was employed to determine the relationship between the volume and extent of access. The result of the Binary Logit Regression showed that included variables were robust in modelling the relationship. Among the variables are; Educational qualification, farming years, amount borrowed, belong to cooperative, interest rate, average annual income and collateral were found to statistically significant in predicting extent of access. Access to credit is regarded as one of the key elements in raising agricultural productivity (DBSA, 2005). Access to this credit is being determined by various variables which is discussed:

Age: the coefficient for age of the farmers' were positively and significantly related with determining the extent of access to credit by the farmer at 10% level of probability. In other words, age was correlated to extent of access to credit by farmers'. This implies that extent of access to credit by the farmer when the farmer is an adult invariably would be able to have access to credit than those who are below adult age. Sabopetji and Belete (2009) contradict this finding.

Value of asset: the coefficient for value of asset of the farmers' were positively and significantly related with determining the extent of access to credit by the farmer at 5% level of probability. In other words, the asset value of the farmer was correlated to extent of access to credit by farmers'. This implies that value of asset of the farmer can determine his/her access to credit when the farmer has value of asset in which he/she would invariably have access to credit than those who don't have value of asset. Ibrahim and Aliero (2012) in their study found that the level of income, value of assets, collateral, educational attainment and marital status have significant positive influence on farmers' access to formal credit.

Gender: the coefficient for gender of the farmer was positively and significantly related with determining the extent of access to credit by the farmer at 5% level of probability. In other words, gender was correlated to extent of access to credit by farmers'. This implies that extent of access to credit by the farmer when the farmer is a male invariably would be able to have access to credit than those who are female. In a study carried out by Ibrahim and Aliero (2012), they found out that age and sex have insignificant positive influence on the farmers' access to credit, which negates the findings of this study. On minimum account balance: the coefficient for minimum account balance of the farmers' was positively and significantly related with determining the extent of access to credit by the farmer at 10% level of probability. This implies that farmers who meet the minimum account balance requirements can access credit more than farmers who do not meet up to the minimum account balance requirements.

Length in days: the coefficient for length in days the farmers' will be paying back was positively and significantly related with determining the extent of access to credit by the farmer at 10% level of probability. In other words, the length in days of repayment was correlated to extent of access to credit by farmers'. This implies that extent of access to credit by the farmer when the length in days is minimum invariably would be able to have access to credit than those who have longer or maximum length in days as regards repayment. The findings of Ibrahim and Aliero (2012) negates that of this findings as it states that interest rate and length in days have significant negative influence on the farmers' access to formal credit, which the findings of this study has a positive significance.

Document required: the coefficient for document required of the farmer was positively and significantly related with determining the extent of access to credit by the farmer at 10% level of probability. In other words, document required was correlated to extent of access to credit by farmers'. This implies that extent of access to credit by the farmer when the farmer provides the required document invariably would be able to have access to credit than those who do not provide or have the document required. This study similarly finds that collateral has significant positive influence on access to finance. Thus, the positive influence implies that farmers who can provide the required collateral are more likely to access formal credit.

Table 2: Factors Determining the volume and extent of Access to Credit

Variable	Coef.	Std. Err.	Z – Value	Prob.
Educational qualification	-9.320448	6.398595	-1.456640	0.1452
Farming years	-1.279479	1.047988	-1.220891	0.2221
Age	2.360059	2.731598	0.863985*	0.0838
Value of asset	8.05E-06	3.53E-06	2.277146**	0.0228
Amount borrowed	-4.07E-06	3.03E-06	-1.344326	0.1788
Belong to cooperative	-3.411640	1.330686	-2.563820	0.0104
Gender	1.037694	0.603428	1.719665**	0.0455
Interest rate	-0.318127	0.165749	-1.919330	0.0549
Average annual income	-1.06E-06	1.34E-06	-0.793630	0.4274
Collateral	-1.19E-07	6.15E-08	-1.936972	0.0527
Minimum account balance	1.145883	1.012201	1.132071*	0.0757
Length in days	0.012646	0.009768	1.294580*	0.0955
Document required	1.094370	0.573172	1.909324**	0.0462
Statistics: No. of observations =	180			
McFadden R-squared	0.419029			
Restr. Deviance	87.60279			
LR-statistic =	36.70811			
Prob(LR-statistic) =	0.000249			

Source: field survey, 2023, *, **, *** indicates significant at 10%, 5% and 1% respectively.

Perceived constraints hindering access to commercial bank credit

From the analysis in Table 2, it was viewed that the items where all accepted. Showing that the listed constraints are perceived as hindrances to get access to commercial bank credit. Some of the constraints with their mean score are high interest rate (3.40), inadequate collateral required to secure loan (3.22), inadequate information on commercial bank credit (2.94), few or no availability of commercial banks in the area (3.04), communication problem between commercial bank and farmers (3.42), lending terms and procedures are too difficult for farmers (3.57), unfavorable attitude of the lender to the farmers (3.26), insecurity (3.17), long time lag between the time of application and disbursement of the credit facilities (3.05).

Table 3: Perceived constraints hindering access to commercial bank credit

Item	N	Mean (X)	Std. Deviation	Decision
High interest rate	81	3.40	.719	Accept
Inadequate collateral required to secure loan	81	3.22	.758	Accept
Inadequate information on commercial bank credit	81	2.94	.857	Accept
Few or no availability of commercial banks in the area	81	3.04	.843	Accept
Communication problem between commercial bank and farmers	81	3.42	.668	Accept
Lending terms and procedures are too difficult for farmers	81	3.57	.631	Accept
Unfavorable attitude of the lender to the farmers	81	3.26	.685	Accept
Insecurity	81	3.17	.755	Accept
Long time lag between the time of application and disbursement of the credit facilities	81	3.05	.757	Accept
Inadequate guarantors	81	3.41	.738	Accept
Commercial bank are located far from rural farmers	81	3.23	.729	Accept
High Minimum account balance of the farmer in the lending bank is required	81	3.17	.771	Accept
Inadequate credit history of the farmers	81	3.44	.791	Accept
High cost of processing the loan	81	3.00	.837	Accept
Valid N (listwise)	81			

Source: Field Survey, 2023; The mean ratings of the respondents based on the 4-point rating scale is given as: 4+3+2+1/3=10/4=2.5.

This supports of other studies like the study conducted by Okoye *et al.* (2020) who found out that 67% of smallholder farmers were not able to access credit due to a lack of collateral. These findings also agree with

Bolana and Oyeyemi (2020) and Osaghae and Ehiakhamen (2010) who noted that the lack of bank accounts, collateral, information regarding the procedure for accessing credits from banks, and complex mechanism of commercial banking, limit farmers from accessing credit from formal institutions. Also, Philip *et al.* (2021) stated that high interest rate and the short term nature of loans with fixed repayment periods do not suit annual cropping, and thus constitute a hindrance to credit access.

CONCLUSION AND RECOMMENDATIONS

Educational level, farming experience, and value of asset holding, were found to be the factors influencing access to credit by the rural farmers. On the perceived constraints hindering access to commercial bank credit, all the variables were accepted. Based on the findings, it was recommended that Government should create more awareness about the existence of formal agricultural credits for agricultural production among the farmers especially in the rural areas and should put in place deliberate policy to ensure that rural farmers have access to adequate credit facilities; Enough funds should be disbursed by the government to enhance the level of credit facilities that could boost agricultural production of the rural farmers.

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Awareness and Access of Research Output from Faculty of Agriculture, Nnamdi Azikiwe University to Farmers in Awka Metropolis

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ABSTRACT

The study examined awareness and access of research output from Faculty of Agriculture, Nnamdi Azikiwe University (FANAU) to farmers in Awka Metropolis, Anambra State, Nigeria. Multiple stage sampling technique was used to select 100 respondents from residents within and around Awka Metropolis. Primary data were collected using interview schedule and focus group discussion. Data collected were analysed using descriptive statistics. The Hypothesis was tested using independent T Test to determine significant differences in the socio-economic characteristics of respondents and their access to research output from FANAU. Results revealed that only 35% of the farmers interviewed were aware of FANAU research output. Out of the 35 farmers that were aware, 66.0% became aware through radio. Only 28% of farmers reported that they have access to research output from FANAU. About 91%of the farmers that were aware of the research output from FANAU, was in the area of crop production. More than 95% of the farmers that had access, expressed difficulty in accessing FANAU research output. Lack of link ($\bar{x}$= 3.42) between farmers and researchers was perceived by farmers as the most serious challenge in accessing research output from FANAU. The study established that socio-economic characteristics such as age (p <0.001), educational Level (p <0.001) and farming experience (p <0.001) had significant relationship with access at both 1% and 5% level of significance. The study concluded that only 35% of farmers were aware and 28% had access to research output from FANAU.

INTRODUCTION

Agriculture can be defined as the practice of cultivating crops and rearing animals for food, fibre, and other products. It involves various activities such as land preparation, planting, harvesting, and marketing of agricultural products.

According to African Development Bank (2020), agriculture is considered as the backbone of the economy, providing employment and income to millions of people. It accounts for about 15% of the continent's GDP and employs over 60% of the population. The sector also plays a crucial role in ensuring food security and reducing poverty in the region.

In a comprehensive review of trends, priorities, and challenges by the International Food Policy Research Institute IFPRI (2020), it was stated that in Africa, access and relevance of agricultural research output to rural farmers is critical to achieving food security and reducing poverty. According to the African Union Commission (2015), agricultural research should focus on developing technologies and innovations that are relevant and accessible to smallholder farmers in rural areas.

Sub-Saharan Africa is home to some of the world's poorest countries, where agriculture is the main source of livelihood for rural communities. However, the sector is faced with numerous challenges such as climate change, low productivity, and inadequate infrastructure. As a result, many farmers struggle to make ends meet and are often unable to access markets for their produce (World Bank, 2020). Also, in sub-Saharan Africa, IFPRI (2020) has identified the need for more investment in agricultural research and development to improve the productivity and income of smallholder farmers. The institute emphasizes the importance of involving farmers in the research process to ensure that the output is relevant to them.

In Nigeria, agriculture is the largest employer of labour and contributes about 25% of the country's GDP. The sector has the potential to transform the economy and create jobs for millions of people. However, like other African countries, Nigerian agriculture is faced with challenges such as low productivity, inadequate infrastructure, and poor market access (Federal Ministry of Agriculture and Rural Development, 2021). Agriculture is a vital sector in Nigeria's economy, contributing significantly to the country's Gross Domestic Product (GDP) and providing employment opportunities for a large Percentage of the population (Ogundele *et al*., 2018).

In Nigeria, the Federal Ministry of Agriculture and Rural Development has established several research institutes and centres to develop technologies and innovations that are relevant to local farmers. The ministry also collaborates with international organizations such as the International Institute of Tropical Agriculture (IITA) to improve the access and relevance of agricultural research outputs to rural farmers.

However, despite the importance of agriculture, rural farmers in Nigeria face numerous challenges, including low productivity, inadequate access to markets, and limited access to information and technology (Adepoju *et al*., 2019). Agricultural research and technological development are prerequisites for increasing agricultural productivity and generating income for farmers and the rural work force; thereby solving societal and national problems (Adeoye, 2005; Osabohien *et al*, 2019).

Awareness and access of agricultural research output to farmers refer to the knowledge and availability of research findings and innovations to farmers in rural areas. It involves ensuring that farmers have access to the latest technologies, information, and best practices to improve their productivity and livelihoods.

The Faculty of Agriculture at NnamdiAzikiwe University, Awka is one of the institutions in Nigeria that is actively engaged in research aimed at improving agricultural practices and addressing the challenges faced by farmers. It plays a crucial role in generating research output aimed at improving agricultural production and rural livelihoods.

Over the years, Faculty of Agriculture, NnamdiAzikiwe University, Awka, has been engaged in research activities and introduction of her research output through extension programmes to farmers in Awka Metropolis and surrounding communities. Some of these programmes include: Consumers and Farmers forum on the Unizik 94.1FM anchored by Agricultural Technologists of Department of Agricultural Economics and Extension, Agricultural journals and research work published by Lecturers in FANAU as well as extension outreaches in villages. Extension programmes have been the main conduit for disseminating agricultural information and supporting of rural adult learning as well as assisting farmers in developing their farm technical and managerial skills. It is expected that extension programmes will help increase farm productivity, farm revenue, reduce poverty and minimize food insecurity.

In spite of all these efforts, farmers access to research output is very crucial and fundamental in ensuring productivity and sustainability of the beneficiaries (farmers). The use of radio and journal publications to disseminate information on research output may be a good effort but farmers who may not have access to radio or the time to listen to radio or who may not be literate enough may find it quite difficult to access information through these means.

Moreover, it is one thing to have access to research output and another is for the research output to be relevant to the farmers' needs. Waddington and White (2018) emphasizes the need to improve the quality and relevance of agricultural research for development. The relevance of agricultural research output is crucial for productivity, sustainability and food security. To ensure that research outputs are relevant and impactful, researchers should collaborate closely with farmers and other end users to understand their felt needs and priorities.

Despite the availability of valuable agricultural research output at FANAU, it is not clear whether farmers in Awka Metropolis are aware of the output. Also, one thing is to be aware another is to have access to such output. Presently, there is limited research specifically focused on the awareness and access of research outputfrom FANAU to farmers in Awka Metropolis, Nigeria. Therefore, it is important to examine the awareness and access of the research output from FANAU to ruralfarmers in Awka Metropolis in order to ensure that the research effort is positively affecting the development of Anambra State, Nigeria.

On the basis of the foregoing, the study sought to: describe the socio-economic characteristics of the respondents; ascertain the awareness of farmers about the research output from FANAU; ascertain farmers' access to research output from FANAU; identify challenges farmers face in accessing research output from FANAU; and identify strategies to enhance the relevance of research output from FANAU to farmers.

Hypothesis of the Study

Ho_1: There is no significant relationship between the research output from FANAU and their access to farmers in Awka Metropolis.

METHODOLOGY

The study was conducted in the towns surrounding NnamdiAzikiwe University, Awka (Coordinates: 6.2459°N, 7.1199°E) (Wikipedia 2023) which are located within and around Awka Metropolis in Anambra State of the south-eastern region of Nigeria. Awka Metropolis extended to two Local Government Areas (LGAs) namely Awka South and Awka North LGAs. Agriculture is practised within and around the Metropolis with crops such as yam, cassava, maize as well as animal production like sheep, goat, cattle and poultry. The population of the study comprised all farmers in the towns spanning the area around the Nnamdi Azikiwe University, Awka. Multi-stage sampling technique was used to select respondents for the study. In the first stage, five town communities with consistent farming operations inside and around the University were purposively selected. In the second stage, two villages engaged in active farming were also purposively selected from each of the selected towns to give a total of ten villages. In the final stage, a list of 20 farmers was compiled from each of the ten villages and ten respondents randomly selected to give a total of one hundred respondents for the study. Data were obtained by means of questionnaire/interview schedule issued to the selected farmers. The socio-economic characteristics of the respondents were measured thus: age (years), farm size (ha), income (Naira) etc. In case of awareness of research output from FANAU, farmers were asked to indicate 'yes' or 'no' in the option provided. Similarly, farmers were asked to indicate 'yes' if they have access to research output from FANAU and 'no' if they have no access. Challenges of farmers in accessing research outputfrom FANAU were captured on a 5point Likert type scale. A mean threshold of 3.0 was used for the decision-making. Variables with a mean score of 3.0 and above were said to be serious challenges to the farmers in accessing research outputs from FANAU. Conversely, variables with a mean score below 3.0 were not considered as serious challenges of concern to the farmers.

RESULTS AND DISCUSSION

Socio-economic characteristics of respondents

The results in Table 1 reveal that majority of the respondents (56.0%) were males.Theaverage age of respondents was 43 years while the average year of formal education was 13 years with 11.0% of the respondents having no formal education. The implication of this finding is that the respondents who are still in their active years can utilize their energy in farming activities if they are aware of the research output from FANAU and most importantly if they have access to the output. Also, 13 years of formal education implies that at least 50% of the respondents may have completed their secondary education and so can be more receptive to research output from FANAU. The result is similar to the study conducted by Modirwa (2019) in which most of the respondents received up to 13 years of formal education.Majorityof the respondents (75.0%) were married which implies that family labour may be available for utilization in the execution of research output from FANAU. The average monthly income was ₦95,099.01 indicating that the respondents are already performing above national minimum wage of ₦30,000.00 and could do more if they have access to research output from FANAU. The diverse socio-economic characteristics of respondents is in line with recommendation of Ullah, *et al*, (2022) that any intervention aimed at the awareness of agricultural research should recognize the heterogeneity in the farmers' socioeconomic characteristics.

Table 1: Distribution of respondents based on selected Socio-economic characteristics

Variables	Frequency(f)	Percentage(%)	Mean($\bar{x}$)	Std Deviation.
Gender				
Male	56	56		
Female	44	44		
Age(years)				
≤30	11	11		
31-40	36	36	42.83	10.33
41-50	27	27		
51-60	5	5		
Education(years)				
0	11	11	13.25	0.77
1-6	30	30		
7-12	40	40		
>12	19	19		
Occupation				
Farmer	49	49		
Trader	29	29		
Craftsman	12	12		
Civil/Public Servant	10	10		
Household size				
<4	34	34		
5-8	57	57	6	
>8	9	9		
Marital status				
Single	19	19		
Married	75	75		
Widow(er)	3	3		
Divorced	3	3		
Monthly household income				
<30000	3	3	95099.01	48489.90
30000-59000	18	18		
60000-89000	34	34		
90000-119000	31	31		
≤120000	14	14		
Farming experience(years)				
<5	10	10		
5-9	26	26		
10-14	35	35		
15-19	29	29		
Farm size(plots)				
1	18	18		
2	30	30		
3	18	18		
4	34	34		
Extension contact				
Contact	36	36		
No contact	64	64		

Source: field survey, 2023

Awareness of Research Outputs from FANAU

The data based on awareness of research output from FANAU was represented on Table 2. Only 35% of the farmers interviewed were aware of research output from Faculty of Agriculture NnamdiAzikiwe University Awka. The low percentage of farmers that are aware of research output from FANAU is an indication of weak extension system. This has serious implication on food productivity and security as well as setback on huge investments in research and industry. Out of the thirty-five percent of farmers that are aware of FANAU research output: 66.0% became aware through radio; 14.0% by their neighbours; 6.0% by the staff of the university; 9.0% by television programmes; 3% farmers were informed through community meetings and 3% were informed by friends.This implies that use of radio for creation of awareness remains a veritable tool that should be explored. Aminu, *et al*, (2018) suggest that radio should be utilized more by extension service providers. It is curious to observe that the researchoutput most of the farmers were aware of was mostly in area of crop production (91.43%) while only 2.86% of farmers were aware of research output in the areas of animal production, food technology and soil test respectively. In a study carried out by Ndimbwa, *et al* (2019), farmer groups and agricultural shows were suggested as channels to speed up agricultural information and knowledge penetration to farmers.

Table 2: Awareness of Research Outputs from FANAU

Variables	Frequency(f)	Percentage(%)
Awareness of research output from FANAU		
Yes	35	35.00
No	65	65.00
Sources of awareness:		
Radio	23	66.00
Television	3	9.00
Community meetings	1	3.00
Neighbour	5	14.00
Friends	1	3.00
University staff	2	6.00
Research output they were aware of:		
Crops	32	91.43
Animals	1	2.86
Food	1	2.86
Soil	1	2.86

Access to Research Outputs from FANAU

Data in Table 3 reveal that only 28% of farmers reported that they have access to research output from FANAU. This implies that majority of farmers have no access to research output from FANAU. This is unfortunate and may have been part of the problems for the food crisis being experienced in various parts of the country. Part of the primary tasks of extension agents is dissemination of new technologies to farmers in form of research output from universities especially from faculties of agriculture.

In Table 3, out of the 28% of farmers that had access to research output from FANAU, 42% perceived that their means of access was through UNIZIK radio. This implies that UNIZIK radio is playing a crucial role in dissemination of research output from all the faculties in NnamdiAzikiwe University Awka. About 29% of farmers perceived training programme as their means of access to research output from FANAU. Only 14% of farmers perceived extension workers as their means of access to FANAU research output. This finding is in line with Ogunlade*et al*, (2019) report that only 5% of smallholder farmers in Nigeria have access to scientific publications andOnwuegbuna*et al*, (2018) report that only 10% of smallholder farmers in Nigeria had access to agricultural research information, with the majority relying on traditional knowledge and practices. Therefore, the need to empower the extension unit of FANAU cannot be overemphasized. Eze *et al*, (2020) confirm the need for agricultural extension which can serve as a bridge between researchers and farmers.

Table 3: Access to Research Outputs from FANAU

Variables	Frequency(f)	Percentage(%)
Access to research output from FANAU		
Yes	28	28.00
No	72	72.00
Means of assessing research output from FANAU		
Books/Journals	3	10.71
Training programmes	8	28.57
Technologists/Technology demonstrations	1	3.57
Extension workers	4	14.26
Researchers	0	0.00
UNIZIK radio	12	42.86
Ease of accessing research output from FANAU		
Very difficult	2	
Difficult	95	
Not difficult	3	

Challenges of farmers in accessing research output from FANAU

The results in Table 4 reveal that lack of link between researchers and farmers ($\bar{x}$= 3.42), was perceived by the respondents as a very serious challenge in accessing research output from FANAU. Ngunyale (2023) affirms that there is a significant disconnect between the research conducted in academic institutions and the needs of the farmers. Also, lack of extension workers to link the farmers with the researchers ($\bar{x}$= 3.33) posed another serious challenge to farmers in accessing research output from FANAU. This is true because extension workers' primary role is to make available to farmers new research findings and bring farmers' problems to researchers. Uganneya*et al* (2013) observed that lack of extension workers to link farmers and researchers creates a deficit in accessing research findings related to agriculture. Furthermore, lack of money to purchase ICTs and airtime ($\bar{x}$= 3.21) was also perceived as a serious challenge. Olayiwola, *et al*, (2023) identified that high cost of facilities was one of the challenges farmers face in accessing ICTs. However, inability of farmers to use ICTs ($\bar{x}$= 2.32) to access research output was perceived as not serious challenge in accessing research output from FANAU. The mean clustered around 3.00 was an indication that the challenges were serious and equally affected majority of the farmers.

The values of the standard deviations were greater than unity showing high variability of farmer's responses and indicating that the challenges may not be as serious as expected.

Table 4. Challenges of farmers in accessing research outputs from FANAU

Variables	Mean($\bar{x}$)	Std. Dev.	Level
Lack of link between researchers and farmers	3.42	1.42	1st
Lack of extension workers to link farmers and researchers	3.33	2.31	2nd
Inability of farmers to use ICTs to access research output	2.32	2.00	4th
Lack of money to purchase ICTs and airtime	3.21	1.30	3rd

Source: field survey, 2023

Table 5. Test of Null Hypothesis: No significant relationship between farmers selected socioeconomic characteristics and access to research output

Socio-economic characteristics(SC)	Mean value of SC	Mean value of Access	T-value
Sex	0.56	0.37	1.08440
Age	42.83	0.37	40.5634
Educational level	2.67	0.37	12.0376
Farming experience	12.00	0.37	12.6760
Farm size	2.94	0.37	12.6760
Major occupation	1.83	0.37	7.4775
Monthly income	3.85	0.37	118.9420

Except sex, all the selected socio-economic characteristics age (p <0.001), educational. Level (p <0.001), farming experience (p <0.001), cooperative membership (p <0.001), farm size (p <0.001), major occupation (p <0.001), monthly income (p <0.001), had significant relationship with awareness at 1% and 5% as shown in the table above, therefore, Ho: that no significant relationship between farmers selected socio-economic characteristics and access to research output is rejected and Ha is accepted. THhis aligns with the study by Ullah, *et al*, (2022) which found out that level of farmers' education had great influence on their awareness and ability to access research outputs.

CONCLUSION AND RECOMMENDATION

The study established that only few farmers were aware of research output from Faculty of Agriculture, NnamdiAzikiwe University, Awka. Also, few farmers had access to research output from FANAU. Majority of farmers perceived that lack of link between researchers and farmers was a very serious challenge in accessing research output from FANAU. The study recommended among other things that researchers should collaborate with farmers through the help of extension workers from conception of research to the end.

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Financial Technology (Fin Tech) Credit Volume and its Implication on Women Cassava Farmers' Profit in Anambra State

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ABSTRACT

Access to microcredit by women farmers is challenged by lack of collateral security among others. This impacts negatively on the productivity and profitability of women cassava farmers. Thus, this study examined access to financial technology (fin-tech) credit volume and its implication on profit of women cassava farmers in Anambra State. A Three-stage sampling method was adopted. Five Local Government Areas (LGA) were purposively selected. Three villages were then randomly selected from each LGA, and random sampling was used to select ten 10 women cassava farmers. In all, 150 were sampled using structured questionnaires. Data collected were access to fintech credit and profit of farmers. Data were analyzed using descriptive statistics and Ordinary Least Square. Result showed that only (36.10) had access to credit through fin-tech. Majority (47.16%) of the farmers, had access to between 5,000-30,000 Naira, (22.64%) had access to credit range of 31,000-60,000 Naira, (20.75%) had access to between 61,000-100,000 Naira while (9.43%) had access to credit worth 100,000 Naira and above. Farm size, volume of loan accessed through fintech and cost of weeding had positive and significant influence on profit, while cost of transportation had negative and significant influence on profit. The profitability of women cassava farmers was established increased with an increase in the volume of credit access through fintech. The study recommends that farmers' access to fintech credit be improved through sensitization and provision of required resources.

INTRODUCTION

Women in agriculture play significant role in ensuring food security of a nation, (Adigun, (2022). Ogundele (2014) asserted that Women were now left in agricultural sector to provide hours of productive physical labour. Adigun (2022) stated that if women could have access to productive resources like their counterpart-men, they could improve their farm yields by 20-30%, raising total Nigeria agricultural output by 2.5-4%. Despite, their contributions to agriculture, women have been marginalization in accessing productive resources such as land, capital, agricultural input (Iwena 2015). Women lack access to credit, access new technology, access education and training which is an instrument for social, economic, and political change as they were exposed to unfavourable customs and traditions that stipulates that only males have right to land ownership (Iwena (2015).

Credit is key in agricultural production. Credit is the fund borrowed by individuals, farm, business, and others for use in producing, storing, processing, and marketing crops and livestock products (Ojukwu, 2017). Credit in agriculture is about lending and borrowing by organizations and farmers. Credit is a means of acquiring and control of assets, ownership by cash purchase or borrowing or leasing or custom hiring in agriculture by farmers to bear the cost of productive activities to the time of returns. Access to credit, labour and other required inputs are stimulant for the use of modern technology in agriculture (Komolafe and Adeoti, 2018). Credit institutions plays a vital role in agriculture as it helps in the development of the agricultural sector by providing loans required by farmers to establish economic size farms or large-scale farmsand to expand existing farms to improve food production. Requirement of most credit facilities in Nigeria include clear plan of farmers, good asset base and collateral. Nwaru (2017) has described agricultural credit as transferring of purchasing power from the owner to someone who needs it on a temporary basis with the willingness and ability to repay it back at a specified period with or without interest. However, Komolafe and Adeoti (2018) asserted that farmers who had access to credit adopted modern technologies than those who do not. This implied that availability of credit facilitates to farmers would enhance technology adaptation which could further improve farmers' socio-economic condition, productivity and profitability. Female farmers were deprived of access to productive resources and access to credit in this part of the world Apeh, Ukwuaba, Osuagwu, Ugwuoti, and Apeh, (2023).

The potential of financial technology (fin-tech) for farmers to access credit is high, but there are serious challenges in adopting fin tech solution. These challenges are the required infrastructural facilities (smartphones and internet connectivity), financial exclusion, inadequate financial literacy and operating skills (Kou *et al*., 2021). Women cassava farmers have little awareness on the existence and potential benefits of fin-tech solutions for the agricultural production and this limit their ability to navigate digital financial platforms and make the most of available resources. Through fin-tech, saving of money and access to credit for investment in agriculture becomes easier, as well as managing their finances efficiently, and ultimately improving their financial well-being. Fin-tech facilitate seamless and efficient transactions within the agricultural value chain whereby farmers receive payments directly to their mobile wallets, eliminating the need for cash transactions, which are often time-consuming and prone to risks Craig and Caio-Scuarcialup, (2018). The potential of financial technology (fin-tech) has been underutilized by rural women who were majorly in the agricultural sector. Consequently, this study examined the financial technology (fin-tech) credit volume and its implication on women cassava farmers' profit in Anambra State with these specific objectives:

1. ascertained women cassava farmers' access to credit facilities through fin tech.
2. ascertained the volume of credit women cassava farmers access through fin-tech.

Test of Hypothesis

H_o: Profitability of women cassava farmers do not change with volume of credit accessed through fin-tech.

MATERIAL AND METHODS

Three-stage sampling method was adopted. In the first stage, the study purposively selected Ihiala, Idemili North, Ogbaru, Anambra west and Anaocha Local Government Areas based on Anambra State Agricultural Development Program (ASADP, 2019) report of high dominance of women cassava in these areas. Three villages were then randomly selected from each LGA and in the third stage, random sampling was used to select ten (10) women cassava farmers. Total of thirty (30) farmers were sampled per LGA. In all, one hundred and fifty farmers were sampled, but only 147 questionnaires that gave consistent responses were analyzed. Data were collected on farmers' characteristics, fintech data and profit of farmers. Data were analyzed using using descriptive statistics and Ordinary Least Square α0.05.

Analytical framework

Ordinary Least square (OLS)

Ordinary least squares estimates the unknown parameters in a linear regression model, aimingto minimize the sum of the squares of the differences between the observed responses in the dataset and estimated parameters by a linear function of explanatory variables. Visually, this is observed as the sum of the squared vertical distances between each data point in the set and the corresponding point on the regression line – the smaller the differences, the better the model fits the data. The resulting estimator can be expressed by a simple formula. Equation below represents a basic OLS regression equation

$Y_i = \alpha + \beta x_i + \varepsilon_i$. In this equation,

Y_i represents the dependent variable,
α represents a constant,

β represents the coefficient,
x_i represents the independent variable and
ε_i represents the error term.

OLS analysis provides a predictive equation.
$Y_i = \beta_0 + \beta x_i + \varepsilon_i$. In this equation,
Y_i represents the dependent variable,
β_0 represents a constant,
β represents the coefficient,
x_i represents the independent variable and
ε_i represents the error term.

The explanatory variables
X_1 Labour used (Man-days)
X_2 = Farm size (Ha)
X_3 = cost ofcassava cuttings used (kg)
X_4=Volume of loan through fintech (₦)
X_5= Cost of weeding (naira)
X_6 = Cost of land preparation (naira)
X_7 = Cost of transportation naira)
X_8 = Cost of harvesting (naira)
X_9 = Depreciation on fixed assets (naira)
X_{10}= Rent on farmland (naira)

RESULTS AND DISCUSSIONS

Table 1 shows the responses on if the farmers have access to credit facilities. The result shows that (63.9%) of the farmers did not have access to credit facilities through fin tech while (36.1%) have access to credit facilities. This means that majority of farmers do not has access to credit facilities. This align with the work of Apeh, Ukwuaba, Osuagwu, Ugwuoti, and Apeh,. (2023).

Table 1: Farmers responses on whether they have access to credit facilities through fin tech

Responses	Frequency	Percentages (%)
No	94	63.9
Yes	53	36.1
Total	147	100

Source: Field survey, 2021

Table 2 shows the range of credit available to women cassava farmers accessed through fin-tech. The table show that (47.16%) of the farmers had access to credit worth 5,000-30,000 Naira, (22.64%) had access to credit worth 31,000-60,000 Naira, (20.75%) had access to credit worth 61,000-100,000 Naira while (9.43%) had access to credit worth 100,000 Naira and above. This corroborate the work of Apeh, Ukwuaba, Osuagwu, Ugwuoti, and Apeh,. (2023).

Table 2: Distribution of farmers on the range of credit they have access to through fin-tech

Responses	Frequency	Percentages (%)
5,000-30,000	25	47.16
31,000-60,000	12	22.64
61,000-100,000	11	20.75
Above 100,000	5	9.43
Total	53	100

Source: Field survey, 2023

Test of Hypothesis

H_o: Profitability of women cassava farmers do not change with volume of credit accessed through fin-tech

Effect of financial technology (fin tech) credit on profit of women cassava farmers

The factors influencing the profitability of women cassava farmers was presented in Table 3. The coefficient of multiple determinant (R^2) of 0.763 implies that 76.3% of variation in the profit of women cassava farmers was explained by the joint action of the explanatory variables, while the remaining resulted from the omitted variables and error beyond the control of the farmers. The F-statistics value of 71.97** significant at 1% indicates that the effect of the explanatory variables was significant which means that the production factors influenced the profitability of women cassava farmers. The coefficient of the farm size (1.77) was positive and significant at 1% level of significance. This implies that increasing the farm size by one percent would increase the profit realized from the sales of cassava by 177%. This agrees with the findings of Ogunleye, (2018), Agboklou, and Ozkan, (2023) who asserted that as the area of land cultivated increases, the yield tends to increase, so also the profitability of the producer moves in the same direction.

The coefficient of the volume of loan accessed through fintech (0.24) was positive and significant at 5% level of probability. This implies that 5 percent increase in the volume of loan accessed through fintech would increase the profit from the sale of cassava by24%. This corroborates the findings of Assouto (2020) who reported that farmers' access to credit leads to an increasing of productivity and profitability. The coefficient of the cost of transportation (-0.204) was negative and significant at 1% level of probability. This implies that one percent increase in the cost of transportation would reduce profit by 20.4%. The coefficient of the cost of weeding (0.993) was positive and significant at 5% level of probability, this implies that 5 percent increase in the 0.993 would increase the profit from the sale of cassava by 99.3%.

Table 3: Effect of financial technology (fin tech) credit on profit of women cassava farmers

Variable	Coefficient	(P>|t|)
Intercept	3.132	(3.35)
Labour used (Man-days)	0.020*	(0.041)
Farm size (Ha)	1.77***	(0.000))
Cost of cassava cuttings used (kg)	-0.377	(-0.86)
Volume of loan through fintech (₦)	0.24 * *	(0.009)
Cost of transportation (naira)	-0.204 ***	(0.000)
Cost of weeding (₦)	0..993**	(0.004)
Cost of harvesting (naira)	-0.020*	(0.021)
Depreciation on asset	-0.353	(1.53)
Rent on farmland(naira)	0..993**	(0.004)
F-statistics	71.97***	
R^2	0.763	
Adj R^2	0.721	

Source: Filed Survey, 2023. (*, ** and ***) Sig. @ 10%, 5% and 1% respectively.

CONCLUSION

The study empirically established that there is an increase profitability of women cassava farmers with an increase in the volume of credit access through fintech.

RECOMMENDATIONS

Based on the findings of the study, the researcher recommends among others that:

1. More credit facilities should be made available to farmers through fintech since it allows for flexible inaccessing the creditfacilityand enable farmers to expand their scale of production and improve farmers' cultural practices such as weeding that enhances profitability. This could be done through sensitization and provision of required resources.
2. Government should provide suitable means of transportation for agricultural produce at reduced cost to improve the profit of women cassava farmers.

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Effects of Livestock Production on Rural Development in Ishielu Local Government Area of Ebonyi State, Nigeria

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KEYWORDS

Livestock production, Socio-economic livelihood, Sustainable development, Wealth creation.

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ABSTRACT

The study assessed the effects of livestock production on rural development in Ishielu Local Government Area of Ebonyi State, Nigeria. Multi-stage sampling procedure involving purposive and random sampling techniques were used in the selection of 150 respondents. Primary data were collected through interview schedule and analyzed using both descriptive and inferential statistics such as frequencies, percentages, mean score and factor analysis. Result showed that the major types of livestock enterprises undertaken by the respondents were: poultry production (85.3%), fishery (68.0%), goat keeping (66.0%), cattle rearing (58.0%) and piggery enterprise (53.3%). These enterprises improved the livelihood of respondents through increased income *($\bar{X}$ = 3.69), employment generation ($\bar{X}$ = 3.46) and enhanced availability of meat and egg products ($\bar{X}$ = 3.45). Other benefits were: increased food nutrition/daily protein requirement (85.3%), increased profitability (79.3%), increased soil fertility (78.7%) and supplies of raw materials for industries (76.0%). High cost of livestock feeds, livestock diseases, low access to veterinary services and inadequate extension service are some of the constraints limiting the performance of the farmers. Therefore, the study recommended that farmers should organize themselves into groups in order to share knowledge and experience for the improvement of livestock farming. This will also help them to secure loans from micro and macro credit institutions.*

INTRODUCTION

Livestock systems dominate about 30 percent of the planet's ice-free terrestrial surface area and are a substantial global asset with a worth of at least $1.4 trillion (Meissner *et al*, 2023; Yitbarek, 2019). The livestock sector is increasingly organized in long market chains that employ at least 1.3 billion people globally and directly support the livelihoods of 600 million poor smallholder farmers in the developing world (Khade *et al*, 2021; Obot *et al.,* 2021). Livestock are important in supporting the livelihoods of poor farmers, consumers, traders and labourers throughout the developing world. The greatest impact of livestock in sustainable development designed to help the poor is enhancement of livestock-production systems. Animal diseases are crucial constraints, in that the animals of poor farmers are particularly vulnerable to disease because of the high cost or unsuitability of animal-health and production inputs (Nwose *et al.,* 2021; FAO, 2010). The majority of the world's estimated 1.3 billion poor people live in developing countries where they depend directly or indirectly on livestock for their livelihoods. Globally, livestock contributes about 40 percent to the agricultural gross domestic product (GDP) and constitutes about 30 percent of the agricultural

GDP in the developing world (Obot *et al*., 2020; Michalk *et al.*, 2019. These estimates highlight the important contribution of livestock to sustainable agricultural development.

For many years livestock departments have attempted to improve the lives and productivity of rural communities' livestock owners. Although the most common problems relate to nutrition (availability and quality of feed) and to diseases, many development programmes concentrate on specific aspects, such as disease control Godswill *et al.* (2020). In reality there is a need to integrate different components to ensure that sustainable systems of production are established (Mohammed *et al.* 2013).

The contribution of livestock to the world's food supply, family nutrition, income, employment, soil fertility, livelihoods, transport and sustainable agricultural production continues to be a subject of significant review and debate (Randolph *et al.*, 2017). Furthermore, estimates show that globally, livestock provide animal traction to almost a quarter of the total area under crop production (Devendra, 2010). Livestock also provide a safety net in times of need in the form of liquid assets and a strategy of diversification for food production (Freeman *et al.*, 2018). All these reviews and studies thus far have shown that livestock play multiple roles in the livelihoods of people in developing communities, especially the poor.

National Bureau of Statistics pointed that small ruminant animals (sheep and goats) are an important source of income in western Asia and North Africa, semi-arid areas with less than 300 mm average annual rainfall. According to Randolph *et al.* (2017) small ruminants in Southern Nigeria are integral components of the household, where they contribute to the cultural, food and socio-economic life of the people. Traditionally, sheep and goats have served as means of ready cash and a reserve against economic and agricultural production hardship. Sheep and goats play a significant role in the food chain and overall livelihoods of rural households. They are key opportunities for smallholder small ruminant producers to not only engage in income generating activities, enabling them to escape the poverty trap but also to consume animal source food they could not afford to buy. Randolph *et al.* (2017) affirmed that livestock are important in supporting the livelihoods of poor livestock keepers, traders and labourers throughout the developing world.

Although, with a fast growing population, Nigeria is threatened with the problem of food insecurity and poverty which can be addressed with a more developed animal production sector in addition to other sectors (Fasoyiro and Taiwo 2012). The average Nigerian still consumes far less animal protein than his counterpart in the developed world because the animal production industry is still in its infancy due to hydra-headed problems and the per capita income is low leading to a consumption of less than 9grams of animal protein per capita per day as compared to over 50 grams per capita per day in North America and Europe (Boland *et al.* 2013). Some countries even in the developing world are already considering novel approaches to meat production such as *in vitro* meat production (Sachan *et al.* 2012) but in Nigeria, animal production is facing numerous challenges with certain factors militating against successful animal production.

Livestock contribute directly to the economy through employment generation, increase in savings and investment, foreign exchange earnings, contribution to human food and nutrition. Livestock also contribute indirectly to food security by increasing crop output through providing manure, and serve as a buffer to mitigate the impact of fluctuations in crop production on the availability of food for human consumption, thereby stabilizing food supply. Despite its smaller output compared with that of staple crops, productivity and income growth in the livestock sector have strong income multiplier and poverty reduction impacts (Tyohen and Mbakpene, 2023; Alabi *et al*., 2019). It is on this premise, that this study is birthed.

Objectives of the Study

The aim of the study was to assess the effect of livestock production on rural development in Ishielu L.G.A of Ebonyi State. The specific objectives were to:

i. identify the various types of livestock enterprises in the study area;
ii. evaluate the effect of livestock production on rural development;
iii. identify the benefits of livestock production in the development of the rural dwellers; and
iv. identify constraints to livestock production for enhancing rural development.

METHODOLOGY

This study was conducted in Ishielu Local Government Area of Ebonyi State Nigeria. Ishielu Local Government Area is one of the thirteen (13) Local Government Areas in Ebonyi State, South east Nigeria with its headquarters at Ezillo which is 37 kilometer away from the state capital. Ishielu L.G.A is made up of twelve (12) autonomous communities; Ntezi, Amauzo, Ezillo, Okpoto, Nkalagu, Ezzagu, Iyonu, Obeagu, Agba, Azinyaba, Umuhuali and Nkalaha. Ishielu L.G.A has a land area of 517 km^2 and a total of 198,793 in population (NPC, 2006). Geographically the local government lies between latitude 4°N and longitude of 8°S of Ebonyi State. The local government is situated at north boundary of Benue state, in South by Ezza South Local Government Area.

The Local Government Area is characterized by mean temperature of 27-30 °C and the prominent climate seasons are rainy season and annual rainfall of 1770mm to 2000mm, lasting from late March to October, dry season, lasting from late October to early March (Omaka, Offor and Onwe, 2015). The vegetation of the place is tropical derived savanna populated by grasses and trees of different sizes in the area. The soil types is basically clayey, loamy clay and clayey loam. The main occupation of the dwellers are crop and livestock farming. Other occupations include: civil services, trading, building and construction work and some artisanal activities. The major crops grown in the area include; yam, cassava, maize, potatoes, oil palm, rice and vegetables. Some farmers also engage in livestock rearing at subsistence level, animals raised are chickens, fishes, rabbits, pigs, donkeys, cattle, sheep and goats.

Sampling Techniques

A multistage sampling procedure was used in selecting the respondents for this study. The first stage involved a random selection of five communities in Ishielu LGA. From the selected five communities, two (2) villages each were randomly selected making it a total of 10 villages. From the 10 villages selected, 15 households were randomly selected from the list containing the names of the household heads obtained from the village head, making a total of 150 respondents that were used in this study.

The data for the study were collected from primary source with the aid of a well-structured questionnaire administered as interview schedules. Descriptive statistics such as frequency distribution, mean, tables and percentages were used in analyzing objectives i, ii and iv. Objective iii was analyzed using mean score derived from 4-point Likert rating. Objective v was analyzed with the aid of factor analysis obtained from Varimax rotated component matrix.

Model Specification

Factor Analysis Model

In order to obtain the factor loadings of each of the variables necessary for achieving objective iv, factor analysis model was used. Each dependent variable (Y) can be expressed as a weighted composite of a set of latent variables (F) such as:

$Y = \alpha_1 F_1 + \alpha_2 F_2 + \text{-----------} + \alpha_n F_n$
Where:
Y = Dependent variable
α = Constant
F_1 - F_n = Independent variable
n = Number of independent variable
For this study, factors of 0.40 and above were selected and used for the analysis and otherwise ignored.

RESULTS AND DISCUSSION

Various Livestock Enterprises
Various livestock enterprises were considered and analyzed in this section, the result obtained is presented in Table 1.

The result in Table 1 showed that the major types of livestock enterprises available in the area were: poultry production (85.3%), fishery (68.0%), and goat keeping (66.0%). Others were: cattle rearing (58.0%) and piggery enterprise (53.3%). But, sheep rearing and rabbitry were undertaken by 30.0% and 10.0%, respectively by the respondents. This implies that all the seven (7) livestock enterprises analyzed were practiced in the area but poultry farming ranked first and the most practiced type of livestock enterprise in the study area. This could be attributed to the fact that poultry production gives quick output (Orebuji, (2010).

Table 1: Percentage Distribution of the Respondents based on the Livestock Enterprises

Livestock Enterprises	Frequency	Percentage (%)
Cattle rearing	87	58.0
Goat keeping	99	66.0
Poultry production	128	85.3
Swine production	80	53.3
Rabbitry	15	10.0
Sheep rearing	46	30.7
Fishery	102	68.0

Source: Field Survey, 2023. ***Multiple Responses Recorded**

Effect of Livestock Production on Rural Development

The effect of livestock production on rural development was analyzed with the help of mean score and the result presented in Table 2.

The result shows that livelihood support in terms of income generation ($\bar{X} = 3.69$), creates employment ($\bar{X} = 3.46$), increased availability of meat and egg products ($\bar{X} = 3.45$) and attracts installation of mechanized cold rooms ($\bar{X} = 3.16$) were the major impact of livestock production on rural development in the study area. Other impact of livestock production on rural development in the area were reduction in political thuggery ($\bar{X} = 2.98$), complements crop production ($\bar{X} = 2.95$), reduced dependency on fulani reared cattle beef ($\bar{X} = 2.91$), creates avenue for diversification among farmers ($\bar{X} = 2.87$) and reduced involvement in social vices (yahoo + etc) ($\bar{X} = 2.82$). The total mean was 3.16, which implies that the impact of livestock production on rural development in the area were moderate.

Table 2: Mean Score Distribution of the Respondents on Impact of Livestock Production on Rural Development

Impacts	Mean	Remark
Livelihood support in terms of income generation	3.69	Accepted
Increased availability of meat and egg products	3.45	Accepted
Creates employment	3.46	Accepted
Poverty reduction	3.27	Accepted
Reduced dependency on Fulani reared cattle beef	2.91	Accepted
Complements crop production	2.95	Accepted
Attracts installation of mechanized cold rooms	3.19	Accepted
Creates avenue for diversification among farmers	2.87	Accepted
Reduction in political thuggery	2.98	Accepted
Reduced involvement in social vices (yahoo + etc)	2.82	Accepted
Total mean	3.16	Accepted

Source: Field Survey, 2023

Benefits of Livestock Production on the Socioeconomic Development of the Rural People

The benefit of livestock production as it relates to the socioeconomics development of the rural people was examined and the result presented in Table 3.

Result of the analysis in Table 3 revealed that the major benefits of livestock production on the development of lives of rural people were increased food nutrition/daily protein requirement (85.3%) and increase of income (84.7%), followed by increased profitability (79.3%), droppings increases soil fertility (78.7%) and provides raw materials for industry (76.0%). Other benefits were some of the livestock are used for ploughing (50.7%), safer working conditions (50.0%) and avoidance of herders-farmers crises (49.3%). This implies that livestock production has benefited rural peoples in diverse ways.

Table 3: Percentage Distribution of the Respondents based on the Benefits of Livestock Production on the Socioeconomic Development of the Rural People

Benefits	Frequency	Percentage (%)
Increased food nutrition/daily protein requirement	128	85.3
Some of the livestock are used for ploughing	76	50.7
Avoidance of herders-farmers crises	74	49.3
Increase of income	127	84.7
Safer working conditions	75	50.0
Increased profitability	119	79.3
Droppings increases soil fertility	118	78.7
Provides raw materials for industry (bone, hides, skine.t.c)	114	76.0

Source: Field Survey, 2023 ***Multiple Responses Recorded**

Constraints to Livestock Production for Enhancing Rural Development in the Study Area.
Factor analysis was used to determine constraints to livestock production for enhancing rural development in the study area. The result obtained is presented in Table 4. Table 4 showed the Varimax rotated component matrix on constraints to livestock production for enhancing rural development in the study area. From the field data collected, two (2) major constraints were extracted based on the responses of the respondents. Only variable with constraints loading of 0.40 and above at 10% overlapping variance (Ashley *et al*., 2006) were used in naming the constraints. Variable that loaded in more than one constraint were discarded while variables that have constraints loading of less than 0.40 were not used.

Factor 1 was considered and named production factor due to the variables that loaded high under it. This high loading variables includes; high cost of livestock feeds (0.743), livestock diseases (0.723), low access to veterinary services (0.801), Poor access to market (0.817), poor attitudes to livestock production (0.693) and inadequate grazing land (0.759). This result agrees with the findings of Afolabi and Tiamiyu (2021) who noted that livestock business in Egbeda Local Government Area of Oyo State, Nigeria were attributed to weak information on potential production type and innovations.

Also, factors 2 was considered and named institutional factor because of the constraints that loaded high under it. These include: Inadequate extension service (0.806), Lack of Government support (0.708), poor transportation facilities (0.716) and climatic and environmental factors (0.695). This findings is in line with the report of Silong and Gadanakis (2020) who noted that poor transportation limits livestock production in Nigeria. Also, Nkonki-Mandleni *et al.* (2019) reported that poor tranportation and lack of climate equipment affect livestock production negatively in South Africa. Therefore, two major constraints to livestock production for enhancing rural development in Ishielu L.G.A of Ebonyi State were production and institutional constraints. This result is in line with the findings of Mapiye *et al.* (2021) who reported that institutional constraints affect livestock production.

Table 4: Varimax Rotated Component Matrix on the Constraints to Livestock Production for Enhancing Rural Development in the Study Area.

Constraints	Factor 1	Factor 2
	Production	Institutional
High cost of livestock feeds	0.743	0.291
Livestock diseases	0.723	0.280
Low access to veterinary services	0.801	-0.019
Level of farmers education	0.268	0.282
Urbanization	0.331	0.099
Poor access to market	0.817	0.278
Inadequate extension service	0.149	0.806
Inadequate manpower	-0.464	0.263
Lack of Government support	0.338	0.708
Poor transportation Facilities	0.273	0.716
Climatic and environmental factors	0.299	0.695
Poor attitudes to livestock production	0.693	-0.437
Lack of supporting livestock policy	0.650	0.612
Distance to market	0.354	0.315
Inadequate grazing land	0.759	0.219

Source: Field Survey, 2023

CONCLUSION AND RECOMMENDATIONS

The study has shown that livestock production contributed significantly to improving the socioeconomic conditions of the farmers by ensuring rural development in the study area. Based on the findings of the study, the following recommendations were made:

i. Farmers should organize themselves into groups, preferably cooperative societies in order to share knowledge and experience for the improvement of livestock farming. This will also help them to secure loans from micro and macro credit institutions.
ii. Farmers should be motivated through credit facilities and series of trainings on technological advancements in order to ensure sustainable production of livestock, since the farmers were majorly affected by production factors in the study area.
iii. The government and other stake holders should organize sensitization programmes on livestock production for youths as this will increase their awareness on livestock farming.
iv. Government should ensure the availability of enough inputs and capital for rural farmers.

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SUB-THEME EIGHT

NOVEL TECHNOLOGIES IN FOOD PROCESSING

Chemical and Sensory Properties of Stiff Dough Produced from Blends of Water Yam and Black Bean Flours

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ABSTRACT

This research aims to make stiff dough from water yam and black turtle bean (Akidi) flours and ascertain the quality attributes. The water yam was peeled, sliced while in water, oven dried at 60℃ for 4 h and milled into flour while the black bean was sorted, divided into two equal parts one part was soaked for 5 h while the other was boiled for10 mins and thereafter oven dried at 65 ℃, dehulled and milled into flour. The flour samples were blended at different ratios of water yam to black turtle bean, 100 % water yam flour (WY) served as control, 90:10 (WB1), 80:20 (WB2), 70:30 (WB3), 60:40 (WB4), 50:50 (WB5), 90:10 (WS1), 80:20 (WS2), 70:30 (WS3), 60:40 (WS4) and 50:50 (WS5). The proximate, anti-nutritional and consumer acceptability were assessed. The nutritional compositions of the product all showed significant differences. The flours' proximate composition revealed the following ranges of results: 1.84 to 5.20% ash, 0.61 to 1.87% crude fat, 0.72 to 2.17% crude fibre, 2.57 to 8.17% moisture, and 71.35 to 81.95% carbohydrate. The antinutritional compositions showed that boiling reduced the phytate and tannin contents to 0.05 mg/100g and 0.06 mg/100g while soaking caused a significant reduction ($p<0.05$) in the saponin and oxalate contents to 0.06 mg/100g and 0.02 mg/100g respectively. Stiff dough prepared from soaked sample WS1(90:10) had the highest overall acceptability. These findings suggests that water yam/black turtle stiff dough can meet the nutritional demands of the populace. This study provides an alternative way of utilizing water yam and black turtle bean thus preventing post-harvest losses and ensuring eradication of protein energy malnutrition and proper food security.

INTRODUCTION

The economic condition in Nigeria and other developing nations is such that low-income families cannot afford the recommended daily ration of animal protein. According to Onwuka and Ihuma (2007) over a billion people suffer from undernourishment. Legume and tuber crop fortification or enrichment can help reduce the worldwide malnutrition (Hoover, 2001). Water-yam (*Dioscorea alata*), also referred to as greater yam (majorly cylindrical in shape), or Ji Abana in Igbo, is known for its high nutritional content, with crude protein content of 7.4%, starch (75 - 84%) and vitamin C content ranging from 13.0 to 24.7 mg/100g (Dauda *et al*., 2022).

In general, they have a longer shelf life and less sugar, which guarantees availability during times of scarcity. Varieties of *D. alata* are also excellent providers of zinc, which lowers blood pressure in people. According to Bhandari *et al*. (2013), water yams are an excellent source of potassium, which is necessary for healthy kidney function and blood pressure regulation. Thus, those with high blood pressure may benefit from eating water yam. Black turtle beans (*Phaseolus vulgaris*) also known as "Akidi oji" in Igbo (Odo, 2010). The seeds can be processed to make a variety of goods, including flour, starch, protein isolates, concentrates, and extruded foods. Although very nutritious, Nigerians rarely use black turtle beans. It has long been known that beans are an excellent source of dietary fiber, minerals (P, K, Ca, and Mg), vitamins (thiamine and niacin), and plant protein. Minerals like calcium, iron, copper, zinc, potassium, phosphorus, and magnesium are abundant in black beans (Siddiq and Uebersax, 2013). On the other hand, some anti-nutritional components found in legumes include tannins, protease inhibitors, trypsin and phytic acid must be reduced or eliminated in order to avoid poisoning from these anti-nutrients. Water yam as an underutilized food product with high moisture content, can be processed into flour and appropriately fortified with black turtle bean flour to create composite flour which can be reconstituted with boiling water to form a stiff-dough. According to Oyango (2014), stiff dough is a food prepared from flour that is stirred continuously in boiling water to obtain a homogenized gelatinous mixture without lumps. The incorporation of black turtle bean to water yam will improve the nutritional quality of the stiff dough as well help combat protein-energy malnutrition in the general population and provide the necessary nutrients for proper body metabolism when compared to pounded yam only.

MATERIAL AND METHODS

Raw materials: Black turtle beans (*Phaseolus vugaris*) and water yam (*Dioscorea alata*) were bought from Ogige market in Nsukka, Enugu state Nigeria.

Experimental Design: Experimental design used was completely randomized design.

Table 1: Experimental Design

S/N	Sample Code	Soaked Black Turtle Beans Flour	Boiled Black Turtle Beans Flour	Water Yam Flour
1.	WY	0.00	0.00	100.00
2.	WB1	0.00	10.00	90.00
3.	WB2	10.00	0.00	90.00
4.	WB3	0.00	20.00	80.00
5.	WB4	20.00	0.00	80.00
6.	WB5	0.00	30.00	70.00
7.	WS1	30.00	0.00	70.00
8.	WS2	0.00	40.00	60.00
9.	WS3	40.00	0.00	60.00
10.	WS4	0.00	50.00	50.00
11.	WS5	50.00	0.00	50.00

Production of Water Yam Flour

With few adjustments, the approach outlined by Babajide *et al.* (2006) was employed. Five kilograms of water yam tubers were cleaned to get rid of extra dirt and sand, they were peeled with a sanitized kitchen knife, immersed in potable water, and cut to a thickness of two millimeters while still submerged in water to prevent browning. After they were oven dried for four hours at 60°C, the sliced water yam was ground into powder using a Qasa high power blender and grinder (Model: QBL-8008 PR), and the resulting fine flour was sieved through an 80mesh screen. After being carefully packed and sealed in an airtight container, the water yam flour was kept for later examination.

Processing of Soaked and Boiled Black Turtle Bean Flours

Black turtle bean seeds (*Phaseolus vulgaris*) were prepared according to the method described by Okafor *et al.* (2015). A measure weight (3 kg) of black turtle beans were manually sorted to remove physical impurities, cleaned with potable water to get rid of dust, dirt, and other sticking impurities. The cleaned beans were then split into two parts one part was soaked for five hours in potable water and the other part boiled for ten minutes at 100°C and finally oven (Model: HS206A) dried for five hours at 65°C. In order to obtain bean flours, they were dehulled, milled using a Qasa high power blender (Model: QBL-8008PR) and sieved through an 80 mm mesh screen. Samples of flour were stored in an airtight container until when needed for analysis.

Preparation of stiff dough from composite flour

The method described by Karim *et al.* (2013) was adopted. The stiff dough was formed by mixing the blended flour samples in boiling water, which was allowed to boil at 100°C for 3 minutes, the blended flour samples were poured into the boiling water and mixed manually using a stirrer until a smooth dough was formed, then a little water was added to cook properly for 1 minute and the stiff dough was ready.

Determination of Proximate Composition and Anti-Nutrients:

The proximate composition of flour samples was determined using methods described by AOAC (2010), tannin, saponin and oxalate contents were determined using the method of AOAC, (2010) while phytate was determined using methods described by Hangh and Lantzscl (1993).

Sensory Evaluation:

The method described by Iwe *et al*. (2014) was adopted for the sensory evaluation. 25-man semi-trained panelists evaluated the quality of the formulated stiff dough and accessed the samples on a 9-point Hedonic scale for taste, colour, texture, aroma, and overall acceptability, with 9 representing strongly like and 1 representing extremely dislike.

Statistical Analysis: The Statistical Package for Social Science (SPSS) version 23.0 software was used to analyze the generated data. Duncans New Multiple Range Test (DNMRT) was used to separate and detect significant differences ($p<0.05$) among means using Analysis of Variance (ANOVA) and Least Significant Difference (LSD).

RESULTS AND DISCUSSION

Proximate composition of instant flours produced from water yam and black turtle bean.

Table 3 displays the findings of the flour samples' proximate compositions. The flour samples had moisture contents ranging from 2.57 to 8.00 %. Sample WB1(90:10 – water yam:boiled black Turtle Bean), had the highest moisture content (8.20 %), whereas sample WS5 (50:50 - water yam:boiled black Turtle Bean), had the lowest moisture content (2.57 %). There were notable variations ($p<0.05$) between the boiled and soaked samples' moisture contents. The moisture content of the sample flours increased significantly after boiling at 100°C for 10 minutes. This phenomenon may have been produced by the protein molecules' heat-denaturation, which allowed them to absorb moisture from the surrounding medium. This low moisture content indicates that the flour samples won't be susceptible to microbial deterioration and will be shelf stable in storage settings.

The flour samples' ash contents varied from 0.72 to 2.17%. There were significant variations ($p<0.05$) between the samples, but not between soaked samples WS3 (70:30) and WS4 (60:40) for their ash contents of 2.07% and 2.05% percent respectively. It was shown that soaking marginally increased the ash level of the flour samples, whereas boiling greatly decreased the ash content. The amount of ash in a sample indicates the mineral salts present. These samples' high ash content indicates that they will have a high mineral content. These results are lower than the values of 4.87 - 4.98 % obtained by Dauda *et al.* (2022) for white, water, and cocoyam flour, but they are higher than 0.50 - 2.53 % obtained by Odoh *et al.* (2022) for fufu composite flours.

Significant variations ($p<0.05$) were observed in the fat content of the flour samples, which varied between 0.61 and 1.86 %. Sample WS5(50:50- water yam: soaked black turtle bean), had the least value of 0.61 % while sample WY (100% water yam) had the highest fat content of 1.86 %. These values are in agreement with the result (0.60 to 2.18 %) obtained by Bolaji *et al.* (2021) for fermented cassava flour (lafun) and pigeon pea flour.

Table 2: Proximate Composition of Instant Flour Blends from Water Yam and Black Turtle Beans

S/N	Samples	Moisture (%)	Ash (%)	Fat (%)	Fibre (%)	Crude Protein (%)	Carbohydrate (%)
1	WY	$5.40^{e}\pm 0.17$	$2.17^{a}\pm 0.02$	$1.87^{a}\pm 0.03$	$5.20^{a}\pm 0.10$	$5.50^{l}\pm 0.10$	$79.86^{c}\pm 0.00$
2	WB1	$8.17^{a}\pm 0.25$	$0.87^{g}\pm 0.02$	$1.53^{e}\pm 0.01$	$2.00^{f}\pm 0.02$	$8.12^{k}\pm 0.03$	$81.68^{a}\pm 0.00$
3	WB2	$5.23^{f}\pm 0.03$	$1.96^{d}\pm 0.02$	$1.64^{d}\pm 0.02$	$4.91^{c}\pm 0.03$	$10.73^{g}\pm 0.15$	$75.77^{f}\pm 0.00$
4	WB3	$7.61^{d}\pm 0.04$	$0.72^{j}\pm 0.01$	$1.72^{c}\pm 0.03$	$1.85^{h}\pm 0.05$	$14.95^{d}\pm 0.03$	$73.15^{g}\pm 0.00$
5	WB4	$7.78^{c}\pm 0.02$	$0.76^{i}\pm 0.02$	$1.79^{b}\pm 0.02$	$1.84^{h}\pm 0.02$	$15.94^{c}\pm 0.03$	$71.87^{h}\pm 0.00$
6	WB5	$3.15^{h}\pm 0.03$	$1.77^{e}\pm 0.02$	$0.62^{f}\pm 0.02$	$4.36^{d}\pm 0.02$	$16.05^{bcd}\pm 0.02$	$71.35^{h}\pm 0.00$
7	WS1	$7.82^{bc}\pm 0.02$	$0.82^{h}\pm 0.02$	$1.86^{a}\pm 0.02$	$1.93^{g}\pm 0.03$	$8.90^{j}\pm 0.03$	$81.95^{a}\pm 0.00$
8	WS2	$5.23^{f}\pm 0.03$	$1.96^{d}\pm 0.02$	$1.64^{d}\pm 0.02$	$4.91^{c}\pm 0.02$	$10.73^{g}\pm 0.15$	$77.05^{d}\pm 0.00$
9	WS3	$5.33^{ef}\pm 0.01$	$2.07^{c}\pm 0.02$	$1.71^{c}\pm 0.02$	$4.94^{c}\pm 0.02$	$9.50^{i}\pm 0.10$	$76.63^{e}\pm 0.00$
10	WS4	$5.31^{ef}\pm 0.01$	$2.05^{c}\pm 0.02$	$1.67^{d}\pm 0.03$	$4.93^{c}\pm 0.03$	$12.06^{f}\pm 0.20$	$75.77^{f}\pm 0.00$
11	WS5	$2.57^{i}\pm 0.04$	$0.93^{f}\pm 0.01$	$0.61^{f}\pm 0.02$	$2.15^{e}\pm 0.02$	$14.14^{e}\pm 0.04$	$73.44^{g}\pm 0.00$

Valus are Mean ± standard deviations of three (3) replicate. Data in the same column bearing different superscripts, differ significantly ($p<0.05$).

KEY: WY: Whole Water Yam Flour (100 %); WB1: (90:10): Water Yam + Boiled Black Turtle Bean Flour; WB2: (80:20): Water Yam + Boiled Black Turtle Bean Flour; WB3: (70:30): Water Yam + Boiled Black Turtle Bean Flour; WB4: (60:40) Water Yam + Boiled Black Turtle Bean Flour; WB5: (50:50) Water Yam + Boiled Black Turtle Bean Flour; WS1: (90:10): Water Yam + Soaked Black Turtle Bean Flour; WS2: (80:20): Water Yam + Soaked Black Turtle Bean Flour; WS3: (70:30) Water Yam + Soaked Black Turtle Bean Flour; WS4: (60:40) Water Yam + Soaked Black Turtle Bean Flour; WS5: (50:50) water yam + soaked black turtle flour.

and Dauda *et al*. (2022) for water yam and soybean flours,

The crude fiber content varied from 1.83 to 5.20 %. There were significant differences ($p<0.05$) between the samples. The high heat treatment during boiling resulted in a noticeable drop (1.84 %) in the samples' fiber content, whilst soaking produced a discernible increase (4.94 %) in same. This may be due to the fact that high thermal processes soften the fibre content (soluble and insoluble fibres) of foods which must have resulted to this decrease in fibre while soaking has less permissible strength. These results were greater than the values of Olapade *et al.* (2014) for fufu flours and Dauda *et al.* (2022) for white yam and cocoyam flours, which were 2.37 to 2.44 % and 0.14 to 1.42 %, respectively.

The percentages of protein varied between 5.50 and 16.56 %. Control Sample WY (100% water yam), had the lowest value of 5.20 %, while sample WB5(50:50- water yam: boiled black turtle bean), had the highest value of 16.50 %. Significant variations ($p<0.05$) were seen in the protein composition of the flour samples. The findings demonstrated that when the amount of black turtle beans in the flour blends increased, so did their protein level. This may be explained by the fact that 100% yam flour has a lower protein level (5.50%) than black turtle bean (16.05%). These values are greater than the values of 7.80–8.30 % for white yam and coco yam flours reported by Dauda *et al.* (2022) and 2.40 to 11.16 % for fufu composite flours reported by Odoh *et al*. (2022).

The carbohydrate values ranged from 71.35 to 81.95 %, with sample WB5 (50:50-water yam: boiled black turtle bean) having the lowest value of 71.35 %, which may have decreased due to decreased inclusion of water yam, and sample WS1 (90:10-water yam: black turtle bean) having the highest value of 81.95 % which may be attributed to the high ration of water yam in the flour sample. There were notable variations ($p<0.05$) between the samples. This outcome demonstrated that as the ratio of the water yam decreased the carbohydrate content of the sample increased with an increase in black turtle bean.

Anti-nutritional composition of instant flours produced from water yam and black turtle bean:

Table 3 shows the anti-nutritional composition of stiff dough flour blends from water yam and black turtle bean. The tannin content of the flour samples varied from 0.06 to 0.94 mg/100g. Samples WB1 (90:10- water yam:boiled black turtle bean) had the highest value while sample WB5(50:50) had the lowest value. The outcome demonstrates that the high concentration of water yam in the flour samples raised the degree of tannin content. These values compared well with the values 0.00 to 1.65 mg/100g obtained by Olaposi *et al.* (2017) for soaked and boiled Bambara groundnut cultivars. The significant reductions in tannins may be due to the removal of the seed coat from the legumes and leaching of tannins into the water. Mazahib *et al.* (2013) stated that soaking reduced the tannin content of cowpea, African yam beans, Bambara nut to non-detectable levels. Kalu *et al.* (2019) asserted that phenolics and tannins are water soluble and can be removed by soaking together with boiling.

The saponin contents varied from 0.06 to 0.98 mg/100g. The control sample WY (100 % water yam), had the highest 0.98 mg/100g while sample WS1 (90:10- water yam: soaked black turtle bean) had the lowest value of 0.06 mg/100g. The significant reduction in saponin may be due to the removal of the legume seed coat and the leaching of saponin into the soaking water. The saponin content obtained in this study were lower than the values 3.04 to 9.10 mg/100g reported by Olaposi *et al.* (2017) for newly developed Bambara groundnut cultivars after soaking for 0, 12, 24, 48 h and 1.37 mg/100g reported by

Table 3: Anti-Nutritional Composition of Flour from blends of Water Yam and Black Turtle Bean Flour (mg/100g)

S/N	Samples	Tannin	Saponin	Phytate	Oxalate
1	WY	$0.87^{a}\pm 0.02$	$0.98^{a}\pm 0.02$	$0.77^{a}\pm 0.01$	$0.87^{a}\pm 0.03$
2	WB1	$0.94^{d}\pm 0.01$	$0.71^{b}\pm 0.02$	$0.69^{c}\pm 0.01$	$0.56^{c}\pm 0.02$
3	WB2	$0.76^{c}\pm 0.01$	$0.79^{c}\pm 0.02$	$0.72^{b}\pm 0.00$	$0.68^{b}\pm 0.02$
4	WB3	$0.07^{d}\pm 0.00$	$0.63^{d}\pm 0.02$	$0.06^{d}\pm 0.05$	$0.04^{f}\pm 0.00$
5	WB4	$0.85^{b}\pm 0.03$	$0.63^{d}\pm 0.02$	$0.06^{g}\pm 0.00$	$0.09^{d}\pm 0.00$
6	WB5	$0.06^{d}\pm 0.00$	$0.07^{g}\pm 0.00$	$0.05^{h}\pm 0.02$	$0.04^{f}\pm 0.00$
7	WS1	$0.91^{a}\pm 0.05$	$0.06^{f}\pm 0.02$	$0.06^{g}\pm 0.00$	$0.02^{h}\pm 0.00$
8	WS2	$0.07^{d}\pm 0.00$	$0.07^{g}\pm 0.04$	$0.07^{g}\pm 0.05$	$0.03^{g}\pm 0.00$
9	WS3	$0.08^{d}\pm 0.00$	$0.08^{e}\pm 0.00$	$0.07^{g}\pm 0.00$	$0.03^{g}\pm 0.02$
10	WS4	$0.79^{c}\pm 0.00$	$0.08^{e}\pm 0.01$	$0.07^{g}\pm 0.04$	$0.04^{f}\pm 0.01$
11	WS5	$0.07^{d}\pm 0.06$	$0.71^{b}\pm 0.02$	$0.07^{g}\pm 0.00$	$0.05^{e}\pm 0.00$

Mean ± standard deviations of three (3) replicate. Data in the same column bearing different superscripts, different significantly (p<0.05%).

KEY: WY: Whole Water Yam Flour (100 %); WB1: (90:10): Water Yam + Boiled Black Turtle Bean Flour; WB2: (80:20): Water Yam + Boiled Black Turtle Bean Flour; WB3: (70:30): Water Yam + Boiled Black Turtle Bean Flour; WB4: (60:40) Water Yam + Boiled Black Turtle Bean Flour; WB5: (50:50) Water Yam + Boiled Black Turtle Bean Flour; WS1: (90:10): Water Yam + Soaked Black Turtle Bean Flour; WS2: (80:20): Water Yam + Soaked Black Turtle Bean Flour; WS3: (70:30) Water Yam + Soaked Black Turtle Bean Flour; WS4: (60:40) Water Yam + Soaked Black Turtle Bean Flour; WS5: (50:50) water yam + soaked black turtle flour.

Mbagwu *et al*. (2011) for Bambara groundnut after soaking for 48 h.

The range of phytates was 0.05 to 0.77 mg/100g. The lowest level (0.05 mg/100g) was found in boiled sample WB5 (50:50), while the highest (0.77 mg/100g) was found in sample WY (100 percent water yam). Phytic acid frequently forms complexations with salts and minerals, it is possible that some of these compounds seeped into the soaking and boiling solutions, contributing to the decrease in the phytate concentration of the flour samples. These results are lower than the values of 365 to 813 mg/100g reported by Olaposi *et al.* (2017) for newly developed Bambara groundnut cultivar flours. Soaking which caused a significant reduction of phytate agreed with the result of Udensi *et al.* (2008) who reported phytate level of 0.387 to 0.097 after 24 h soaking.

The range of oxalate was 0.87 to 0.02 mg/100g. The highest amount of oxalate (0.87 mg/100g) was observed in sample WY (100 percent water yam) while sample WS1 (90:10), which was soaked, had the lowest content of 0.02 mg/100g. Soaking significantly reduced the oxalate content of the samples than boiling. This decrease might be the consequence of soluble oxalate salts seeping into the soaking and boiling media.

Sensory evaluation of stiff dough produced from blends of water yam and black turtle bean

The consumer acceptance of stiff dough made from mixtures of black turtle beans and water yam is shown in Table 4. Significant variations (p<0.05) were observed in every sensory parameter assessed. The sensory score for appearance ranged from 4 to 8. Sample WB1 (90:10- water yam: boiled black turtle bean) had the lowest value of 4.0 whereas sample WY (100 percent water yam) had the highest score of 8.0. Colour ranged from 4.0 to 8.0. Control sample WY (100% water yam) had the highest. This was followed by soaked sample WS1(90:10) with 7.0 while boiled sample WB1(90:10) had the lowest score of 4.0. Texture was rated on the basis of roughness/smoothness and ranged from 6.0 to 7.0. The control sample WY, boiled sample WB2(80:20), soaked sample WS2(80:20) and soaked sample WS4(60:40) had the highest scores 7.0, while the rest of the samples did not differ significantly (p>0.05). The texture decreased with increased inclusion of black turtle bean. The mouldability scores ranged from 4.0 to 7.0. The control sample (100 % water yam) and the boiled sample WB1 (90:10) received the highest ratings (7.0), whereas the boiled sample WB5 (50:50) received the lowest ratings. Thus, the higher the legume the lesser the mouldability. Taste ranged from 3.0 to 8.0. Significant variations existed. The sensory scores for aftertaste varied from 3.0 to 7.0. Sample WY (100 % water yam) had the highest value of 7.0, while sample WS4 (60:40) had the lowest value of 3.0. The overall acceptability of the stiff dough samples ranged from 5.0 to 8.0. The control sample WY (100 % water yam) was the most preferred by the consumers followed by soaked sample WS1 (90:10) while boiled sample WB1 (90:10) was rated the lowest score of 5.0.

Table 4: Sensory Evaluation of Stiff Dough Produced from Blends of Water Yam and Black Turtle Bean Flours

S/N	Sample Code	Appearance	Colour	Texture (roughness andsmooth-ness)	Moulda-bility	Taste	After taste	Mouthfeel	Overall acceptab-ility
1	WY	$8^{a} \pm 0.73$	$8^{a} \pm 0.85$	$7^{a} \pm 1.05$	$7^{b} \pm 0.65$	$8^{a} \pm 0.65$	$7^{a} \pm 0.82$	$7^{a} \pm 0.92$	$8^{a} \pm 0.79$
2	WB1	$4^{e} \pm 1.26$	$4^{e} \pm 1.37$	$6^{ab} \pm 1.80$	$7^{a} \pm 1.01$	$3^{h} \pm 1.21$	$3^{i} \pm 1.27$	$4^{g} \pm 1.72$	$5^{d} \pm 1.76$
3	WB2	$6^{bcd} \pm 0.66$	$6^{bcd} \pm 0.69$	$7^{a} \pm 0.91$	$5^{ef} \pm 1.15$	$5^{ef} \pm 1.12$	$4^{efg} \pm 1.21$	$6^{cde} \pm 1.09$	$6^{c} \pm 0.50$
4	WB3	$7^{bc} \pm 0.91$	$7^{bc} \pm 0.99$	$6^{ab} \pm 1.01$	$6^{de} \pm 1.16$	$4^{f} \pm 1.29$	$4^{gh} \pm 1.27$	$6^{bcd} \pm 1.04$	$6^{bc} \pm 0.62$
5	WB4	$6^{bcd} \pm 0.79$	$6^{cd} \pm 0.82$	$6^{ab} \pm 0.97$	$6^{cd} \pm 1.13$	$5^{def} \pm 1.04$	$5^{def} \pm 1.10$	$5^{fg} \pm 1.44$	$6^{c} \pm 0.94$
6	WB5	$6^{cd} \pm 1.00$	$6^{bcd} \pm 0.89$	$6^{ab} \pm 0.61$	$4^{f} \pm 1.61$	$6^{cde} \pm 1.62$	$5^{d} \pm 1.54$	$5^{efg} \pm 1.01$	$6^{bc} \pm 0.80$
7	WS1	$7^{b} \pm 1.01$	$7^{b} \pm 0.83$	$6^{a} \pm 0.71$	$6^{bc} \pm 0.65$	$7^{b} \pm 0.85$	$6^{b} \pm 0.91$	$7^{b} \pm 0.82$	$7^{b} \pm 0.79$
8	WS2	$6^{cd} \pm 0.65$	$6^{bcd} \pm 0.76$	$7^{a} \pm 1.23$	$6^{bc} \pm 0.94$	$6^{bc} \pm 0.72$	$6^{bc} \pm 0.89$	$6^{bc} \pm 0.89$	$6^{bc} \pm 0.71$
9	WS3	$7^{bc} \pm 1.08$	$7^{bc} \pm 0.98$	$6^{b} \pm 1.08$	$6^{de} \pm 1.16$	$6^{cd} \pm 1.42$	$5^{cd} \pm 1.29$	$6^{bcd} \pm 1.12$	$6^{bc} \pm 1.39$
10	WS4	$6^{bcd} \pm 0.92$	$6^{cd} \pm 1.29$	$7^{a} \pm 0.94$	$6^{bc} \pm 1.22$	$3^{g} \pm 1.19$	$3^{i} \pm 1.08$	$6^{cde} \pm 1.68$	$6^{c} \pm 0.85$
11	WS5	$6^{cd} \pm 1.17$	$6^{bcd} \pm 0.90$	$6^{ab} \pm 0.61$	$5^{ef} \pm 1.47$	$4^{f} \pm 1.66$	$4^{fg} \pm 1.59$	$5^{def} \pm 1.54$	$6^{bc} \pm 0.67$

Values are Means±standard deviations of three (3) replicate. Data in the same column bearing different superscript are significantly different ($p<0.05$)

Key: WY: whole water yam flour (100%); WB1: (90:10): water yam + boiled black turtle bean flour; WB2: (80:20): water yam + boiled black turtle bean flour; WB3: (70:30): Water yam + boiled black turtle bean flour; WB4: (60:40) Water Yam + Boiled Black Turtle Bean Flour; WB5: (50:50) Water Yam + Boiled Black Turtle Bean Flour; WS1: (90:10): Water Yam + Soaked Black Turtle Bean Flour; WS2: (80:20): Water Yam + Soaked Black Turtle Bean Flour; WS3: (70:30) Water Yam + Soaked Black Turtle Bean Flour; WS4: (60:40) Water Yam + Soaked Black Turtle Bean Flour; WS5: (50:50) water yam + soaked black turtle flour

CONCLUSION

This study revealed the usefulness of water yam and black turtle bean both of which are underexploited agricultural products in Nigeria. In addition, samples containing 10, 30, and 40% black turtle bean flour were the most desirable in terms of protein, thus improving the reconstitution ability compared with yam flour. Soaking decreased favourably the saponin and oxalate contents while boiling reduced significantly the phytate and tannin content of the flour samples. Stiff dough made from soaked sample WS1 (90:10) were mostly preferred by the panelist's asides the control (100 % water yam). Using water yam flour in the preparation of stiff dough could be improved in terms of the nutritional, and sensory properties of the stiff dough by adding an appropriate proportion as seen in samples WB5(50:50- water yam:boiled black Turtle Bean), and WB4(60:40-water yam:boiled black Turtle Bean), which contains high levels of protein (16.05 % and 15.94 %) makes them highly recommended. By replacing yam flour with water yam black turtle bean flour, yam's economic significance and its reliance on the production of stiff dough is decreased.

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Calcium and Phosphorus Contents of Non-Bioprocessed and Bio-Processed *Mucuna pruriens* (Egbara) Seed Flour

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KEYWORDS

Cooking,
Fermentation
Mucuna pruriens,
Germination,
Soaking,

ABSTRACT

This study evaluated the effect of non-bioprocessing and bioprocessing on the calcium and phosphorus content of Mucuna pruriens seed flour. The seeds were cleaned, washed, soaked in distilled water (24 h, 48 h and 72 h), cooked (20 min, 40 min, 60 min and 80 min), roasted (10 min, 15 min and 20 min), germinated (24 h, 48 h and 72 h) and fermented with Rhizopus oligosporus (24 h, 48 h and 72 h). Calcium and phosphorus contents of the samples were determined. Calcium ranged from 187.10 – 425.68 mg/100 g while phosphorus ranged from 778.00 – 1790 mg/100 g. Germination (24 h) and fermentation (24, 48 and 72 h) significantly (p < 0.05) increased calcium while other treatments decreased it. Roasting for 10 min significantly increased phosphorus content while others decreased it. Fermentation with Rhizopus oligosporus and roasting for 10 min are therefore recommended for the improvement in the calcium and phosphorus contents of Mucuna pruriens seed flour respectively.

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INTRODUCTION

Mucuna pruriens commonly known as velvet bean, cowitch or cowhage is of the family leguminosae, genus; Mucuna and Specie; *Mucuna pruriens* (Pathania *et al*., 2020). In Nigeria, *Mucuna pruriens* is known as "Egbara" or "Agbara" in south Eastern part of Nigeria or "Werepe" in the Western part of Nigeria. *Mucuna pruriens* is a good source of crude protein (24 - 31.44 %), crude fibre and ash (2.9 - 5.5 %) and its digestibility is comparable to that of other pulses like soybean, rice bean and lima bean (Pathania *et al*., 2020). Raw seed of *Mucuna pruriens* contains minerals in the following range; Potassium: 806 - 2,790 mg/100 g, Sodium: 4 – 70 mg/100 g, Calcium: 104 – 900 mg/100 g, Phosphorus: 98 - 498 mg/100 g, Magnesium: 85 – 477 mg/100g, Iron: 1.3 – 15 mg/100 g, Copper: 0.33 - 4.34 mg/100 g, Zinc: 1 – 15 mg/100 g and Manganese: 0.56 - 9.26 mg/100 g (Pathania *et al*., 2020).

In the body, Calcium (Ca) is needed for maintenance of good health and the integrity of several systems like the musculoskeletal system, nervous system, and the heart (Buturi *et al*., 2021). Maintaining good bone, tooth, and mineral homeostasis is essential (Buturi *et al*., 2021). Calcium also acts as a cofactor in many enzymatic reactions and contributes to parathyroid function (Beto, 2015). Phosphorus is a macro-mineral required by the body for the first steps in carbohydrate metabolism and B-group Vitamins utilization (Okaka *et al*., 2002). More than 80% of phosphorus in the human body is bound to calcium as hydroxyapatite in teeth and bones (Okaka *et al*., 2002).

To reduce/eliminate the anti-nutritional factors and improve the nutritional quality and effectively utilize grain legumes like *Mucuna pruriens*, soaking, dehulling, cooking, fermentation, germination, toasting/roasting and autoclaving can be adopted. During these processes geared towards making *Mucuna pruriens* seed wholesome, there are possibilities of reduction or improvement in the calcium and phosphorus content whose details are largely lacking. Hence this study was embarked on to investigate the effects of soaking, cooking, roasting, germination and fermentation on the calcium and phosphorus content of *Mucuna pruriens* seed flour.

MATERIALS AND METHODS

Mucuna pruriens seeds were purchased from New Market in Enugu State, Nigeria. Soaking, boiling, roasting, germination and fermentation were used in processing *Mucuna pruriens* seed. A completely randomized design was adopted in this experiment.

Soaking of *Mucuna pruriens* seeds

As outlined by Mugendi *et al*. (2010), whole *Mucuna pruriens* seeds (1.2 kg) were cleaned of any extraneous materials while in dry form, sorted and washed with distilled water. The seeds were divided into three batches (400 g each) which were coded S24h, S48h and S72h and were soaked in distilled water (1:5 w/v) for 24 h, 48 h and 72 h respectively. A 6-hour interval change of distilled water was maintained during the process. At the end of soaking for each batch, the samples were drained and dried in a hot air oven (Laboratory Oven, England Labscience, DHG-9053A) at 70˚C (for 18 h with constant turning after every 4 h) to constant weight. They were finally ground using a blender (Binatone BL-1500PRO, China) and stored in a high-density polyethylene bag in readiness for analysis.

Boiling of *Mucuna pruriens* seeds

As described by Mugendi *et al*. (2010), whole *Mucuna pruriens* seeds were cleaned, sorted and washed with distilled water. The seeds were divided into four batches of 400 g each. The four batches coded C20m, C40m, C60m and C80m were boiled in distilled water (1:5 w/v) for 20, 40, 60 and 80 min respectively. The samples were drained, dried in a hot air oven (Laboratory Oven, England Labscience, DHG-9053A) at 70˚C (for 18 h with constant turning after every 4 h) to constant weight, ground and stored in high-density polyethylene bags in readiness for analysis.

Roasting of *Mucuna pruriens* seeds

As described by Mugendi *et al*. (2010), whole *Mucuna pruriens* seeds were sorted and cleaned of unwanted and extraneous materials. The seeds were divided into three batches (R10m, R15m and R20m) of 400 g per batch. The batches were roasted in an oven (Electric hot Oven, Saisho Model: S-936R, China) at 150˚C; batch 1 (R10m) was roasted for 10 min, batch 2 (R15m) for 15 min and batch 3 for 20 min respectively. The samples were allowed to cool, ground and stored in high-density polyethylene bags in readiness for analysis.

Germination of *Mucuna pruriens* seeds

The procedure of Mugendi *et al.* (2010) was used for the germination process. One hundred grams (100 g) of *Mucuna pruriens* seeds were soaked in ethanol (1:2 w/v) for 1 min to aid decontamination. The ethanol was drained afterwards. Seeds were soaked in distilled water (1:10, w/v) for 12 h at room temperature (27±2°C). The water was drained, the seeds were divided into three (3) groups (G24h, G48h and G72h) and spread on jute bags that were placed on top of a wool-cloth, covered with a black-coloured low-density polyethylene bag and allowed to germinate (27±2°C) in the dark. The seeds in group 1 (G24h) were removed after 24 h, group 2 (G48h) removed after 48 h and group 3 (G72h) removed after 72 h. Seeds were afterwards dried in an oven (Laboratory hot air Oven, England Labscience, DHG-9053A) at 70°C (for 18 h with constant turning after every 4 h) to constant weight. Dried germinated seeds were ground with a blender (Binatone BL-1500PRO, China) into flour and stored in high-density polyethylene bags for analysis.

Fermentation of *Mucuna pruriens* seeds

The procedure described by Egounlety (2003) was adopted for the fermentation process. *Mucuna pruriens* seeds were boiled in distilled water for 45 min (1kg/6 L), hand-dehulled, chopped into 2-3 pieces per grain, soaked twice (1 kg/3 l) for 12 h with removal of soak water after each soaking period, re-cooked for 45 min (1kg/6 L), drained and cooled. To prevent the growth of the other microorganisms and to maintain the pH for the convenient growth of *R. oligosporus*, pH of the substrate was adjusted using vinegar of grapes at 2.85 mL per 100 g of substrate. The grains obtained were divided into three portions, inoculated with *Rhizopus oligosporus* (Ragi Tempe, Raprima Inokulum Tempe, PT.Aneka Fermentasi Industri, Sandung 40553 -Indonesia) (0.4 g/kg drained grain), packed in low-density polyethylene perforated bags (50 µm) and allowed to ferment (29°C) in an incubator (LAB-TECH 150421, India) for 24 h, 48 h and 72 h to obtain samples F24h, F48h and F72h, respectively.

Determination of calcium and phosphorus

The minerals in the *Mucuna pruriens* seed flours were analysed using the method described by Asaolu *et al*. (2012). An aliquot of 2.0 g of the samples was digested with concentrated nitric acid and concentrated perchloric acid in ratios 5:3(v/v), the mixture was placed on a water bath for 3 hours at 80°C. The resultant solution was cooled and filtered into 100 mL standard flask and made to mark with distilled. The appropriate lamps for the minerals were used. After digestion and appropriate dilution, the digested samples were aspirated into an air–acetylene flame to burn the elements into atomic components, which were then detected in a spectrophotometer (Buck scientific model 211A, USA) at 422.7 nm for calcium. Phosphorus content in the digested extract was determined colorimetrically by the addition of 1mL molybdate reagent with shaking gently to mix thoroughly and it was allowed to stand for 15 min. Afterwards, 1mL of 1% ascorbic acid was added and also allowed to stand for 15 min. The absorbance of the solution was then measured at 660 nm. The concentrations of the minerals were determined using standard curves generated with standard solutions (0.5, 1.0, 2.0, 5.0 mg/L) of the respective minerals (Sigma Chemical Co., USA). The same procedure was used for blank solutions but devoid of the respective mineral solutions and the values deducted accordingly.

RESULTS AND DISCUSSION

Calcium content of non-bioprocessed and bioprocessed *Mucuna pruriens* seed flour
Calcium content was in the range of 187.10 – 425.68 mg/100 g. The various treatments effected significant ($p < 0.05$) differences in the calcium content of the samples. The treatments significantly reduced the calcium content except 24 h germination and fermentation (24 h, 48 h and 72 h) which significantly increased Calcium from 218.17 mg/100 g in the raw *Mucuna pruriens* seed flour (CON) to 234.36 mg/100 g and 425.68 mg/100 g respectively. The microbial biomass of *R. oligosporus* formed during fermentation contribute to the overall increase in minerals like calcium of the fermented legume seeds (Toor *et al*., 2021). Germination also has the ability to increase the calcium content of legumes as corroborated by Luo and Xie (2013) who reported an increase in calcium after germination of Faba Bean and Soybean. Fermentation for 24, 48 and 72 h significantly ($p < 0.05$) increased calcium in an irregular pattern. Calcium, along with vitamin D, may improve bone health and is associated with a reduced risk of various types of cancer (Castiglione *et al*., 2018). The Recommended Daily Allowance (RDA) for Calcium is between 1,000 - 1,300 mg per day (Buturi *et al*., 2021). Calcium (187.10 – 425.68 mg/100 g) content of the samples were lower than the RDAs of 1,000 mg/d for calcium as documented by Benayad and Aboussaleh (2021).

Treatments

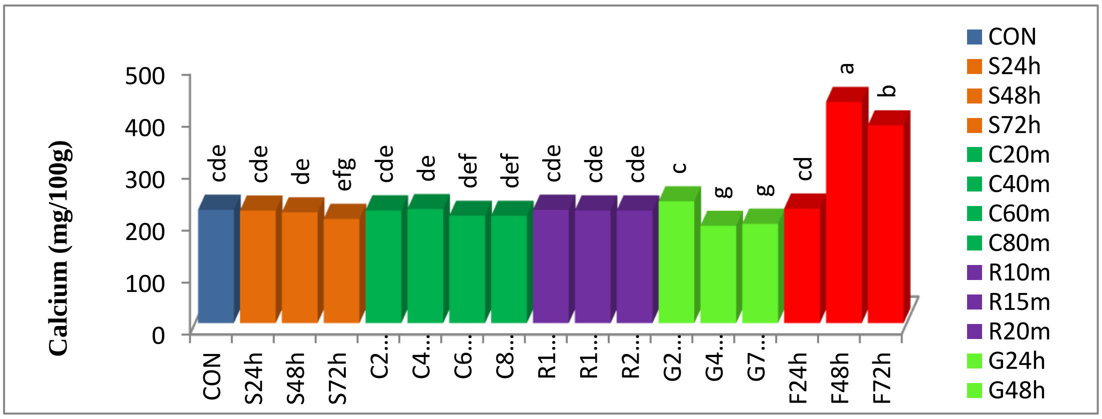

Figure 1: Calcium content of *Mucuna pruriens* seed flour that received single treatments

CON = Control; S24h = 24 h soaked; S48h = 48 h soaked; S72h = 72 h soaked; C20m = 20 min cooked; C40m = 40 min cooked; C60m = 60 min cooked; C80m = 80 min cooked; R10m = 10 min roasted; R15m = 15 min roasted; R20m = 20 min roasted; G24h = 24 h germinated; G48h = 48 h germinated; G72h = 72 h germinated; F24h = 24 h fermented; F48h = 48 h fermented; F72h = 72 h fermented.

Phosphorus content of non-bioprocessed and bioprocessed *Mucuna pruriens* seed flour

Phosphorus content ranged from 778.00 – 1790 mg/100 g. The phosphorus content was significantly ($p < 0.05$) reduced by many of the treatments except cooking (20 min) and roasting (10 and 15 min). These findings regarding the increase in phosphorus during roasting agree with the findings of Aware *et al*. (2019) which indicated an increase in phosphorus after the roasting of *Mucuna macrocarpa* seeds. Phosphorus functions as part of the high energy storage molecules adenosine tri-phosphate and adenosine di-phosphate, which are important for the phosphorylation of several components required for optimal body function (Okaka *et al*., 2002). Suboptimal phosphorus intake can cause rickets, osteomalacia, and fragile bones in adults (Okaka *et al*., 2002). The recommended daily intake of phosphorus is 1,200 mg/day by Benayad and Aboussaleh (2021) and many of the values recorded for phosphorus in this research were higher than the 1,200 mg/day Recommended Dietary Allowance (RDA) for Phosphorus.

Treatments

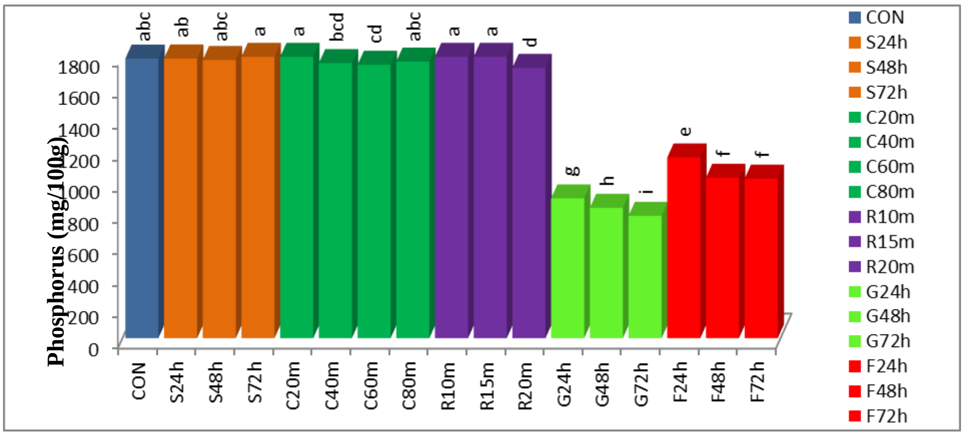

Figure 2: Phosphorus content of *Mucuna pruriens* seed flour that received single treatments

CON = Control; S24h = 24 h soaked; S48h = 48 h soaked; S72h = 72 h soaked; C20m = 20 min cooked; C40m = 40 min cooked; C60m = 60 min cooked; C80m = 80 min cooked; R10m = 10 min roasted; R15m = 15 min roasted; R20m = 20 min roasted; G24h = 24 h germinated; G48h = 48 h germinated; G72h = 72 h germinated; F24h = 24 h fermented; F48h = 48 h fermented; F72h = 72 h fermented.

CONCLUSION

Germination for 24 h and fermentation for 24 h, 48 h and 72 h are suitable for the improvement of calcium in Mucuna pruriens seed flour. Soaking, cooking, roasting, germination and fermentation (*Rhizopus oligosporus*) of *Mucuna pruriens* seed are not very suitable for the enhancement of phosphorus in Mucuna pruriens seed flour.

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Mineral and Sensory Properties of 'Àmala' Produced from Yam and Cassava Flours Flavoured with Ginger Flour

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KEYWORDS

Àmàla,
Cassava,
Composite flour,
Ginger,
Yam,

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ABSTRACT

This study assessed the mineral and sensory properties of 'àmàlà' produced from yam (Dioscorea rotundata) and cassava (Manihot esculenta) flours flavoured with ginger (Zingiber officinale) flour. The three raw materials were individually processed into flour and mixture design generated by the design expert software version 12 was used to formulate a total of 13 runs. The results were compared with two controls; sample 1 (100% yam flour) and sample 2 (100% cassava flour). The samples were evaluated for mineral and sensory properties using standard operating procedures. The results obtained for the mineral analysis showed that the calcium, magnesium, zinc and iron contents ranged from 3.17-93.81 mg/100 g, 3.35-103.77 mg/100 g, 0.61-1.83 mg/100 g and 0.17-10.87 mg/100 g respectively. Sample 13 (55 yam flour: 30 cassava flour: 15 ginger flour) had the highest iron content. Major striking observation revealed that the addition of cassava flour to these flour samples improved the mineral content of these samples as the control, sample 1 (100% yam flour) had very little mineral content when compared to the rest of the samples. For the sensory evaluation of the 'àmàlà', sample 10 (50 yam flour: 30 cassava flour: 20 ginger flour) and sample 1 were the most preferred in terms of general acceptability amongst other samples on the 9-point Hedonic scale and of all the minerals analyzed in this work, only the iron content met the requirements for Recommended Dietary Allowance of iron for men and postmenopausal women.

INTRODUCTION

Àmàlà' is a traditional Nigerian cuisine originating from the Yoruba ethnic group in the western regions of the country. Crafted from yam and/or cassava flour, as well as unripe plantain flour, 'amàlà' is prepared by peeling, slicing, cleaning, drying, and blending yams into a flour known as 'elubo.' Notably, this 'elubo' serves as the base for making 'amàlà.' Recognized for its nutritional benefits, it boasts a higher protein content compared to other root tubers (Okigbo and Nwakammah, 2005). Furthermore, the carbohydrate and rich dietary fibre content in 'amàlà' contribute to the elimination of body waste, while also reducing the risk of heart conditions associated with elevated cholesterol levels. Additionally, the presence of vitamins and antioxidants in 'amàlà' plays a role in enhancing the immune system.

"Over the years, the production of 'amàlà' has predominantly relied on yam alone. However, research, Magallanes *et al*., (2017) indicates that yam flour lacks the sufficient mineral content necessary for 'amàlà' to be considered suitable for consumption by individuals who are obese or have high blood pressure. As a response to this, a composite of cassava and ginger flours has been introduced alongside yam flour. This combination can provide the essential requirements needed to address these health conditions and render 'amàlà' more fit for consumption.

Yam, the common name for certain plant species in the Dioscorea genus, yields edible tubers. Independently domesticated on three continents—Africa (*Dioscorea rotundata*), Asia (*Dioscorea alata*), and the Americas (*Dioscorea trifida*)—yams play a crucial role in the culinary landscape (Nora, 2019).

Yam flour, being gluten-free, serves as a viable option for individuals with gluten allergies (Okigbo and Nwakammah, 2005).

Cassava (*Manihot esculenta*) flour, a noteworthy substitute for wheat flour in various recipes, is rich in carbohydrates, vital vitamins such as Vitamin C, and essential minerals. With fewer than 120 calories per quarter-cup serving, cassava flour stands out as a lower-calorie alternative among gluten-free flours. Notably, cassava flour contains resistant starches, exhibiting properties akin to soluble fibre, which bypass digestion in the small intestine (Magallanes *et al*., 2017).

Ginger (*Zingiber officinale*), a flowering plant renowned for its rhizome or ginger root, serves dual roles as a spice and folk medicine. Studies, Murad *et al*., (2018) suggest that ginger may contribute to a reduction in body mass index (BMI) and blood insulin levels. Moreover, ginger has demonstrated the ability to significantly decrease LDL (bad) cholesterol, total cholesterol, and blood triglyceride levels, thereby mitigating the risk of heart disease (Murad *et al*., 2018). The anti-inflammatory and antioxidant properties of ginger further positions it as a preventive measure against cancer (Dugasani *et al*., 2010).

MATERIALS AND METHODS

Tubers of cassava were sourced from Nnamdi Azikiwe University farmers association, Awka, Anambra State. Tubers of white yam (*Dioscorea rotundata*) and fresh gingers were bought from Eke Awka Market, Awka South Local Government Area Anambra State and validated by the Department of Crop Science, Nnamdi Azikwe University, Awka. At the period of purchase, wholesome produce free of insect infestation or any physical damage was purchased.

Research Design

The composite flour mixture was generated using Mixture design D- Optimal from Design Expert 12 statistical software. The design key is as shown on Table 1. The experiment had a total of 13 runs and 2 controls (Table 2). The mixture components, A (Yam flour), B (Cassava flour), C (Ginger flour) was summed up to 100.

Table 1: Design key

Factors	Unit	Name	Low	High
X1	G	Yam flour	50	60
X2	G	Cassava flour	30	40
X3	G	Ginger flour	10	20

Table 2: Design of experiment for composite flour

Run	Component 1 A:Yam flour g	Component 2 B:Cassava flour G	Component 3 C:Ginger flour g
1	100	0	0
2	0	100	0
3	55	35	10
4	50	40	10
5	50	30	20
6	53.33	33.33	13.34
7	51.67	36.66	11.67
8	50	40	10
9	51.67	36.66	11.67
10	50	30	20
11	60	30	10
12	60	30	10
13	55	30	15
14	56.67	31.67	11.66
15	50	35	15

METHODS

Production of yam flour

The yam tubers were thoroughly inspected for wholesomeness. They were washed properly in order to get rid of sand and other extraneous materials. The washed yam was peeled using a kitchen knife and sliced to 1 mm thickness. The yam slices were washed after which the sliced yam was steeped into boiled water for 3 minutes. The parboiled yam slices were dried in oven at 70ºC for 17 hours. The yam chips were milled using Mouliner 1000W blender to get flour and finally sifted with standard sieve BSS 44 to get uniform particle size (Nojimu *et al*., 2003).

Production of cassava flour

Mature wholesome cassava tubers were chosen from the lots. They were properly washed in order to get rid of sand and other extraneous materials. The tubers were peeled, sliced to 3 mm thickness and washed. The washed tubers were soaked in water for 3 days for fermentation at 35ºC to take place, to remove hydrogen cyanide in it. After fermentation, the slices were removed from the water, rinsed, further sliced to 1 mm thickness and dried in an oven at 70ºC for 11 hours. The cassava chips were milled into flour using Mouliner 1000 W blender. The flour was sifted with BSS 44 standard sieve size to get uniform particle size (Achidi *et al*., 2008).

Production of ginger flour

The ginger roots were washed, peeled and sliced into thin slices of 1 mm. They were dried in an oven at 70ºC for 13 hours and milled into flour using Mouliner 1000W blender and sieved with BSS 44 standard sieve size to get fine flour (Ravindran, 2016).

Production of 'Àmàlà'

The flour samples were weighed with regards to the runs. Water was made to boil and the flour was reconstituted into the boiling water to form a thick paste of desired consistency.

Mineral Analysis of 'Àmàla'

Calcium, magnesium, Zzinc and iron were analyzed using Atomic absorption spectrophotometer (Varian Australia Pty Ltd.) according to (AOAC, 2010).

Sensory Evaluation of 'Àmàlà'

The processed flour was subjected to sensory evaluation. The flour was stirred in boiling water to make paste for each sample. A 9 point Hedonic scale was used in measuring the intensity and the acceptability of the pastes' colour, taste, aroma, mouldability, texture and general acceptability. A panel consisting of 25 judges including students and staff of the Nnamdi Azikwe University, Awka were used as semi trained panelists to evaluate the flour samples using the questionnaire provided for scoring different parameters using a 9-point Hedonic scale with the following rating: 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 and 1 – Dislike extremely (Iwe, 2010).

RESULTS AND DISCUSSION

Mineral composition of 'Àmàlà' samples

The mineral composition of the 'àmàlà' samples is shown in Table 3. The Calcium results of these samples ranged from 3.17 – 93.81 mg/100g with sample 5 (50 yam flour: 30 cassava flour: 20 ginger flour) having the highest calcium content. Omohimi *et al*., (2017) on the study of the proximate and mineral compositions of different yam chips, flakes and flours reported that the value of calcium in the yam flour samples to range from 16.1 – 25.9 mg/100 g. According to Kemi *et al*., (2010), calcium is an important element for bone formation. Adults aged 19 to 64 need 700 mg of calcium a day. In this study, the calcium proportion in these samples are low, this means that the diet should be modified with foods with high calcium levels.

The Magnesium content of the 'àmàlà' samples ranged from 3.35-103.77 mg/100 g. Sample 5 (50 yam flour: 30 cassava flour: 20 ginger flour) had the highest magnesium content. Omohimi *et al*., (2017) on the study of the proximate and mineral compositions of different yam chips, flakes and flours reported the magnesium content of yam flour to range from 31.1 – 36.0 mg/100 g which is low compared to the value of this study. The Recommended Dietary allowance (RDA) of Magnesium in adults aged 19-51 years is 200-400 mg daily for men and 310-320 mg for female. This goes further to show that the amount consumed per serving is not enough to meet the RDA.

The zinc content of the 'àmàlà' samples ranged from 0.61-1.83 mg/100 g. Sample 10 (50 yam flour: 30 cassava flour: 20 ginger flour) had the highest zinc content among other samples. From the study carried out by Omohimi *et al*., (2017) on the study of the proximate and mineral compositions of different yam chips, flakes and flours, it was recorded that the zinc content of yam flour samples ranged from 0.65-0.85 mg/100g which is slightly different from the results of this study. Zinc is a mineral that is essential for cell development and replication. RDA for zinc is 8 mg/day for females and 11 mg/day for males (Mason, 2008). From this research, the 'àmàlà' samples did not meet the Recommended Dietary Allowance (RDA).

Iron is an important mineral for red blood cell formation. The results showed that the iron content ranged from 0.17-10.87 mg/100 g, this is slightly different from the results reported on the study of the proximate and mineral composition of different yam chips, flakes and flours by Omohimi *et al*., (2017) which ranged from 7.61-11.49 mg/100 g. According to Mason (2008), the recommended dietary allowance of iron for men and postmenopausal women is 8 mg/day while 11, 15, and 30 mg/day were recommended for adolescents, premenopausal and pregnant women respectively. Our results showed that these 'àmàlà' samples can adequately supply iron in the diet except the control sample 1(100% yam flour) which had low iron content. Sample 13 (55 yam flour: 30 cassava flour: 15 ginger flour) had the highest iron content.

Table 3: Mineral analysis of the 'Àmàlà' samples

Sample	Calcium	Magnesium	Zinc	Iron
S1	$3.17^{o} \pm 0.01$	$3.35^{o} \pm 0.01$	$0.61^{m} \pm 0.00$	$0.17^{m} \pm 0.00$
S2	$57.31^{n} \pm 0.01$	$56.70^{n} \pm 0.00$	$1.53^{g} \pm 0.00$	$9.82^{g} \pm 0.03$
S3	$66.85^{m} \pm 0.03$	$82.63^{j} \pm 0.01$	$1.40^{k} \pm 0.00$	$10.54^{c} \pm 0.01$
S4	$67.13^{l} \pm 0.00$	$82.00^{m} \pm 0.00$	$1.33^{l} \pm 0.00$	$8.75^{k} \pm 0.00$
S5	$97.81^{a} \pm 0.01$	$103.77^{a} \pm 0.00$	$1.83^{b} \pm 0.00$	$8.80^{i} \pm 0.00$
S6	$69.11^{i} \pm 0.00$	$95.76^{e} \pm 0.01$	$1.51^{h} \pm 0.00$	$10.06^{f} \pm 0.01$
S7	$67.88^{j} \pm 0.00$	$82.57^{k} \pm 0.00$	$1.50^{i} \pm 0.00$	$9.62^{h} \pm 0.00$
S8	$67.42^{k} \pm 0.00$	$82.03^{l} \pm 0.00$	$1.47^{j} \pm 0.00$	$8.75^{k} \pm 0.00$
S9	$73.60^{h} \pm 0.00$	$83.00^{i} \pm 0.00$	$1.50^{i} \pm 0.00$	$8.78^{j} \pm 0.00$
S10	$93.25^{b} \pm 0.12$	$103.75^{b} \pm 0.06$	$1.85^{a} \pm 0.00$	$8.50^{l} \pm 0.00$
S11	$85.03^{f} \pm 0.06$	$85.30^{f} \pm 0.00$	$1.60^{d} \pm 0.01$	$10.33^{d} \pm 0.00$
S12	$85.10^{e} \pm 0.00$	$85.00^{g} \pm 0.00$	$1.58^{e} \pm 0.01$	$10.83^{b} \pm 0.01$
S13	$90.72^{c} \pm 0.00$	$97.83^{c} \pm 0.00$	$1.62^{c} \pm 0.00$	$10.87^{a} \pm 0.00$
S14	$83.73^{g} \pm 0.00$	$83.94^{h} \pm 0.00$	$1.53^{g} \pm 0.01$	$10.10^{e} \pm 0.00$
S15	$86.30^{d} \pm 0.00$	$97.14^{d} \pm 0.00$	$1.55^{f} \pm 0.00$	$8.35^{l} \pm 0.00$

Values of are mean ± standard deviation of triplicate determinations. Values in the same column bearing different superscript differed significantly ($p < 0.05$). S2 = 100 g cassava flour, S3 = 55:35:10 of yam flour, cassava flour and ginger flour, S4 = 50:40:10 of yam flour, cassava flour and ginger flour, S5 = 50:30:20 of yam flour, cassava flour and ginger flour, S6 = 53.33:33.33:13.34 of yam flour, cassava flour and ginger flour, S7 = 51.67:36.66:11.67 of yam flour, cassava flour and ginger flour, S8 = 50:40:10 of yam flour, cassava flour and ginger flour, S9 = 51.67:36.66:11.67 of yam flour, cassava flour and ginger flour, S10 = 50:30:20 of yam flour, cassava flour and ginger flour, S11 = 60:30:10 of yam flour, cassava flour and ginger flour, S12 = 60:30:10 of yam flour, cassava flour and ginger flour, S13 = 55:30:15 of yam flour, cassava flour and ginger flour, S14 = 56.67:31.67:11.66 of yam flour, cassava flour and ginger flour, S15 = 50:35:15 of yam flour, cassava flour and ginger flour..

Sensory properties of 'Àmàlà' samples

The appearance of 'àmàlà' as shown in Table 4 ranged from 1.80 - 6.92. Samples 10 (50 yam flour: 30 cassava flour: 20 ginger flour) and 1(100% yam flour) had the highest score of 6.92 while sample 7 (51.67 yam flour: 36.66 cassava flour: 11.67 ginger flour) and sample 2 (100% cassava flour) had the least score of 1.80.

The taste of the 'àmàlà' as presented in Table 4 showed that the score ranged from 2.28 - 6.16. The aroma of the 'àmàlà' samples ranged from 3.24 - 6.20. Samples 10 (50 yam flour: 30 cassava flour: 20 ginger flour) and 1 (100% yam flour) had the highest score as they were liked slightly on the 9-point Hedonic scale.

The mouldability of the 'àmàlà' samples ranged from 1.44 – 7.20. Samples 7 (51.67 yam flour: 36.66 cassava flour: 11.67 ginger flour) and 2 (100% cassava flour) are significantly different ($p < 0.05$) from the rest of the samples as they had the lowest score and were disliked extremely on the 9-point Hedonic scale.

On overall acceptability, the result of the 'àmàlà' samples ranged from 2.08 – 7.16. Samples 10 (50 yam flour: 30 cassava flour: 20 ginger flour) and 1(100% yam flour) were liked moderately on the 9-point Hedonic scale. Samples 8 (50 yam flour: 40 cassava flour: 10 ginger flour) and 12 (60 yam flour: 30 cassava flour: 10 ginger flour) were liked slightly as they scored 6 on the 9-point Hedonic scale. Sample 2 (100% cassava flour) which was one of the controls used for this experiment was disliked very much on all parameters, this was because cassava is gluten-free which resulted to a watery paste hence less appealing.

Table 4: Sensory evaluation result of 'Àmàlà'

Sample	Appearance	Taste	Texture	Aroma	Mouldability	General Acceptability
S1	$6.92^{a}\pm 2.00$	$6.16^{a}\pm1.62$	$6.60^{a}\pm1.08$	$6.20^{a}\pm1.53$	$7.20^{a}\pm1.00$	$7.16^{a}\pm1.07$
S2	$1.80^{f}\pm1.19$	$2.28^{f}\pm1.60$	$1.92^{f}\pm1.58$	$3.24^{c}\pm2.26$	$1.44^{h}\pm1.19$	$2.08^{g}\pm1.15$
S3	$5.12^{cd}\pm1.81$	$4.76^{bcde}\pm2.33$	$5.24^{bcd}\pm2.08$	$5.40^{ab}\pm2.74$	$4.76^{cde}\pm1.85$	$5.24^{bcde}\pm2.11$
S4	$4.56^{d}\pm2.33$	$3.88^{e}\pm1.86$	$4.16^{e}\pm2.15$	$5.24^{ab}\pm2.28$	$3.60^{fg}\pm2.24$	$4.56^{def}\pm2.36$
S5	$4.64^{d}\pm1.89$	$4.28^{de}\pm1.88$	$4.56^{de}\pm2.16$	$5.16^{ab}\pm2.37$	$4.92^{cd}\pm2.12$	$4.84^{cde}\pm1.97$
S6	$5.04^{d}\pm1.81$	$4.84^{bcde}\pm1.86$	$5.48^{abcd}\pm1.69$	$5.56^{ab}\pm1.92$	$6.08^{b}\pm1.38$	$5.56^{bcd}\pm1.53$
S7	$1.80^{f}\pm1.19$	$2.28^{f}\pm1.59$	$1.92^{f}\pm1.58$	$3.24^{c}\pm2.26$	$1.44^{h}\pm1.19$	$2.08^{g}\pm1.15$
S8	$6.00^{abc}\pm1.63$	$5.88^{ab}\pm1.36$	$6.00^{ab}\pm1.26$	$5.96^{ab}\pm1.70$	$6.40^{ab}\pm1.14$	$6.24^{ab}\pm1.74$
S9	$4.56^{d}\pm1.98$	$4.52^{cde}\pm2.40$	$4.76^{cde}\pm2.13$	$5.08^{ab}\pm2.14$	$4.28^{def}\pm2.37$	$4.72^{cde}\pm2.17$
S10	$6.92^{a}\pm1.00$	$6.16^{a}\pm1.62$	$6.60^{a}\pm1.08$	$6.20^{a}\pm1.53$	$7.20^{a}\pm1.00$	$7.16^{a}\pm1.07$
S11	$5.72^{bc}\pm2.21$	$6.04^{a}\pm1.95$	$5.64^{abcd}\pm1.66$	$5.44^{ab}\pm2.08$	$6.16^{ab}\pm1.97$	$5.76^{bc}\pm1.98$
S12	$6.68^{ab}\pm1.99$	$5.48^{abcd}\pm2.04$	$5.92^{ab}\pm1.96$	$5.52^{ab}\pm2.00$	$6.04^{b}\pm2.13$	$6.24^{ab}\pm2.01$
S13	$3.40^{e}\pm2.00$	$4.00^{e}\pm2.10$	$2.92^{f}\pm1.89$	$4.68^{b}\pm2.58$	$2.68^{g}\pm2.25$	$3.56^{f}\pm2.24$
S14	$6.00^{abc}\pm1.71$	$5.56^{abc}\pm1.80$	$5.76^{abc}\pm1.56$	$6.08^{ab}\pm1.73$	$5.56^{bc}\pm1.53$	$5.96^{b}\pm1.37$
S15	$4.08^{de}\pm2.08$	$4.76^{bcde}\pm2.22$	$4.08^{e}\pm2.23$	$4.76^{b}\pm2.39$	$3.76^{ef}\pm2.07$	$4.40^{ef}\pm1.78$

Values are mean ± standard deviation. Values in the same column bearing different superscript differed significantly ($p < 0.05$). S1 = 100g yam flour, S2 = 100g cassava flour, S3 = 55:35:10 of yam flour, cassava flour and ginger flour, S4 = 50:40:10 of yam flour, cassava flour and ginger flour, S5 = 50:30:20 of yam flour, cassava flour and ginger flour, S6 = 53.33:33.33:13.34 of yam flour, cassava flour and ginger flour, S7 = 51.67:36.66:11.67 of yam flour, cassava flour and ginger flour, S8 = 50:40:10 of yam flour, cassava flour and ginger flour, S9 = 51.67:36.66:11.67 of yam flour, cassava flour and ginger flour, S10 = 50:30:20 of yam flour, cassava flour and ginger flour, S11 = 60:30:10 of yam flour, cassava flour and ginger flour, S12 = 60:30:10 of yam flour, cassava flour and ginger flour, S13 = 55:30:15 of yam flour, cassava flour and ginger flour, S14 = 56.67:31.67:11.66 of yam flour, cassava flour and ginger flour, S15 = 50:35:15 of yam flour, cassava flour and ginger flour..

CONCLUSION

This study revealed that 'àmàlà' produced from composite flours of yam, cassava and ginger can compete favourably with 'àmàlà' produced from yam only. Analytically, these composite flours had a significant effect on the mineral and sensory properties of the 'àmàlà'. Of all the mineral analyzed in this work, the iron content met the requirements for Recommended Dietary Allowance (RDA) of iron for men and postmenopausal women which is 8 mg/day. This proves that the 'àmàlà' is highly recommended for men and postmenopausal women. Moreso, this further creates the need for more researches of other food raw materials that can be used to enrich 'àmàlà'. This study also showed that 'àmàlà' sample produced with yam flour alone do not meet the needed mineral requirement for the body. Hence, the need to always fortify yam flour with flours that will complement in the lacking minerals or give an increase to mineral insufficiency so that it meets the needs of individuals that are obese or has high blood pressure. This study also showed that 'àmàlà' can be flavoured with ginger up to 20% which had the highest acceptability in the study competing favourably with àmàlà produced with 100 percent yam as they both had same highest acceptability. Therefore, production of 'àmàlà' from blends of yam and cassava flour flavoured with ginger (Sample 10;50 Yam flour: 30 Cassava flour: 20 Ginger) should be encouraged as cassava and ginger are affordable, readily available and has been proved in this study to fortify 'àmàlà'.

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Harnessing the Potential of Plant-Based Nutrition for Dietary Health in Nigeria

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ABSTRACT

The role of plant-based nutrition for dietary health in Nigeria has been recognized. The nutritional challenges both globally and in Nigeria are increasing while the world is becoming more aware of the impact of malnutrition and global efforts are increasingly concentrating on addressing malnutrition and increasing food security. Diets affect nutrition and health outcomes and thus have social, economic, and environmental impacts. Nutraceuticals are food or food-derived products with additional characteristics to minimize the occurrence and prevention of certain chronic diseases. They include dietary fibre, probiotics, prebiotics, polyunsaturated fatty acids, antioxidant vitamins, carotenoids, polyphenols, spices, fruits, and vegetables that have proven to have potential health benefits. The link between plant-based nutrition and overall health and well-being is already gaining momentum as a diet rich in plant-based foods and with fewer animal-source foods confers both improved health and environmental benefits. At the same time, an increased intake of fruits, vegetables, nuts, and whole grains has been associated with a lower incidence of mortality due to cardiovascular diseases. This study advocates for leveraging plant-based nutrition in Nigeria to address health and nutrition challenges. Recommendations include targeted education and supportive policies for widespread adoption, fostering improved public health.

INTRODUCTION

Nutrition plays a critical role in maintaining the health and well-being of individuals (Kesari and Noel, 2023) while the nutritional status of an individual can be defined as the result between the nutritional intake received and the nutritional demands and should allow for the utilization of nutrients to maintain reserves and compensate for losses (Fernández-Lázaro and Seco-Calvo, 2023). According to the World Health Organization WHO (2024), health is defined as the state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity of an individual. Good nutritional status can only be realized and sustained when individuals within families and communities are food secure.

Humans have used plants for medicinal purposes for thousands of years, with archaeological evidence suggesting that this may date back sixty thousand years (Loedolff *et al.*, 2021). Many of the medicines we use today were first derived from plants, including aspirin, digoxin, quinine, and morphine. While herbal drug preparations have been used for generations, it was only in the 19th century that scientists began to isolate and extract the compounds responsible for these health benefits. This gave rise to the development of synthetic forms of natural products (Loedolff *et al.*, 2021). Plants are important as they represent the largest source of calories (70–80%) and protein (60–70%) intake for mankind (Shahzad *et al.*, 2021).

Humans rely on a diverse array of vitamins, minerals, and phytochemicals for general and preventative health purposes, the latter of which are obtained solely from plant-based foods. Functional plant-based foods and food products contain abundant amounts of health-beneficial phytochemicals, which provide enhanced antioxidant capacity to prevent diseases associated with oxidative damage (Xonti *et al.*, 2020). Data from cross-cultural epidemiological studies reveals that fruit and vegetable consumption has a preventive effect on certain pathologies (Fahrasmane *et al.*, 2007). The analytical knowledge of fruit and vegetables, whole cereals, spices, condiments, aromatic, culinary, and medicinal herbs, vegetable gum, roots, and peel has increased considerably over the past few decades. Fruit and vegetables appear to be relatively rich in antioxidant compounds with health-preserving properties (Gerber, 2004; Scalbert *et al*., 2005).

Basic nutrition is the cornerstone of good health and requires an adequate intake of foods rich in macro- (carbohydrates, proteins, and fats) and micro-nutrients (vitamins and minerals). Functional foods (foods that provide health benefits beyond basic nutrition) contain many biologically active compounds known to be positively associated with human health. These include terpenes, polyphenols, glucosinolates, phytoestrogens and carotenoids (Xonti *et al*., 2020). All these are collectively termed phytochemicals, these biologically active compounds form part of a plant's secondary metabolite profile and often accumulate as part of global stress response (both abiotic and biotic) mechanisms (Forni *et al.*, 2019).

Preventive nutrition has recently become one of the aspects of public health policies on a global scale. (Fahrasmane *et al.*, 2007). Adoption of a plant-based diet will not only help an individual but also help the environment. Springmann *et al*., 2018 study concluded that a shift towards healthier diets alone could reduce greenhouse gas emissions and other environmental impacts by 29% and 5–9%, respectively, while the adoption of plant-based diets increased these percentages to 56% and 6–22%, respectively. The Eat Lancet Commission on Healthy Diets from Sustainable Food Systems estimated that a whole food plant-based diet could prevent 11 million deaths annually from diet-related illnesses (Kanwar, 2020).

Background and Context of Nutritional Challenges Globally

Nowadays, the food systems rely on a narrow range of plant species of limited nutritional value such as rice, maize, and wheat which account for more than 50% of calories consumed while we continue to disregard the huge diversity of nutrient-rich plant species utilized by humanity throughout our history (Hunter *et al.*, 2019). One of the monumental challenges currently facing humanity is how to secure universal access to sufficient, nutritious, healthy, and affordable food that is produced in a sustainable manner (Bioversity International, 2017).

In 2017, the number of undernourished people increased to 821 million, signaling a rise in world hunger and a reversal of trends following a prolonged decline (FAO, IFAD, UNICEF, WFP, WHO 2018). Child stunting remains unacceptably high with approximately 151 million children affected and 51 million children wasted. About 2 billion people lack the key micronutrients they need for physical and mental development such as iron and vitamin A (Development Initiatives 2017); more than one in eight adults are obese – over 672 million people worldwide (FAO, IFAD, UNICEF, WFP, WHO 2018), while three out of four deaths are caused by non-communicable, diet-related diseases (e.g., diabetes, hypertension), particularly in emerging economies and in low-to-middle income countries (Forouzanfar *et al.*, 2015). Extremes such as stunting in children and overweight in adults are occurring concurrently while countries that experience multiple forms of malnutrition are increasingly common (Haddad *et al.*, 2016).

Background and Context of Nutritional Challenges in Nigeria

The Nigerian population is growing rapidly at an estimated growth rate of 2.8% per annum (Matemilola and Elegbede, 2017), currently estimated at over 230 million with a life expectancy of 56.05 (56) years (Macrotrends, 2024). Even though urbanization is generally seen as the engine of growth and development, it may also lead to urban health crises when not managed carefully. Evidence shows that urbanization in Nigeria has created urban health crises of "inadequate safe water supply, squalor and shanty settlements, sanitation, solid waste management, double burden of diseases and inefficient, congested, and risky transport system" (Aliyu and Amadu, 2017). The nutrition in Nigeria presents a complex dilemma because the challenge of nutritional deficiencies faced in Nigeria is not only because of insufficient food; but also, because of poor food choices (Caeser *et al*., 2015).

According to Ecker *et al*., (2020), Nigeria faces a growing triple burden of malnutrition:

1.Chronic childhood undernutrition remains stubbornly high. That is, 36.8% of children under five years were estimated to be stunted.

2. Micronutrient malnutrition, including iron deficiency anaemia among young children and women of reproductive age.

3. Overweight and obesity among adults. Obesity significantly increases the risk of diet-related noncommunicable diseases (NCDs) such as type-2 diabetes, cardiovascular diseases (like heart attack and stroke), and hypertension.

Ecker *et al.* (2020) opined that the root cause of malnutrition is poor dietary quality, which is a universal problem in Nigeria, characterized by increased consumption of too many calories from staple foods and far too few calories from vegetables and fruits, pulses, and animal-source foods (including fish, poultry, and eggs; red meat; and dairy products). Among urban households in Nigeria, the average share of total calories consumed at home which comes from staple foods is 52.5% for the highest income quintile (Q5) and 66.8% for the lowest income quintile (Q1) relative to the optimal calorie intake levels of the "EAT diet".

The EAT diet is a global reference diet recommended by the EAT-Lancet Commission that optimizes healthy nutrition and minimizes its environmental footprint (Willett *et al*. 2019). According to this diet, only about one-third of the daily total calorie intake (34.0%) should be obtained from staple foods (including grains and starchy roots and tubers). Meanwhile, Nigeria is experiencing a shift in dietary consumption towards increased intake of foods high in fats, sugar, and salts (HFSS), and decreased caloric expenditure that coincides with economic, demographic, and epidemiological changes. Adegboye *et al.* (2016) summarized evidence of the dietary changes from "traditional" to more processed foods which has been observed in recent years in Nigeria.

Dietary intake describes the food consumption patterns as well as the quality of the foods consumed. Dietary intake of the Nigerian population is dynamic and influenced by several factors: culture, religion, socio-economic, geographical location, prevailing food systems, and the nutrition transition through urbanization, technology, social media, and improved transportation Ene-Obong *et al.* (2013).

Ene-Obong *et al.* (2020) described the nutritional indices in Nigeria to be below global averages, and lack of data to adequately assess the nutrition situation. Inadequate intakes of energy, protein, calcium, iron, zinc, vitamin A and B vitamins, particularly among the vulnerable groups and low-income and rural households in Nigeria have been recognized by several researchers. This predisposes Nigerians to Non-communicable diseases (NCDs) which have become major causes of disease and death in Nigeria.

Globalization, urbanization, affluence, physical inactivity, and nutrition transition are responsible for the trend in non-communicable diseases (NCDs). In 2013, estimates showed that NCDs caused 24% of total deaths that occurred in Nigeria, with 20% of these arising from cardiovascular diseases, cancers, diabetes, and chronic respiratory diseases (WHO, 2024). Hypertension is the most prevalent form of cardiovascular disease in the country with prevalence ranging from 8 – 48% (Oguanobi *et al*., 2013). Obesity is a risk factor for diabetes mellitus, hypertension, and cancer; thus, an increasingly obese population will bear the increased burden of these NCDs (Fernandez *et al*., 2021). The Nigerian population is becoming more overweight and obese as shown by a recent Global Nutrition report which indicates a prevalence rate of 36.1% and 13.1%, respectively in women and 21.7% and 4.6%, respectively in men (Development Initiatives, 2018).

In 2017, Nigeria ranked 145th out of 157 countries, ranked based on progress toward meeting the Sustainable Development Goals (SDGs). The ranking was 159 out of 162 countries in 2019, with a score that is 13.8% less than the regional average. Although the country recorded a moderate improvement towards achieving SDG 2 of ending hunger, achieving food security and improved nutrition and promote sustainable agriculture however, this progress has been insufficient to meet the goal (John *et al*., 2022). Achieving sustainable economic development in Nigeria will continue to be a mirage without well-nourished and healthy people (Matemilola and Elegbede, 2017). Nigeria is thus struggling to meet the 2030 nutrition targets (SDG 2), and there is a need for accelerated progress in tackling malnutrition in all its forms (Ene-Obong *et al*., 2020). According to Aina (2024), "The world is becoming more aware of the impact of malnutrition and global efforts are increasingly concentrating on addressing malnutrition and increasing food security. One of such effort is evident in the sustainable development goals 2 which aims to address malnutrition through action plans geared towards ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture. This implies there is potential to nudge consumer behaviour towards healthier and sustainable diets and address nutritional challenges through changes in the food systems. Identifying entry points for interventions requires an understanding of the link between dietary consumption and the components of the existing food systems (Mekonnen *et al*., 2021).

Solutions to Malnutrition in Nigeria (proposed by Enang, 2023)

1. Proper dietary education should be given to all

Most people need to realize that a balanced meal is not an expensive meal but simply a meal that contains all classes of food. Stakeholders in the catering industry should make the education available to all that food does not have to be expensive to be a balanced diet, they just must be rich in nutrients.

2. More jobs should be created so that unemployment can be reduced. Some people in the country cannot afford a square meal in a day, and when starvation sets into a nation, it begets malnutrition by default.

3. The cost of food items should be made affordable. No matter the level of employment in a nation, when the cost of things exceeds the income of a person, malnutrition is inevitable because the victim will just eat anything just to meet up with his daily bread.

Significance of Harnessing Plant Potential for Nutritional Development

Malnutrition has been defined as a pathological condition, brought about by inadequacy of one or more of the nutrients essential for survival, growth, reproduction, and capacity to learn and function in society (Caeser *et al.*, 2015). A principal cause of the multiple burdens of malnutrition is poor diet. Food systems produce large quantities of food, but not enough of the required nutrient-rich, plant-based foods needed for healthier and sustainable diets (Willett *et al.* 2019).

Interactions between components of the food systems determine diets – quantity, quality, diversity, and safety. Nonetheless, dietary patterns may also act as drivers of change for future food systems (HLPE, 2017). This is because diets affect nutrition and health outcomes and have social, economic, and environmental impacts. This growing demand for food would necessitate sustainability in production, consumption, and enabling conditions such as the future regarding behaviour by the food systems actors. These interlinkages may affect the food systems directly through political or institutional actions or indirectly by influencing the drivers of the food systems including biophysical and environmental, innovation, technology and infrastructure, political and economic, socio-cultural, and demographic drivers (HLPE, 2017).

Overview of existing literature on plant-based nutrition

Nutraceutical was defined by Stephen DeFelice as a food or part of food that renders medical or restorative health benefits along with prevention and curative potential against diseases (Dwivedi, 2023). Nutraceuticals have gripped more attention in recent years; especially during the COVID-19 pandemic and day-to-day health hazards made people more conscious of health-related products (Puri *et al.*, 2022). Many traditional systems of medicine have considered food and diet as important parts of their medical treatment. The basic idea of nutraceuticals is likely to evolve from the extant idea of well-being proposed by the great philosopher Hippocrates (the father of medicine) "Let food be thy medicine and medicine be thy food" who realized the potential of food and explored the medicinal benefit by conscious use of food (Smith, 2004).

Nutraceuticals are food or food-derived products with additional characteristics to minimize the occurrence and prevention of certain chronic diseases. The rational use of these nutraceuticals not merely gives us nutrition and restoration but also supports in fighting against diseases and overcoming illness.

According to Dwivedi (2023) a wide variety of food and dietary supplements, i.e., dietary fibre, probiotics, prebiotics, polyunsaturated fatty acids, antioxidant vitamins, carotenoids, polyphenols, and spices have proven to have potential health benefits and could be used as nutraceuticals.

Dietary fibre: This helps to overcome constipation and hardening of stools, reduce cholesterol and blood glucose levels that might be helpful in the prevention of heart diseases and diabetes, and could be used as an effective weight loss agent, and support the growth of beneficial bacteria.

Probiotics: These are primarily present in fermented products, i.e., curd, buttermilk, yogurt, and other fermented foods. Probiotics do help to digest food, improve immunity to fight against diseases, and secrete vitamins and neutralize toxins.

Prebiotics: These are used to improve digestion, and boost immunity and could be used as weight loss agents. Examples include chicory root, dandelion greens, garlic, onions, leeks, asparagus, bananas, barley, oats, apples, konjac root, flaxseeds, and wheat bran.

Polyunsaturated fatty acid (PUFA): They are useful in the prevention of depression and anxiety, vision impairment, brain growth and development, heart disease, metabolic syndrome, autoimmune diseases, premature aging, and sun damage. Major sources of PUFA are soybeans, flaxseed, sunflower oil, safflower oil, corn oil, cod liver oil, chia seeds, walnuts, fish, meat, and eggs.

Antioxidant vitamins: These could help to reduce the risk of heart disease, cancer, diabetes, cataracts, arthritis and gout, age-related degeneration, and immunity booster. Good sources of Vitamin C are Oranges, kiwi, lemon, grapefruit, bell peppers, strawberries, tomatoes, broccoli, cabbage, and cauliflower while vegetable oils such as wheat germ oil, sunflower oil, safflower oils, and certain nuts, i.e., peanuts, hazelnuts, almonds are among the best sources of Vitamin E.

Carotenoids: Carotenoids are used to reduce the risk of cardiovascular diseases, cancer, diabetes, and age-related degeneration. They have been used to improve eye and skin health and boost immunity. They are well known for their antioxidant, therapeutic, and protective potential against various diseases. Good sources of carotenoids are yams, kale, watermelon, cantaloupe, bell peppers, tomatoes, carrots, mangoes, oranges, spinach, pumpkin, avocado, yellow-fleshed fruits, corn, and egg yolks.

Polyphenols: They provide efficient protection against certain pernicious chronic diseases such as cardiovascular diseases, cancer, diabetes, neurodegenerative diseases, aging, asthma, and infections. Sources include cereals, dry legumes and chocolate, tea, coffee, grapes, apples, pear, cherries and berries, red onion, spinach, olives, nuts, cloves, cocoa powder, plums, and soy products have substantial polyphenolic compounds.

Spices: Spices have a significant role as carminative, antioxidant, chemoprotective, anti-inflammatory, cholesterol-lowering, anti-diabetic, anti-cancer, and immune stimulant. They include turmeric, fenugreek, garlic, onion, cumin, caraway, fennel, coriander, mint, asafetida, cinnamon, mustard, black pepper, red pepper, clove, and cardamom. Apart from their popular use as spice, they also help to enhance the organoleptic properties of food.

Minerals and trace elements: They help to reduce oxidative stress, abnormal function of various organs, and UV-induced cytotoxicity. Some of them are also helpful in DNA synthesis and repair, cell apoptosis, and wound healing. Good sources of minerals are nuts, seeds, seafood, meat, whole grains, dairy products, eggs, seaweed, legumes, green vegetables, and oats.

Fruit and vegetables: These contain vitamins, three of which are provided primarily by this food group: vitamin C, vitamin B9 or folates, and beta-carotene or provitamin A. In addition to their vitamin function, they fulfil an antioxidant function. At the cell level, antioxidants can oppose the accumulation of free radicals, which leads to DNA and membrane damage, promoting carcinogenesis and atherogenesis. Fruit and vegetables are rich in other antioxidant compounds: lycopene, alpha-carotene, lutein, zeaxanthin, polyphenols, etc.

The link between plant-based nutrition and overall health and well-being: Food as Medicine

Transformation to healthy diets by 2050 will require substantial dietary shifts. Global consumption of fruits, vegetables, nuts, and legumes will have to double, and consumption of foods such as red meat and sugar will have to be reduced by more than 50%. A diet rich in plant-based foods and with fewer animal-source foods confers both improved health and environmental benefits (Willet *et al*., 2019).

Identification Of Potential Challenges of Food Nutrition

Nutrition is the basic need for a healthy life, but one cannot gain optimum benefit from the food consumed without knowing proper dietary guidelines. Identified challenges according to various authors include instability of food supplies**,** poor food choices, policy inconsistencies, corruption, poverty, hunger, and conflicts.

Opportunities For Overcoming Challenges and Promoting Adoption

Avenues to improving dietary diversity may include improving access to markets and roads while also providing nutrition knowledge (Hirvonen *et al*., 2017), improving incomes and production diversity (Ecker *et al*, 2018), through nutrition-sensitive agriculture programs which incorporate nutrition-related behavioural change communication and improvement in the use of social media for promotion and access to nutritional information.

The opportunities for overcoming challenges and promoting the adoption of a plant-based diet in Nigeria lie in a synergistic and concerted effort across various sectors to unlock the full potential of plant-based nutrition, foster a healthier population, and not only improve the overall health and well-being of its population but also contribute to the global movement towards more sustainable and nutritious dietary practices.

CONCLUSION AND RECOMMENDATIONS

In conclusion, the exploration of plant-based nutrition for dietary health in Nigeria reveals a promising avenue for addressing the country's nutritional challenges. With an abundance of diverse plant resources, Nigeria possesses a wealth of untapped potential to improve dietary health and combat malnutrition. Plant-based diets offer numerous health benefits, including reducing the risk of chronic diseases and promoting overall well-being. However, realizing this potential requires a concerted effort from various stakeholders, including policymakers, healthcare professionals, educators, and the public.

However, it is crucial to acknowledge the existing cultural, economic, and infrastructural barriers that may hinder the widespread adoption of plant-based nutrition in Nigeria. Therefore, this study recommends educational campaigns, policy support, and community engagement initiatives to promote awareness and encourage the incorporation of plant-based foods into daily dietary practices.

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Comparative Studies on the Estimated Glycemic Indices/ Loads of Fufu-Like Products from Coconut and Maize Chaffs

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ABSTRACT

Comparative studies of the estimated glycemic indices/ loads of fufu-like products made with coconut and maize chaffs were studied. Coconut chaff and maize chaff (100g each) were mixed separately with different quantities (2g, 5g and 10g) of each of the binders (psyllium husk and gelatin) and 10ml of water. The paste was stirred in a cooking pot to form dough at 100^0C for 5 minutes. It was allowed to cool and packaged in transparent polyethylene bag, Hydrolysis indices, glycemic indices and glycemic loads of the fufu-like products were determined using standard methods. Hydrolysis index of the fufu-like products made from coconut chaff were found in the range of 0.41% to 0.86% while products made from maize chaff ranged from 1.08% to 6.32%. Estimated glycemic indices of the fufu-like products made from coconut chaff ranged from 39.93% to 40.18% while that of maize chaff ranged from 40.30% to 43.18%. The glycemic loads of the fufu-like product made from coconut chaff ranged from 1.78 to 4.42 (100g serving) while products made from maize chaff ranged from 6.32 to 10.34 (100g serving). The study revealed that all the fufu like products had low glycemic indices and glycemic loads except fufu-like products made with maize chaff that fell under medium range of glycemic load classifications. Fufu-like product made from coconut chaff with 10g psyllium husk yielded lowest glycemic index and glycemic load which could be used as a functional food.

INTRODUCTION

Glycemic index (GI) is a ranking system for carbohydrates based on their effect on blood glucose levels (Blessing *et al*., 2021). According to Wolever *et al*. (1991), it is also known as the incremental area under the blood glucose response curve of a 50g portion of carbohydrates expressed as a percentage of the response to the same amount of carbohydrates from a standard food consumed by the same subject. Glycemic load uses the glycemic index to calculate how much an individual intake of carbohydrates affects them, accounting for the quantity of carbohydrates in a serving (Madu *et al*., 2018). The prevalence of chronic illnesses has been rising globally (Li *et al*., 2014), and studies have indicated that glycemic indices of foods play a significant role in both treatment and prevention of chronic diseases (Guzel and Sayar, 2012, Hoover *et al*., 2010). Foods containing carbohydrates have been categorized into four groups according to their glycemic indices: high (> 70%), intermediate (56-69%), low (20-55%), and free (< 20%) (Ratnaningsih *et al*., 2016). Experts from FAO (2010) recommended the use of glycemic index concept to categorize foods high in carbohydrates. This would help people to select the best foods to consume for maintaining their health and treatment of various diseases (Simsek and Nehir, 2015). Eating foods with low glycemic index may help prevent the development of several diseases, including diabetes, obesity, heart disease and even some types of cancer (Du *et al*., 2014).

Coconut (*Cocos nucifera Lin*.) in the world, is the most widely grown and utilized nut. Long-term research and development on coconuts based food products have resulted in a diversification of products and byproducts. Fresh coconuts are processed by shelling, paring, wet milling and extracting the milk using screw press. This milk can then be used to make coconut oil or dried and powdered into spray-dried coconut milk. After the milk is extracted and dried, the defatted coconut chaff is obtained, which can then be ground into flour (Trinidad *et al*., 2003; Raghavendra *et al*., 2006). Coconut has high dietary fiber, protein, antioxidant and vitamin. Trinidad *et al*. (2006) stated that the residue (chaff) of coconut could be made into flour and used for formulation and development of new food product. It is interesting to note that coconut flour lacks gluten and is a significant source of nutrients, including proteins, fiber and has no trans fats. It also has a low glycemic index (Ramaswamy, 2014).

Zea mays L., commonly known as maize or corn, is a significant annual cereal crop grown worldwide and a member of the *Poaceae* family. The kernels can be extracted and eaten or used to make a variety of foods, such as cereals and flour. The ears can also be cooked and consumed as a vegetable. Maize processing waste (chaff) variously called in Nigeria as *Esususoka* in Igbo, *Dusa* in Hausa and *Eeriogi* in Yoruba is the waste from *akamu* (pap) production (Okafor and Usman, (2015). The waste is relatively available in large quantities both in rural and urban communities in Nigeria. Most of the backyard poultry farmers use it as a source of feed (Iyayi and Aderolu, 2004). In the majority of the world, the only use of these plant wastes produced during the processing of maize and coconut milk is as a source of feed for poultry and livestock. These are biomasses known as lignocelluloses, which are composed of cellulose, hemicelluloses and lignin and have a total dietary fiber content of 90g/100g (Deutschmann and Dekker, 2012).

Fufu, a fermented wet paste made from cassava (Manihot esculenta Crantz) is a staple food in many tropical regions and West Africa (Etudaiye *et al*., 2012; Deniran *et al*., 2022). The fufu's high carbohydrate content is consistent with the nutritional profile of cassava roots, where starch makes up 80% of the total carbohydrate content (Purseglove, 1991). Traditionally, cassava is used to make fufu, but it can also be made with plantains and cassava, plantains and cocoyam, or just yam (Egyir and Yeboah, 2010). During the preparation of fufu-like product, coconut chaff, maize chaff and food binders can be used. This study would help in the acquisition of knowledge of the functional benefits of this innovative product, thus enlighten the public and nutritionists on the vast health benefits of this by-product and enable them to make better dietary choices and food formulations. It will also increase their menu varieties.

MATERIALS AND METHODS

Collection of samples

Fresh and matured coconut, dried white maize and food binders (psyllium husk and gelatin) were purchased at Umungasi Market Aba, Abia State, Nigeria.

Production of coconut chaff: The method described and used by Sanful (2009) was adopted with slight modifications. Freshly dehusked coconuts (*Cocus nucifera*) 10kg was weighed, cleaned and cracked to expel the containing coconut water. The coconut flesh (meat) was removed from the shell with the aid of a stainless steel pointed knife. The brown outer colour of the skin was scraped off manually with a knife. The clean coconut flesh was sliced into smaller (5mm) pieces and milled with an attrition mill (Model CH178RA). The slurry was homogenized with hot water (100^{o}C.) and poured into a muslin cloth, squeezed to separate its creamy (oily) juice and the chaff was further rinsed with hot water (<70^{0}C) until the filtrate becomes colourless. The defatted coconut chaff was dried (60^{0}C for 3h) in the hot air oven (Model SM9023), milled using an electric blender (Philip, HR1702), sieved (0.5mm mesh sieve), packaged in a polythene bag, sealed and store at ambient temperature (27± 2^{0}C) for further use.

Production of maize chaff: The method described and used by John and Osita, (2012) was adopted with slight modifications for the production of *ogi* from which the maize chaff was gotten. White maize grains (10kg) was sorted, cleaned and steeped in clean water at room temperature for 48 h. The water was decanted and the fermented grains were washed with clean water and wet milled using an attrition mill (Model CH178RA). The chaff was removed wet with a muslin cloth and the filtrate was allowed to settle for 24 h to form starchy sediment, which is *ogi*. The wet chaff was rinsed several times and was dewatered in a jute sack. The dewatered chaff was pulverized and dried in a hot air oven (Uniscope Laboratory Model SM9023) (55±5°C), milled using an electric blender (Philip, HR1702), sieved and packaged in air tight container for further use.

Preparation of fufu-like products: Coconut chaff, tiger-nut chaff and maize chaff (100g each) were mixed separately with different quantities (2g, 5g and 10g) of each of the binders (psyllium husk and gelatin) and 10ml of water. The paste was stirred in a cooking pot to form dough at 100^{0}C for 5 minutes. It was allowed to cool and packaged in transparent polyethylene bag,

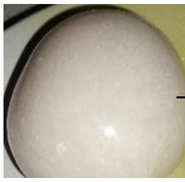
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Plate 1: Fufu-like product made from coconut chaff of 2g gelatin


3

Plate 3: Fufu-like product made from coconut chaff of 10g gelatin


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Plate 2: Fufu-like product made from coconut chaff of 5g gelatin


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Plate 4: Fufu-like product made from coconut chaff of 2g psyllium husk

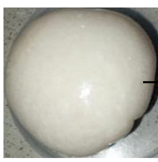
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Plate 5: Fufu-like product made from chaff of 5g psyllium husk


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Plate 6: Fufu-like product made from coconut chaff coconut of 10g psyllium husk .


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Plate 7: Fufu-like product made from maize chaff 2g psyllium husk


8

Plate 8: Fufu-like product made from maize chaff of 2g gelatin


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Plate 9: Fufu-like product made from maize chaff of 5g psyllium husk


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Plate 10: Fufu-like product made from maize chaff of 5g gelatin

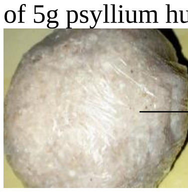
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Plate 11: Fufu-like product made from maize chaff of 10g psyllium husk


12

Plate 12: Fufu-like product made from maize chaff 10g gelatin

Determination of the estimated glycemic index (eGI)

Determination of the eGI of fufu-like products was conducted using the method of Nani *et al*. (2017

Calculation of glycemic load (GL)

Glycemic load of the fufu-like products was calculated using the method of Blessing *et al*. (2021).

RESULTS AND DISCUSSION

Hydrolysis index of the glycemic index fufu-like products

Hydrolysis index (HI) of the fufu-like products are shown in (Table 1) which ranged from 0.45 to 0 6.32 % , with the highest hydrolysis index (HI) mean value seen in product made from maize chaff of 2g gelatin (6.32%) and lowest mean value seen in products made from coconut chaff of 10g psyllium husk (0.45%). The smaller the hydrolysis index the lower the glycemic index. Hydrolysis index is one of the most important criteria for differentiation of starch digestibility from the nutritional standpoint. Hydrolysis index represents the proportion of starch digested in food related to the starch digested in reference food. Estimated glycemic index is calculated from hydrolysis index. The Hydrolysis index of the product were significantly different at ($p < 0.05$).

Table 1: Hydrolysis index (HI %) of the fufu-like products

Binder	**Quantity (g)**	**Coconut HI (%)**	**Maize HI (%)**
Gelatin	2	$0.72^{ef}\pm0.01$	$6.32^{a}\pm 0.01$
Gelatin	5	$0.86^{d}\pm0.01$	$6.01^{ab}\pm0.01$
Gelatin	10	$0.68^{f}\pm0.01$	$1.57^{c}\pm0.00$
Psyllium husk	2	$0.76^{e}\pm0.03$	$6.03^{ab}\pm0.00$
Psyllium husk	5	$0.81^{de}\pm0.07$	$2.35^{b}\pm2.83$
Psyllium husk	10	$0.41^{g}\pm0.07$	$1.08^{d}\pm0.01$

Values are mean ± SD of duplicate determinations. Mean values with different superscripts are significantly ($p<0.05$) different.

Estimated glycemic index (EGI) of the fufu-like products: The estimated glycemic index obtained after the in vitro enzymatic digestion of each fufu-like products are shown in Table 2 and it ranged from 39.93% to 43.18%. The highest mean value was seen in fufu -like product made from maize chaff of 2g gelatin (43.18%), while the lowest mean value (39.93%) was seen in fufu-like product made from coconut chaff of 10g psyllium husk (Table 2). There were significant differences at ($p < 0.05$) in the estimated glycemic index mean values of the fufu-like products. Despite the variations seen in the products, the estimated glycemic indices of the fufu-like products fell within low glycemic index food classification. The low estimated glycemic index values observed in the fufu like products could be attributed to its high content in dietary fibre and it is able to slow down the enzymatic digestion of carbohydrates and reduce the gastrointestinal absorption of glucose. Previous research has illustrated the potential of lowering glycemic response to foods by incorporating different fibre fractions, especially soluble fibre (Blessing *et al*., 2021). Low glycemic index foods are important in the management of hyperglycemia and hyperinsulinemia because they have a high satiety effect and therefore can reduce the likelihood of excessive consumption of calories. Research has shown that food with low glycemic index is known to have a positive health benefit when compared to foods with higher glycemic index (Miao *et al*., 2015).

Table 2: Estimated glycemic index (EGI) of the fufu-like products

Binder	Quantity (g)	Coconut EGI (%)	Maize EGI (%)
Gelatin	2	$40.11^{e}\pm0.01$	$43.18^{a}\pm0.02$
Gelatin	5	$40.18^{d}\pm0.01$	$43.01^{ab}\pm0.02$
Gelatin	10	$40.08^{d}\pm0.01$	$40.57^{bc}\pm0.02$
Psyllium husk	2	$40.12^{e}\pm0.01$	$43.02^{ab}\pm0.02$
Psyllium husk	5	$40.15^{df}\pm0.01$	$41.00^{b}\pm0.05$
Psyllium husk	10	$39.93^{f}\pm0.01$	$40.30^{c}\pm0.01$

Values are mean ± SD of duplicate determinations. Mean values with different superscripts are significantly ($p<0.05$) different.

Glycemic load (GL) of the fufu-like products: The glycemic load was calculated from the results obtained from the glycemic index of the fufu-like products. The glycemic loads of the fufu-like products ranged from 1.38 to 19.34(100g serving) (Table 3). Fufu-like product made with maize chaff of 10g gelatin recorded the highest glycemic load mean value (19.34 /100g serving) while the lowest glycemic load mean value (1.78/100g serving) was seen in product made from coconut chaff of 10g psyllium husk. There were significant differences at ($p<0.05$) in the glycemic loads of the samples. The glycemic load of food, is a number that estimates how much a food will raise the blood glucose level after its consumption in an individual. One unit of glycemic load approximates the effect of consuming one gram of glucose (Jia-Yu Zhang, 2019). Glycemic index does not consider the number of carbohydrates in a food, glycemic load is a better indicator of how a carbohydrate food will affect blood glucose. Although the glycemic index can represent a carbohydrate-containing food's effect on blood glucose, the portion size is also an important factor that needs to be taken into consideration for glucose management as well as the management of weight. According to Christabel. (2022) both the quality and quantity of carbohydrate in a food determine an individual's glucose response to the food. The glycemic load is therefore the current way to evaluate the impact of carbohydrate consumption that takes into account the glycemic index but provides a deeper picture than the glycemic index. The Glycemic loads of the foods are classified as low (less than 10%), medium (between 11 – 19%) or high (more than or equal to 20%) (Blessing *et al*., 2021).Food serving sizes have a major effect on the glycemic index of the food, thereby increasing the glycemic load of the food (Christabel, 2022). The United States Department of Agriculture (USDA) and Food and Drugs Administration and Control (Young and Nestle, 2003) have established standard serving sizes that guide Americans to select the right portion sizes of food to eat for sustained and improved health. Foods that have high glycemic load are linked to an increased risk of certain chronic diseases whiles low glycemic load foods are seen to reduce the risk of acquiring these diseases. In a collection of studies, both the glycemic index and the glycemic load of the total food have been associated with a greater risk of type 2 diabetes in both men and women (Kettleborough *et al*., 2013). Since diabetes is primarily a condition of disordered glucose metabolism, it is important to bear in mind the type of dietary carbohydrate that can influence the risk and course of this disease (American Diabetes Association, 2015). Food that produces higher blood glucose concentration and greater demand for insulin would increase the risk of type 2 diabetes (Sanusi and Olurin, 2012). The glycemic load of the fufu-like products made with coconut chaff fell under low glycemic loads food range while fufu-like products made with maize chaff fell under medium glycemic load food range except the products of 10g psyllium husk that recorded low glycemic load of maize chaff.

Table 3: Glycemic load (EGL) of the fufu-like products

Binder	Quantity (g)	Coconut EGL	Maize EGI
Gelatin	2	$4.42^{f}\pm0.02$	$12.97^{c}\pm0.02$
Gelatin	5	$3.86^{g}\pm0.02$	$13.29^{b}\pm0.01$
Gelatin	10	$2.50^{i}\pm0.02$	$19.34^{a}\pm0.01$
Psyllium husk	2	$3.68^{gh}\pm0.02$	$12.85^{c}\pm0.01$
Psyllium husk	5	$2.78^{h}\pm0.02$	$10.56^{d}\pm0.01$
Psyllium husk	10	$1.78^{i}\pm0.02$	$6.32^{e}\pm0.01$

Values are mean ± SD of duplicate determinations. Mean values with different superscripts are significantly ($p<0.05$) different.

CONCLUSION

The study attempted to investigate the possibility of using coconut chaff and maize chaff for the production of low glycemic index fufu-like products. The study also revealed that all the fufu like products had low glycemic index and glycemic load except fufu-like product made with maize chaff that fell under intermediate range. It is recommended that food scientists, nutritionists and dieticians can as well recommend fufu-like products made with coconut chaff of 10g psyllium husk as a functional food. It is also recommended that greater attention should be placed on researching into the glycemic indices and glycemic loads of our local foods as to provide a comprehensive information about the carbohydrate contents and how much in a food consumed in a serving will affects the blood glucose levels

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Effect of Different Preprocessing Methods on the Proximate Composition of Bottled Tigernut (*Cyperus esculentus*) Milk Varieties

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KEYWORDS

Boiling,
Malting,
Preprocessing methods,
Soaking
Tigernut milk,

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ABSTRACT

This study was carried out to observe the proximate composition of tigernut milk extract from the yellow and brown varieties of tigernut. The tigernut tubers were subjected to different preprocessing operations (boiling, malting, and soaking) before extraction. The proximate composition of the tigernut tubers and drinks were determined. The result showed that the yellow variety recorded high moisture content (39.16%) compared to the brown variety which recorded (9.17%). Values obtained for the tigernut tubers and tigernut milk were significantly different except crude fibre content (0.00%) which recorded no trace of fibre in the extract. The moisture content of the tigernut milk slightly increased after sterilization except for the malted yellow sample, there was a decrease in the carbohydrate, crude fibre, and fat contents after sterilization. However, the protein, ash and fat content of the malted brown variety were not affected. There were significant differences $p<0.05$ between the processing methods and the varieties. The study showed that there was varietal difference in the nutrient composition of tigernut tuber and also the effect of processing and sterilization on tigernut milk. This study highlights the need to increase utilization of tigernut for commercialization in Nigeria and beyond.

INTRODUCTION

Over the past decade, the primary research emphasis on food product development has been to address the changing needs and meet the present demands of consumers by creating newer alternatives to healthy foods. In today's world, beverages are no longer considered simply as thirst quenchers; consumers seek specific functionality in these drinks, which forms a lifestyle. These changes and developments have recently led to newer products in the beverages sector. One such primary functional requirement is milk alternatives to mitigate problems of cow milk allergy, lactose intolerance, calorie concern, and prevalence of hypercholesterolemia (Valencia-Flores *et al.,* 2013). It is important to note that veganism and a healthy lifestyle rule the health charts as a trend. Companies are studying the consumption patterns of different people and maximizing the sales of different beverages by offering combinations of milk and energy drinks. Thus, the future of plant-based beverages is bright. The growing interest in promoting healthy living is expected to create a significant opportunity for a plant-based milk that would cater to the demand of a growing population. Tigernut milk beverages are one of the most appreciated plant-based beverages obtained from the aqueous extract of tigernut tubers (*Cyperus esculentus*) (Coşkuner *et al.,* 2002). These beverages are rich in carbohydrates (50%), unsaturated 55 fatty acids (75% in oleic and ~10% in linoleic acids, of total fat) and dietary fibre (~1%). There are three cultivars of tigernut; yellow, brown and black cultivars. The cultivars possessed different physicochemical properties (Nina *et al.,* 2019; Ayaşan *et al.,* 2021) and functional properties (Nina *et al.,* 2019; Ismaila *et al.,* 2020). The major factors that account for the chemical variation in tigernut are genetic makeup, production location, environment and growing conditions (Ihenetu *et al.,* 2021).

Furthermore, there is a dire need for increased utilization of homegrown crops, highlighted at national and international seminars, conferences, and workshops. Tigernuts have been reported to be a healthy source of nutrients like carbohydrates, protein, and fat with no allergy-causing components, yet they are vastly underutilized. The findings of this research will provide baseline data on tigernut milk thereby diversifying its use and increased production as a valuable means to fight food insecurity. The main objective of this study is to investigate the nutrient composition of tigernut milk and improve its commercial value.

MATERIALS AND METHODS

Sources of raw material

Tigernut tubers (brown and yellow varieties) were purchased from farmers in Jalingo Taraba State. The 26mm crown corks used were produced by Pellconi Company in Italy and successfully delivered through a courier service (DHL). The capping machine manufactured by Officine Pesce bottling system Italy with the model number PG 93/C was purchased from Canada and successfully shipped to Nigeria and was used for capping. Vitamilk bottles were reused for bottling, the bottles were washed with water, sterilized using an autoclave with the model number *ST3028E*.

Sample preparation

Fresh tigernuts were used for the preparation of tigernut extract. Fresh tigernuts were visually inspected. Defective tubers were manually removed and discarded. Hence, only mature, healthy tigernut tubers were selected. Tigernuts were weighed in portions, washed thoroughly in two changes of clean water, and drained before use for all the studies. The tigernut tubers were processed with different methods before extraction.

Boiling method

The method of Asante *et al*. (2014a) with modification was used. Fresh tiger nut (200g) was boiled at 100ºCfor 5 minutes until the tuber became soft for easy extraction. The boiled tiger nut was ground using Omniblend V model TM 800. A portion of 500 mL of distilled water was used together during the blending and slurring process. The slurry was filtered with a clean, damp muslin cloth (pore size 2 mm), and the filtrate obtained was boiled at 70ºC for 15 minutes to avoid curdling before bottling and capping for further studies.

Malting method

The method described by Ndubisi (2009) with slight modification was used. Fresh tigernut was visually selected. A portion of 200g of tigernut was soaked in a vessel for 24 hours and drained out. The soaked tigernuts were washed, drained every 6 hours and was placed in a jute bag at room temperature. Water was sprinkled twice a day to soften the tubers. After five days, it germinated, giving out shoots and roots. After sprouting, the tigernut tubers were cleaned, washed, drained, blended into a paste using Omniblend V model TM 800 blender, and slurred. A portion of 500 mL of water was used during the blending and slurring process. The slurry was filtered with a clean muslin cloth (pore size 2 mm), and the filtrate obtained was boiled at 70ºC for 15 minutes to avoid curdling before bottling and capping for further studies.

Soaking method

The method described by Ndubisi, 2009 with slight modification was used A portion of tigernut (200g) was washed in water, drained, and soaked in 600mL of water for 12 hours. The water was discarded, and the tubers were milled into a paste using Omniblend V model TM 800 blender, and slurred. A portion of 500 mL of distilled water was used during the blending and slurring process. The slurry was filtered with a clean muslin cloth (pore size 2 mm), and the filtrate obtained was boiled at 70ºC for 15 minutes to avoid curdling before bottling and capping for further studies.

Plate 1: **Plate 2** **Plate 3** **Plate 4**




Yellow tigernut **Brown tigernut** **Yellow malted tigernut** **Brown malted tigernut**

Heat penetration studies

Before sterilization, heat penetration was carried out on the different varieties and different processing methods of the tiger nut milk extract. A Nicetymeter thermocouple with the model number DT1311/DT1312 was inserted at the center of the bottle and sealed airtight, then connected to a temperature reading instrument. The initial temperature was noted, and the autoclave temperature was set at 121ºC. Temperature was recorded until the tiger nut extract got to 121ºC. Based on the observation recorded, the F_0 value was determined. F_0 value is the equivalent exposure time at 121ºC of the actual exposure time at a variable temperature. The F_0 was determined at 12 minutes.

Plate 5 **Plate 6** **Plate 7**



Bottling process **Heat penetration studies** **Bottled tigernut milk**

Sterilization of tigernut milk extract

The bottled milk extracts were sterilized after capping using an autoclave. Sterilization was carried out in batches after production and allowed to cool before analysis.

Proximate Analysis

The proximate components of fresh, soaked, boiled and malted tigernut tubers and tigernut milk were determined by the method of Association of Official Analytical Chemist (AOAC 2016).

Statistical analysis

The mean and standard deviation of the result data from the experiment was calculated and analyzed using single factor ANOVA Software (SPSS version12. 0.1 for windows). The Duncan‟s New Multiple Range Test was used to determine the significant difference between mean values. MINITAB version 19.0 was used to show interaction.

RESULTS AND DISCUSSIONS

Proximate composition of tigernut tubers

The proximate composition of the tigernut tubers is shown in Table 4.1. The yellow variety recorded a high value of moisture (39.16%) compared to the brown variety which recorded (9.17%). The high moisture indicated they may be easily susceptible to spoilage if not well preserved. Moisture content influences food's taste, texture, weight, appearance, and shelf life (AOAC, 2005). Even a little deviation from a defined standard can adversely impact the properties of a food material. Hence, obtaining an optimal analytical value for moisture is of great economic importance to a manufacturer (Pearson, 1976). The ash content was recorded at 1.51% for the yellow variety, while the brown variety had a higher value of 2.66%; the tiger nut was within the range reported for other starchy roots and tubers such as yam (1.5%) cassava (2.3%), and potatoes (1.0%). The ash value was similar to the value reported by Temple *et al.* (1998) at (1.86%) but higher than the values reported by Suleiman *et al.* (2018) at 1.18%. However, values reported by Umerie *et al.* (1997) on tigernuts had significantly higher values (2.48% and 6.70% dry weight, respectively). The value obtained showed that the three species are rich in minerals. Generally, ash content, being a micronutrient, varies between 1-2%, a reasonably high value indicating the presence of an adulterant (Ndubuisi, 2009). The crude fibre content recorded 11.54% for the yellow variety and 12.65% for the brown variety. Tigernut fibre values from the findings align with the report of Umerie *et al.*, 1997 which is 12.88 %. Conversely, Temple *et al.(1998)* reported a lower fibre value (5.50%). With about 100 g of tigernuts, the fibre content could be essential in reducing the pressure and transit time of food through the body, aiding digestion (Temple *et al.,* 1998). Fibre aids in the alleviation of flatulence problems. Thus, tiger nut fibre could be explored in formulating diets for treating indigestion, constipation, and non-communicable diseases such as colon cancer, obesity, and coronary heart disease (Wardlaw and Kessel, 2002).

The protein content recorded was 1.74 % for the yellow variety and 2.72% for the brown variety. These values are slightly lower than the results of Oguche and Musa, 2022 who reported 7.98% for yellow variety and 5.17% for brown variety. The protein content of tigernuts is higher than most starchy roots crops such as cassava (0.7%), sweet potatoes(1%) and yams(1.5%) (Sanchez-Zapata *et al.*, 2012). Tigernut's protein content was in comparison with that of cereals such as rice and sorghum (Ndubuisi, 2009). The fat content recorded was 22.49% for the yellow variety and 36.13% for the brown variety. The fat content of tigernuts is relatively similar to that of nuts and seeds (30%- 26%) but is higher than that of wheat (1.9%), rice (2.2%), maize (4.9%) and compares well with that of soya beans (28.20%) (Sanchez-Zapata *et al.*, 2012). Tigernuts, in comparison to other starchy roots and tubers such as sweet potatoes, cassava, and yam, have significantly higher fat content and could contribute more than 73% of fat to a child's daily fat need and more than 49% of fat to an adult daily fat requirement (FAO/WHO, 2002). The carbohydrate content of the tiger nut varieties recorded was 23.58% for the yellow variety and 36.69% for the brown variety. The values obtained for the carbohydrate content of the two varieties are higher than the values obtained by Oguche and Musa, 2022 which recorded 4.39% and 27.17%, respectively, for the yellow and brown varieties, but lower when compared to the values of the results obtained by Waoguikpe (2010) (yellow 46.99% and brown 41.22%). Of their high nutrients, tiger nuts could be eaten fresh as snacks by young children, adults, and pregnant and lactating mothers. These nutrients could contribute to the metabolic processes of the body. Consequently, consuming 100 g of tiger nuts could contribute 40 % of carbohydrates to a child's (4-9 yrs) daily carbohydrate requirement and above 32 % of carbohydrate to an adult's daily carbohydrate need (FAO/WHO, 2002). The actual sourced location and varietal difference may have affected the differences between the two varieties.

Table 4.1: Proximate composition of tigernut tubers

Component	Yellow variety	Brown variety
Moisture (%)	39.16**±0.13	9.17±0.23
Ash (%)	1.51**±0.01	2.66±0.15
Crude fibre (%)	11.54*±0.32	12.65±0.09
Protein (%)	1.74*±0.00	2.72±0.21
Fat (%)	22.49**±0.52	36.13±0.52
Carbohydrate (%)	23.58**±0.05	36.69±0.25

Values are mean ± standard deviation of duplicate determinations.
**: Means in the same row are significantly different at p<0.05.
*: Means in the same row are significantly different at p<0.01.

Proximate composition of tigernut milk

Table 4.1 shows the proximate composition of different varieties of fresh and sterilized tigernut milk. The moisture content ranged from 89.19% to 93.19%. Moisture content increased within the processing methods and varieties. The sterilized samples recorded higher moisture content; the boiled yellow sample had the highest moisture content of 93.19%, and fresh soaked brown recorded the lowest moisture content of 84.77%. There were significant differences p<0.05 between the processing methods and the varieties. The result showed that tigernut milk has a high moisture content, possibly because of the water used during the milling and extraction of milk from the tigernut. This could affect the stability and safety of food concerning microbial growth and proliferation.

The ash content ranged from 0.140% to 0.280%, with the malted samples recording the highest. The highest ash content was seen on the sterilized fresh yellow malted tiger nut, while the boiled sterilized sample had the most negligible ash content, 0.140%. The total ash recorded in various treatments was lower than the ash content of 1.5% recorded by Ukwuru *et al.* (2008). There was a significant difference (p<0.05) between the various processing methods and varieties.

The crude fibre content was 0.00% in all samples, and there was no trace of fibre recorded in the extract. The result shows that the crude fibre was lost during milk extraction from the tigernut tubers. Ayuba *et al.* (2020) also recorded similar observations for tiger nut milk.

The protein content ranged from 0.26% to 0.54%. There was a significant difference (p<0.05) between the processing methods and the different varieties of tiger nut tubers. The brown variety recorded the highest value, 0.54% and 0.49%, for fresh and sterilized samples, respectively, while the malted samples recorded the lowest value 0.26%. The differences in the sterilized sample could be attributed to the effect of heat treatment on the milk extract. Results showed that there was not much effect on the protein content of the tigernut milk after sterilization compared to its fresh state.

The fat content recorded values ranging from 5.13% to 9.17%. There was a significant difference (p<0.05) between the processing methods and the varieties. The highest fat content was recorded at 9.17% on the soaked brown fresh sample, while the least was seen on the malted sterilized yellow sample at 5.13%. The high-fat content recorded in fresh and sterilized soaked brown 9.17% and 9.01% were above the 8% for dairy milk (FAO/WHO 2002a,b), while the other samples were below the 8% standard. It has been reported that tigernut tubers are rich in fat (Belewu and Abdunrin, 2006). The fat level in the milk was higher than the 3% level required by the Codex Alimentarius Standard (Passmore and Eastwood, 1986). The results obtained are similar to the fat content of tiger nuts (7.8% -9.7 %), which Ayuba *et al.* (2022) recorded.

The carbohydrate content ranged from 0.04% to 6.83%. It was observed that the fresh malted brown recorded the highest carbohydrate (6.83%) while the soaked fresh yellow recorded the least (0.04%). Temple *et al*. (1990) showed that tiger nut tuber is a rich protein, fat, and carbohydrate source. The soaked samples recorded low carbohydrates except the fresh soaked brown with (5.12%); the low carbohydrate could be attributed to leaching during the soaking period. Also, the decrease in carbohydrates showed that sterilization affected the carbohydrate content of tigernuts. Decrease in carbohydrate content might be due to leaching of amylose during heating (Singh *et al*., 2006).

Table 2 Proximate composition of tigernut drinks

Pre-processing method	**Variety**	**Post-packaging**	**Moisture (%)**	**Ash (%)**	**Crude fibre (%)**	**Protein (%)**	**Fat (%)**	**Carbohydrate (%)**
Malting	Yellow	Fresh	$91.83^{b}\pm0.33$	$0.280^{a}\pm0.01$	0.00	$0.28^{fg}\pm0.00$	$5.69^{f}\pm0.11$	$1.93^{e}\pm0.23$
Malting	Yellow	Sterilized	$89.93^{c}\pm0.48$	$0.245^{bc}\pm0.01$	0.00	$0.26^{g}\pm0.01$	$5.13^{g}\pm0.6$	$4.44^{bc}\pm0.42$
Malting	Brown	Fresh	$85.45^{d}\pm0.72$	$0.275^{ab}\pm0.01$	0.00	$0.40^{c}\pm0.01$	$7.05^{c}\pm0.03$	$6.83^{a}\pm0.69$
Malting	Brown	Sterilized	$90.29^{c}\pm1.05$	$0.260^{ab}\pm0.01$	0.00	$0.40^{c}\pm0.00$	$7.06^{c}\pm0.02$	$2.00^{e}\pm1.02$
Soaking	Yellow	Fresh	$92.91^{ab}\pm0.18$	$0.200^{de}\pm0.00$	0.00	$0.34^{d}\pm0.01$	$6.53^{d}\pm0.21$	$0.04^{f}\pm0.01$
Soaking	Yellow	Sterilized	$93.05^{ab}\pm0.04$	$0.160^{fg}\pm0.01$	0.00	$0.30^{e}\pm0.01$	$6.15^{e}\pm0.06$	$0.35^{f}\pm0.03$
Soaking	Brown	Fresh	$84.77^{d}\pm0.86$	$0.25^{abc}\pm0.01$	0.00	$0.54^{a}\pm0.01$	$9.17^{a}\pm0.03$	$5.12^{b}\pm0.65$
Soaking	Brown	Sterilized	$89.84^{c}\pm0.30$	$0.170^{ef}\pm0.01$	0.00	$0.48^{b}\pm0.01$	$9.01^{b}\pm0.02$	$0.52^{f}\pm0.28$
Boiling	Yellow	Fresh	$92.94^{ab}\pm0.22$	$0.175^{ef}\pm0.02$	0.00	$0.33^{d}\pm0.01$	$6.20^{e}\pm0.04$	$3.47^{cd}\pm0.28$
Boiling	Yellow	Sterilized	$93.19^{a}\pm0.01$	$0.140^{g}\pm0.01$	0.00	$0.29^{ef}\pm0.01$	$6.13^{e}\pm0.01$	$0.26^{f}\pm0.02$
Boiling	Brown	Fresh	$89.19^{c}\pm0.92$	$0.225^{cd}\pm0.01$	0.00	$0.54^{a}\pm0.01$	$7.06^{c}\pm0.03$	$2.99^{de}\pm0.88$
Boiling	Brown	Sterilized	$89.57^{c}\pm0.25$	$0.190^{ef}\pm0.01$	0.00	$0.49^{b}\pm0.01$	$7.05^{c}\pm0.01$	$2.70^{de}\pm0.21$

Values are mean ± standard deviation of duplicate determinations. Means in the same column bearing different superscripts are significantly different at p<0.05.

CONCLUSION

The study showed that tigernut tubers can be processed into different products with various processing methods. Generally, processing treatment significantly affects the quality of the products. Variations in the chemical values of the samples were a function of the processing treatments. There was a significant difference in the proximate composition of the tiger nut tubers and a significant difference in the tigernut milk at different processing methods. Promoting tiger nut consumption will play an imperative role in many developing countries' health, nutrition, and economy. The study highlighted improvements in utilizing tigernut in order to massively drive the utilization and commercialization of tigernut tubers in Nigeria and beyond.

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Declaration of competing interest

The authors declare that they have no competing financial interest or personal relationship that could have appeared to influence the work.

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Effects of Local Stabilizers (Achi, Ofor, And Cocoyam) on the Physicochemical, Sensory and Microbiological Properties of Yoghurt

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KEYWORDS

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ABSTRACT

This study was conducted to evaluate the use of local soup thickeners known as plant-based stabilizer to produce yoghurt and determine their effects on the physicochemical and microbiological properties of yoghurt. Reconstituted powdered cow milk was homogenized, pasteurized at 95°C for 5 min, cooled to 45˚C and inoculated with a direct-vat-set (DVS) yoghurt starter culture of Streptococcus thermophilus and Lactobacillus bulgaricus for 12 h and cooled at 5˚C. Achi and Ofor seeds were sorted, cleaned, soaked (6 h), toasted, dehulled, dehydrated, milled and sieved to obtain their respective flours. Cocoyam were sorted, peeled, washed, sliced, dehydrated, milled, and sieved to obtain cocoyam flour. These flours were incorporated at 10% into yoghurt samples as stabilizers. The yoghurt samples were subjected to proximate, functional and microbial, and organoleptic evaluation. Proximate analysis revealed significant differences (p <0.05) in carbohydrate, moisture, protein, fat, and ash content among different yogurt samples. Functional properties assessment indicated that the yogurt containing 100% Cocoyam flour displayed the lowest water release. Microbiological evaluation recorded varying total viable bacterial counts (TVC) across samples, with the lowest count observed in yogurt containing 0.33% Cocoyam and 0.67% Ofor. Notably, coliforms were absent in all samples. Overall, the findings suggested the potential of local plant-based soup thickeners as effective stabilizers in yogurt production, enhancing its physicochemical and functional attributes. The study highlights the feasibility of incorporating these indigenous hydrocolloids into yogurt formulation for improved product quality and possibly broader market appeal.

INTRODUCTION

Yoghurt is one of the most popular fermented dairy products, which is semi-solid and most popular of all fermented milk products in Nigeria (Shiby and Mishra, 2013). Yoghurt is made by the fermentation of milk using a starter culture of a particular strain of *Lactobacillus* or a mixed culture of *Lactobacillus delbreickii* subsp. *bulgaricus* and *Streptococcus thermophilus* (Sansawal *et al.*, 2017). It can be manufactured using fresh animal milk or using reconstituted powdered milk. In recent times, powdered cow milk and vegetable milk such as soymilk are a being used a major base material to produce quality yoghurt (Obiora *et al.*, 2020). Lactic acid and the other compounds formed during the fermentation of milk makes yogurt a food product that is acidic and creamy, appreciated for its taste and nutritional qualities, notably for its calcium content (Widayat *et al.*, 2020). Yoghurt is classified primarily according to its chemical composition (full-fat, reduced-fat, and low-fat), manufacturing method (set and stirred yogurt), flavour type, and post incubation process.

Stabilizers are essential in dairy products to increase the viscosity, and inhibit the formation of large crystals. Stabilizers include agar, cornstarch, gelatin, and pectin. Cellulose compounds such as methylcellulose and CMC (sodium carboxyl methyl cellulose) are also used (Bakirci and Macit, 2017). Achi and Ofor seed flours serve as traditional emulsifier and thickening agent. Their seed kernels are added to all kinds of soup such as *egusi*, *oha, onugbu* soups and local beer in Nigeria. Their leaves and flowers are used as condiments or vegetables for cooking (Kouyate, 2011).

Their utilization can potentially reduce the reliance on imported synthetic hydrocolloids (carboxy methyl cellulose, guar gum, etc.) that has no nutritional value, thereby boosting Nigeria's import dependence and ease the pressure on the Nigerian currency. This study also encourages the use of underutilized locally sourced raw materials for commercial production which are readily available, serve as a novel route to increase the nutritive and functional properties of yoghurt. The use of local stabilizers (*achi*, *ofor*, and cocoyam) may also increase the spectrum of purchase of yoghurt to low income and poor families and reduce the overdependence on imported synthetic hydrocolloids (carboxy methyl cellulose, guar gum, etc.) that has no nutritional value as well as boosting the Nigeria's gross domestic product.

MATERIALS AND METHODS

Sources of Raw material

The raw materials used in this study include powdered cow milk (Full Cream Dano milk), *Achi* seed, *Ofor* seed, and Cocoyam tubers (*xanthosomas agittifolium*). The materials were purchased from Eke-Awka market, Anambra State. The raw materials *(Achi* seeds, *Ofor* seeds, and co

coyam tubers) were transported to the lab where they were processed into flours, incorporated into yoghurt and the samples were analyzed for proximate and sensory properties in the laboratory. Reagents and equipment used for the analysis were obtained from laboratory of the Department of Food Science and Technology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

Experimental Design

A simple centroid mixture design approach using JMP Pro software version 23 was employed in this study. Eight samples of local stabilizers and their combinations were were added to yoghurt samples as shown in Table 1.

Table 1: Experimental Design

S/N	Sample code	Cocoyam	*Achi*	*Ofor*
1	CO1	0.33	0	0.67
2	CY2	1	0	0
3	CA3	0.67	0.33	0
4	AC4	0	1	0
5	CH5	0.33	0.67	0
6	AO6	0	0.33	0.67
7	CF7	0.67	0	0.33
8	OF8	0	0	1
9	STD	0	0	0

Proximate Analyses

Reconstituted powdered cow milk (400g to 2 liters of distilled water) was homogenized using a homogenizer for 3 minutes, pasteurized at a temperature of 95˚C for 5 minutes, cooled to 45˚C, inoculated with 2% starter culture (yogourmet), fermented at a temperature of 45˚C for 8 hours and cooled to 5˚C (Lee, 2006; Bristone *et al.,* 2016). The processed stabilizers (*Achi, Ofor* and cocoyam) and their combinations were incorporated into the yogurt as shown in Table 1. Each of the samples was analyzed for carbohydrates, crude protein, crude fibre, fat, moisture and ash using standard methods described by AOAC (2023).

Functional properties Evaluation

The viscosity of the sample was determined using the method outlined by Onwuka (2005), involving washing the viscometer tube with acetone and then suspending it to fill with exactly 20 milliliters of the sample. The sample was allowed to run down to the primary/calibration line. Stop watch was used to ascertain the reading.

The water absorption capacity of the yoghurt sample was determined using a method described by Iwe, (2003). A 10 ml of yoghurt sample was centrifuged for 30 minutes at 3000 rpm. The quantity of whey expelled after centrifugation was expressed as millimeters of water bound in yoghurt sample.

The syneresis of yoghurt sample was measured using drainage method described by Tamime *et al.* (1995) with minor modification. The method was based on spontaneous movement of whey out of the gel under the force of gravity. 25 gram of yoghurt was poured into a funnel with filter paper placed on a 50 ml of volumetric flask and allowed to stand for 6 hours. The amount of drained off whey from the yoghurt was measured.

Microbiological Evaluation

Ten millimeter (10 ml) of each sample of the yoghurt samples was put in 9 ml of sterile distilled water in sterile test tubes, shaken and then serially diluted. From the appropriate dilution, 0.1 ml was inoculated separately on to MacConkey agar, Nutrient agar and Potato Dextrose agar plates and spread evenly using sterile bent glass rod. The inoculated MacConkey agar, Nutrient agar and Potato Dextrose agar plates were incubated at 30 °C and 35 °C for 24 and 48 hours respectively. After the period of incubation, the colonies on the plates were counted and recorded as colony forming unit per mil, cfu/ml (Cheesebrough, 2006).

Sensory Evaluation

Yoghurt samples were subjected to sensory evaluation using 25 semi-trained panelists. The panelists evaluated the samples using a questionnaire provided and the points based on; colour, taste, aroma, flavour and overall acceptability using a 9-point hedonic scale (1 = dislike extremely; 2 = dislike very much; 3 = dislike moderately; 4 = dislike slightly; 5 = neither like or dislike; 6 = like slightly; 7 = like moderately; 8 = like very much; 9 = like very extremely) as described by Ihekoronye and Ngoddy (1985).

Statistical analysis

The data was analyzed using Statistical Package for Social Sciences version 23.0. All data were represented as mean of three replicates. The mean, range and standard deviation of each parameter was determined. Duncan Multiple Range Test was employed for separation of means.

RESULTS AND DISCUSSION

Proximate analyses of the yoghurt samples

Table 2 showed the proximate compositions of nine yoghurt samples. Sample CY2 (100% cocoyam) had the highest carbohydrate content while sample AC4 (100% *achi*) had the least value for carbohydrate. Wursburg (2015) mentioned that carbohydrates are good sources of energy and its high concentration contributes to the texture, viscosity, and moisture retention of yoghurt. Sample CY2 (100% cocoyam) had the highest carbohydrate content while sample AO6 (0.33% cocoyam and 0.67% *achi*) recorded the lowest value for carbohydrate content. This suggests that cocoyam has higher carbohydrate content than achi, and that increasing the proportion of cocoyam in the yoghurt increases its carbohydrate content. Sample AC4 (*achi* 100%) had the highest moisture content while sample OF8 (100% *ofor*) had the least moisture content among the yoghurt samples. Sample OF8 (100% *Ofor*) had the highest protein content while sample AC4 (100% *achi*) had the least protein content. This suggests that ofor had higher protein content than achi, and that increasing the proportion of ofor in the yoghurt increases its protein content. Sample AO6 (0.33% *achi* and 0.67% *ofor*) had the highest fat content while sample CY2 (100% cocoyam) had the least fat content. This suggests that ofor has a higher fat content than cocoyam, and that increasing the proportion of ofor in the yoghurt increases its fat content. Sample AO6 (0.33% *achi* and 0.67% *ofor*) and AC4 (100% *achi)* had highest ash content while sample CY2 (100% cocoyam) had the least ash content. This suggests that achi and ofor have higher ash content than cocoyam, and that increasing the proportion of achi or ofor in the yoghurt increases its ash content.

Table 2: Proximate composition of Nine Samples of Composite Yogurt

Sample Code	Carbohydrate (%)	Moisture (%)	Crude Protein (%)	Fat (%)	Ash (%)
CO1	8.79^{d}±0.50	82.66^{d}±0.57	5.05^{b}±0.01	2.23^{c}±0.05	1.42^{b}±0.01
CY2	13.34^{a}±0.61	84.19^{cd}±0.57	1.04^{e}±0.04	1.12^{d}±0.06	0.31^{f}±0.00
CA3	12.89^{b}0.59	84.29^{cd}±0.57	0.98^{f}±0.01	1.39^{d}±0.90	0.45^{e}±0.01
AC4	7.06^{e}±0.55	88.02^{a}±0.00	2.05^{d}±0.05	2.39^{c}±0.01	0.48^{e}±0.01
CH5	7.24^{e}±0.63	87.49^{b}±0.57	2.44^{d}±0.02	2.33^{c}±0.05	0.50^{d}±0.02
AO6	5.32^{g}±0.50	85.98^{c}±0.57	5.26^{b}±0.01	2.56^{b}±0.05	0.88^{c}±0.01
CF7	10.99^{c}±0.04	83.23^{cd}±0.57	3.63^{c}±0.03	1.72^{d}±0.06	0.43^{e}±0.00
OF8	6.09^{f}±0.67	82.47^{cd}±0.77	5.98^{b}±0.01	3.70^{a}±0.10	1.76^{a}±0.00
STD	9.06^{c}±0.22	81.30^{cd}±0.09	6.21^{a}±0.15	3.20^{a}±0.04	0.23^{g}±0.01

Values are means ± standard deviation. Means with the same superscript in the same column are not significantly different ($p \leq 0.05$).CO1= Cocoyam 33% and *Ofor* 67%, CY2 = Cocoyam 100%, CA3 = Cocoyam 67% and *Achi* 33%, AC4 = *Achi* 100%, CH5 = Cocoyam 33% and *Achi* 67%, AO6 = *Achi* 33% and *Ofor* 67%, CF7 = Cocoyam 67% and *Ofor* 33%, OF8 = *Ofor* 100%, STD= 100% yoghurt

Sensory quality of the yoghurt samples

Table 3 showed the sensory scores of nine yoghurt samples. According to Fellows (2007), the major quality factors for yogurt acceptability include the sensory properties such as the appearance, texture and mouth feel. The mean value of the colour ranged from 4.04 -8.56 relating to "dislike slightly" to "like very m" on the 9-point hedonic scale. The taste ranged from 5.08-7.48 relating to "neither like nor dislike" to "like moderately" on the 9-point hedonic scale. The aroma ranged from 6.76-7.48 relating to "like slightly" to "like moderately" on the 9-point hedonic scale. The texture ranged from 3.96-8.52 relating to "dislike moderately" to "like very much". The mean value for the overall acceptability ranged from 4.24-7.52 relating to "dislike slightly" to "like moderately" on the 9-point hedonic scale. Overall acceptability refers to the general acceptance of the product with reference to all the discriminating sensory attributes of the sample including colour, taste, texture, moldability and flavour (Ogundele *et al*., 2015); it is also an important parameter in organoleptic estimation as it plays a crucial role in decision making and it influences the panelists acceptance and choices of the different samples. Yoghurt made from 100% cocoyam flour (AC4) had the best sensory properties.

Table 3: Sensory Analysis Results of Nine Samples of Composite Yoghurt.

Sample code	Colour	Taste	Aroma	Texture	Overall Acceptability
CO1	7.90^{a}±1.15	7.32^{a}±1.28	7.32^{ab}±1.43	7.20^{b}±1.32	7.52^{a}±0.65
CY2	7.92^{ab}±0.96	7.48^{a}±1.15	6.96^{c}±1.20	8.52^{a}±1.19	7.28^{a}±0.61
CA3	7.08^{a}±1.41	5.08^{c}±1.44	5.16^{d}±1.21	6.36^{c}±1.35	6.36^{c}±0.90
AC4	4.04^{b}±1.36	7.68^{a}±1.14	6.88^{c}±1.30	3.96^{d}±1.39	5.68^{d}±0.85
CH5	6.36^{ab}±1.22	6.92^{b}±1.49	6.76^{c}±1.20	5.24^{a}±1.16	4.24^{e}±0.92
AO6	5.08^{b}±1.38	4.92^{a}±1.28	6.84^{c}±1.10	7.00^{b}±1.25	7.16^{b}±0.80
CF7	7.36^{ab}±1.18	6.88^{b}±0.97	7.04^{b}±1.09	7.16^{b}±1.31	7.28^{a}±0.61
OF8	7.92^{a}±1.18	7.28^{a}±1.54	7.16^{b}±1.49	6.44^{c}±1.26	6.20^{c}±0.95
STD	8.56^{a} ±1.10	6.80^{b}±1.18	7.42^{a}±0.05	6.30^{c}±1.10	7. 30^{a}±1.15

Values are means ± standard deviation. Means with the same superscript in the same column are not significantly different ($p \leq 0.05$).CO1= Cocoyam 33% and *Ofor* 67%, CY2 = Cocoyam 100%, CA3 = Cocoyam 67% and *Achi* 33%, AC4 = *Achi* 100%, CH5 = Cocoyam 33% and *Achi* 67%, AO6 = *Achi* 33% and *Ofor* 67%, CF7 = Cocoyam 67% and *Ofor* 33%, OF8 = *Ofor* 100%, STD = 100% yoghurt.

Functional properties of the yogurt samples

Table 4 showed the results of functional analysis of five yoghurt samples. Five best samples of yoghurt were selected after sensory analysis and subjected to functional and microbial evaluation. The mean values for syneresis ranged from 26.50-54.16% with sample CO1 (0.33% cocoyam, 0.67% *ofor*) having the highest value while sample CY2 (100% cocoyam) had the least value. The water holding capacity ranged from 525 – 901 g/kg. Sample OF8 (100% *ofor*) recorded the least value while sample CA3 (0.67% cocoyam and 0.33% *achi)* recorded the least value. This means that cocoyam and achi are effective stabilizers for reducing the whey separation and increasing the moisture retention of yoghurt, but they also make it more fluid and less thick. The viscosity of the samples ranged from 33.32 – 62.85 mm^2/S. Sample OF8 (100% *ofor*) had the highest value while sample CA3 (0.67% cocoyam and 0.33% *achi*) recorded the least value. This means that *ofor* is a very effective stabilizer for increasing the thickness and firmness of yoghurt, but it also causes more whey separation and shrinkage than *achi* and cocoyam.

Table 4: Functional properties of Six Samples of Composite Yoghurt

Sample code	% Formulation of Cocoyam, *Achi* and *Ofor*	Syneresis (%)	Water Holding Capacity (g/kg)	Viscosity (mm^2/S)
CO1	0.33:0:67	$54.16^a \pm 0.15$	$579.33^d \pm 1.15$	$50.10^b \pm 0.79$
CY2	1:0:0	$26.50^f \pm 0.10$	$701.00^c \pm 1.00$	$39.07^c \pm 2.16$
CA3	0.67:0.33:0	$52.13^b \pm 0.15$	$525.66^{de} \pm 0.57$	$33.32^d \pm 1.96$
CF7	0.67:0:0.33	$50.00^c \pm 0.00$	$588.33^d \pm 0.57$	$41.82^c \pm 1.97$
OF8	0:0:1	$48.73^d \pm 0.05$	$901.33^a \pm 1.52$	$62.85^a \pm 2.91$
STD	0:0:0	$25^f.02^e \pm 0.27$	$500^d.01 \pm 0.15$	$37.02^c \pm 0.85$

Values are means ± standard deviation. Means with the same superscript in the same column are not significantly different ($p \leq 0.05$).CO1= Cocoyam 33% and *Ofor* 67%, CY2 = Cocoyam 100%, CA3 = Cocoyam 67% and *Achi* 33%, AC4 = *Achi* 100%, CH5 = Cocoyam 33% and *Achi* 67%, AO6 = *Achi* 33% and *Ofor* 67%, CF7 = Cocoyam 67% and *Ofor* 33%, OF8 = *Ofor* 100%, STD = 100% yoghurt.

Microbiological quality of the yoghurt samples

Table 4 showed the results of microbiological analysis of six yoghurt samples selected after sensory evaluation. The total viable bacterial count (TVC) ranged from 1.90×10^7- 2.93×10^7 CFU/ml with sample CA3 (0.67% and 0.33% achi) having the highest value while sample CO1 (0.33% cocoyam and 0.67% *ofor*) had the least value. The total yeast and mold counts ranged from 0.50×10^7 - 1.80×10^7CFU/ml. The lowest amount was found in sample CO1 (0.33% cocoyam and 0.67% *ofor*) and the highest amount was found in sampleCF7 (0.67% cocoyam and 0.33*ofor*). There were no coliforms identified in the analysed samples. The absence of coliform could be due to the significant level of sanitary measures implored by the various processing procedures.

Table 4: Results of Microbiological Analysis of Six Yoghurt Samples

Sample code	**% Formulation**	**Total Viable Bacteria count (cfu/ml)**	**Yeast and Mold (cfu/ml)**	**Total Coliform Count**
CO1	0.33:0:67	$1.90^d \times 10^7 \pm 0.07$	$0.50^c \times 10^7 \pm 0.10$	Nil
CY2	1:0:0	$2.30^c \times 10^7 \pm 0.0.70$	$1.36^{ab} \times 10^7 \pm 0.98$	Nil
CA3	0.67:0.33:0	$2.93^{ab} \times 10^7 \pm 0.90$	$1.70^a \times 10^7 \pm 0.20$	Nil
CF7	0.67:0:0.33	$2.60^{bc} \times 10^7 \pm 0.57$	$1.80^a \times 10^7 \pm 0.63$	Nil
OF8	0:0:1	$2.33^{bc} \times 10^7 \pm 1.15$	$1.03^{ab} \times 10^7 \pm 0.25$	Nil
STD	0	$2.90^{ab} \times 10^7 \pm 0.01$	$1.35 \times 10^7 \pm 0.03$	Nil

Values are means ± standard deviation. Means with the same superscript in the same column are not significantly different ($p \leq 0.05$).CO1= Cocoyam 33% and *Ofor* 67%, CY2 = Cocoyam 100%, CA3 = Cocoyam 67% and *Achi* 33%, AC4 = *Achi* 100%, CH5 = Cocoyam 33% and *Achi* 67%, AO6 = *Achi* 33% and *Ofor* 67%, CF7 = Cocoyam 67% and *Ofor* 33%, OF8 = *Ofor* 100%, STD = 100% yoghurt.

CONCLUSION

This study has shown that locally derived plant-based hydrocolloids commonly used as native soup thickeners could also be used in the formulation of generally acceptable yoghurt. There were significant increase proximate and functional properties of yoghurt samples when compared with the standard yoghurt. The yoghurt samples were considered safe for consumption since the highest total viable bacterial count were within the acceptable range. Considering the economic situation of Nigeria, adoption of locally-derived plant-based stabilizers will encourage consumption of more nutritious food and healthy lifestyle among the populace. However, further analysis such as the anti-nutritional and phytochemical qualities may be carried out on the yoghurt.

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Effect of Controlled Fermentation on Proximate Composition of Cocoa Bean

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KEYWORDS

Controlled fermentation,
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ABSTRACT

The source of microorganisms used during fermentation is very important to the output of the fermentation process. The use of naturally predominant species from a fermentation process gives rise to improved fermentation than the use of microorganisms from culture collections. Natural and controlled fermentation of the cocoa bean inoculated with defined starter consortia of Acetobacter pasteurianus, Saccharomyces cerevisiae and Lactobacillus plantarum was done. Cocoa fermentation was carried out under two experimental conditions; beans naturally fermented with micro flora naturally present on the substrate and beans inoculated with a defined cocktail containing defined starters from a batch of previously fermented cocoa beans at different time course. The dynamics in microbial population and time course were determined by microbial count method. The chemical content of naturally fermented and controlled fermented cocoa beans were determined through proximate analysis respectively. The dynamics in microbial composition showed that the yeast, acetic acid bacteria and acetic acid bacteria populations increased slowly and reached maximum of 6.1 x 10^7*, 4.4x 107 and 5.4x* 10^7*cfu\ml respectively, at days 3-4 for the natural fermentation, while they increased abruptly and reached maximum of 7.2x* 10^7*, 6.0x* 10^7 *and 6.1x* 10^7*cfu\ml respectively at day 2-3 for the controlled fermentation. Starter culture addition resulted in significant (P<0.05) decreases in ash (7.10%-4.50%), crude fiber (7.90-6.20%), crude protein (7.70-6.52%) content of the cocoa beans during natural and controlled fermentations, while carbohydrate and fat content increased from (62.00 - 69.70%) and (6.90 -7.70%) with starter addition. Thus, the fermentation of cocoa beans with starter culture addition produced fermented beans with higher natural quality and it potentially reduced the fermentation time* to 3 days, as against 6-7 days recorded in natural fermentation.

INTRODUCTION

Cocoa (*Theobroma cacao L.*) belongs to the family *Sterculiaceae* and is economically important due to its valuable seed. In Nigeria, dry cocoa beans are exported as a foreign exchange earner while a small percentage of the cocoa beans serve as raw material for cocoa powder, cocoa butter and chocolate products (Adeyeye *et al*., 2010).

The fermented cocoa beans are the principal raw material for the chocolate preparation that imparts desirable flavor to the final chocolate (Afoakwa, 2010).The harvested cocoa pods are subjected to spontaneous fermentation through diverse natural micro flora from surroundings such as handling staff, transport containers, knives, pod surfaces, etc. (Daniel *et al*., 2009).

Cocoa fermentation is a crucial step in post-harvest processing of cocoa. It's a spontaneous process in which the different flavor and aroma precursors of cocoa beans desired in chocolate industry are produced, it occurs in two steps: the first stage involves microbial reactions that take place in the pulp and the outer part of the beans, the second phase involves several hydrolytic reactions that occur within the cotyledons (Schawn and Wheals, 2004). The microbial activities in the cocoa pulp is a well-defined temporal succession that is dominated by yeast at first, followed by lactic acid bacteria (LAB), which decline after 48hours of fermentation as they are overcome by acetic acid bacteria (AAB). Species of Bacilli, including other bacterial species and filamentous fungi may also grow during the fermentation and can affect bean quality and cocoa flavour (Schawn and Wheals, 2004).

The spontaneous nature of cocoa bean fermentations may be the source of variable cocoa beans broad quality (Maura *et al*., 2016). That is why many investigations suggest the use of microbial starter culture to improve the fermentation process. The use of selected starter culture improved cocoa fermentation process and the chemical quality of the cocoa beans, (for instance, the use of selected starter culture reduced the fermentation time from 6 days to 3 days this helped to eliminate the reduction in lipid content caused by prolonged fermentation) (Ndife *et al.,* 2013), but results obtained are still insufficient to understand the variations in the mineral composition and cocoa fermentation process standardization.

Therefore, the aim of this research is to assess the diversity of microbial strains involved in the fermentation of cocoa in Nigeria and select appropriate microbial starters that can reduce cocoa fermentation time and yield cocoa beans with higher export quality.

MATERIAL AND METHODS

Cocoa Beans Collection

One hundred (100) ripened cocoa pods were purchased from the local market (Eke Awka) in Awka South Local Government Area of Anambra State, Nigeria. These were transported in sacs to the Microbiology Laboratory of Nnamdi Azikiwe University, Awka for fermentation. The cocoa pods have characteristic size, peel, pulp, 16.32cm in length and 9.75cm in diameter with yellowish bark and 24-27 seeds per pod as identified at the Botany Department, Nnamdi Azikiwe University, Awka.

Proximate analysis of unfermented and fermented cocoa bean

Moisture Analysis

Moisture content was determined using the oven drying method described by AOAC (2012). Approximately 2g of cocoa sample was weighed into Petri dish prior to placing the tins into a forced air drying oven for 1 h at 150° C. Samples were again placed in an oven for another 1 hour until a steady result was obtained. Percent moisture content (%MC) was determined from the formula:

%MC = [(initial weight – dry weight) / initial weight] x 100.

Ash Analysis

Ash content was determined using the ashing method described by AOAC (2012). Approximately 2g of cocoa sample was placed into a pre-weighed, dry crucible prior to placing the crucible into a muffle furnace at 500° C for 3hours. Percent ash was calculated by dividing the ash weight by the initial sample weight and multiplying by 100.

$$\% \text{ Ash content} = \frac{W3 - W1}{W2 - W1} \times \frac{100}{1}$$

Where: W1 = weight of empty crucible, W2 = weight of crucible and sample, W3 = weight of crucible and ash

Determination of Crude Fiber

This was determined by the method described by AOAC (2012). Two gram of each cocoa sample was defatted with petroleum ether. The defatted sample was boiled in 200 ml of 1.25% H_2SO_4 solution under reflux for 30 minutes. After that, the samples were washed with several portion of hot boiling water using a two-fold muslin cloth to trap the particle. The washed samples were carefully transferred quantitatively back to the flask and 20 ml of 1.25% NaOH solution was added to it. Again, the samples were boiled for 30 minutes and washed as before with hot water. Then they were very carefully transferred to a weighed porcelain crucible and dried in the oven at 105°C for 3 hours. After cooling in a dessicator, they were reweighed (W2) and then put into a muffle furnace and burnt at 550°C for 2hours.

Again, they were cooled in a dessicator and weighed.

% Crude Fiber = $\frac{Weight of fibre}{weight of sample} \times 100$

Protein Analysis

Crude Protein (CP) was determined following the method of AOAC (2012)

using a nitrogen determinator (Leco TruSpec CN or Leco FP-2000; Leco Corporation, St. Joseph, MI and Rapid N cube, Elementar, Hanau, Germany).

Total percentage nitrogen was multiplied by a factor of 6.25 to calculate percent protein.

Determination of fat content

Fat content of the samples was determined by the continuous solvent extraction method using a Soxhlet apparatus model. The method used was that described by AOAC (2012). Five grams (5.0g) of each sample was put in a Soxhlet reflux flask containing 300ml of petroleum ether. The upper end of the reflux flask was connected to a condenser. By heating the solvent in the flask through electro-thermal heater, it vaporized and condensed into the reflux flask. The wrapped sample was completely immersed in the solvent and remained in contact with it, until the flask filled up and was siphoned over, thus carrying oil extract from the sample down to the boiling flask. This process was done repeatedly for about 6hours before the defatted sample was removed and reserved for Crude Fibre Analysis (CFA). The solvent was recovered and the oil content in the flask was dried in the oven at 60°C for 30 minutes to remove any residual solvent. After cooling in a dessicator, the flask was re-weighed.

By difference, the weight of fat (oil) extraction was determined and expressed as a percentage of the sample weight.

Determination of Carbohydrate

The carbohydrate content was calculated by method described by Pearson (1976). Using the formula below:

100 – (% protein + % Moisture + % Ash + % Fat + % Fibre)

Cocoa Bean fermentation

The cocoa fruits were manually cut open and the beans separated from the placenta. Five kilo gram cocoa beans was placed in a box fermenter underneath the banana leaves so as to trap the heat generated (act as insulator) during fermentation for six days as described by Ouattara *et al*., (2008).

The fermented cocoa beans were dried in a temperature controlled forced air oven for 24 hours at a temperature of 45 -50ºC by uniformly spreading cocoa beans on the clean tray. They were intermittently stirred (24 hours) with a turner to facilitate uniform drying, as described by Hamdouche *et al*., (2015)

Isolation and Identification of isolates

The method of Lefeber *et al.*, (2012) was used for culture dependent approach which was performed after sampling. Thereafter, 135 ml of 0.1% (w/v) buffered peptone water (Oxoid, Basingstoke, United Kingdom) were added to 15 g of pulp and beans in a sterile conical flask and placed in a shaker for 5 min to obtain a uniform homogenate. Samples (1.0 ml) of the homogenate were serially diluted 10-fold in 0.1 % normal saline, from which aliquots (0.1 ml) were platted on SDA medium (Sabouraud Dextrose Agar), supplemented with 2.5ml of chloramphenicol, to 250g/ml of SDA to inhibit bacterial growth.

Lactic acid bacteria (LAB) medium as constituted by Mann Rogosa Sharpe (MRS) agar (Oxoid) supplemented with 0.5ml/250g/ml (MRS Agar) of nystatin to inhibit yeast growth.

Glucose yeast extract peptone agar (GYPA) consisting of 50g/l of D-glucose, 10g/l of yeasts extract, 1g/ of peptone, 20g/l of glycerol, 15g/l of potato and 40g/l of ethanol (v/v), supplemented with 0.0016 % of bromocresol green as color indicator and 0.5 ml of nystatin to 250/ml of (AAB medium) to inhibit yeast growth.

Nutrient agar also was supplemented with 0.5ml of nystatin for each 250/ml (NA) to inhibit yeast growth.

Samples were then incubated for 1 to 6 days in a standard incubator (Jouan, St. Herblain, France) at 30°C for monitoring and isolation of specific groups of microorganisms responsible for fermentation. Different colonies were picked up from a suitable dilution of each sample on SDA, MRS, GYPA and NA agar media, for morphological analysis and were purified through sub culturing and were stored at 4°C in the refrigerator available in the laboratory, in the same medium. All samples of microbial analysis were done in triplicates.

The isolates were identified by biochemical tests using the method described by Cheesbrough (2006)

Controlled fermentation

The pods were washed with distilled water and cleaned with 90% ethanol and broken open with sterilized knife, Five (5) kg of cocoa beans was inoculated aseptically with cultures from the spontaneous fermentation and fermented on sterilized foil (foils were sterilized by placing them in an oven for 24hours at 50ºC) using the method described by (Schwan and Fleet, 2014). The isolate consortia were cultivated in MRS, SDA, and AAB broth respectively at 28°C in a 100ml conical flask and placed in a shaker for 48hours at 200 rpm. The cells were harvested by repeated centrifugation at 3000 rpm for 20 min, washed with sterile saline (0.85% NaCl w/v) and used as inoculum for the controlled fermentation. For comparison, fermentations without starter addition (natural fermentation) were also carried out, characterized by a succession of microbial activities by inherent microflora and also those from the environment and incubated for 6 days after which they were analyzed. The fermented cocoa beans were collected at a fixed time (24, 48, 72, 96,120 and 144 hours).

Microbial count of isolates during natural and controlled fermentation of cocoa beans

The cocoa beans were aseptically collected at every 12hour interval during the fermentation. Standard microbiological pour plate method was used for plating on SDA, MRS and GYPM (consisting of 50g/l of D-glucose, 10g/l of yeasts extract, 1g/l of peptone, 20g/l of glycerol, 15g/l of potato and 40g/l of ethanol). The agar plates were incubated at 30ºC for 3days. After the incubation period, the number of colony- forming units (CFU\ml) was recorded. Colonies were picked at random in a number equal to the square root the total colonies present on the counted plate, seeking to ensure that all different colony morphologies were represented in each case (Senguna *et al*., 2009). All samples of microbial analysis were done in triplicates.

Statistical Analysis of Data

The results of the proximate analysis of natural and controlled fermentation from the study were subjected to statistical analysis using One-Way Analysis of Variance (ANOVA) and Duncan Multiple range test in Statistical Package for Social Sciences (SPSS) software (version 20).

RESULTS AND DISCUSSIONS

The values for the proximate analysis of dried unfermented cocoa beans are shown in Table 1.

Table 1: Proximate composition of dried unfermented (*Forastero*) cocoa

Parameters	Composition
Moisture	14.3 %
Ash	6.29 %
Crude fibre	7.25 %
Crude protein	7.66 %
Fat	7 .90 %
Carbohydrate	56.6 %

The diversity of microorganisms was studied in order to explain the variability of cocoa beans from Nigeria and identify key species for selecting appropriate starters for Nigerian cocoa fermentation. The yeast species isolated during the spontaneous fermentation process were *Saccharomyces cerevisiae*, which often dominates the main course of the fermentation process, because of its rapid growth at a slightly higher pH, pectinolytic activity, ethanol and heat tolerance (Daniel *et al*. 2009; Papalexandratou and De Vuyst 2011; Hamdouche *et al*. 2015).Odilon *et al*. (2017) and Oauttara *et al*. (2008) reported diversity of yeast species involved in the spontaneous fermentation of cocoa beans, the limited species recorded in this study could be because the fermentation was performed in the laboratory.

The isolates obtained from MRS agar indicated that the fermentation process was dominated by *L. plantarum*. The predominance of homo fermentative LAB strains was also reported by other studies (Kostinek *et al*., 2008; Oauttara *et al*., 2008; Liliane *et al*., 2015). It is well known that homo fermentative LAB strains convert sugars almost exclusively into lactic acid while hetero fermentative strains produce lactic acid and ethanol and thus, compete with yeast for nutrients there by inhibiting their growth, slow down fermentation and impair the production of ethanol (Thomas *et al*., 2002). Therefore, homo fermentative strains producing solely lactic acid may be more interesting and desirable.

The isolates obtained from GYPA agar indicated the fermentation process was dominated by *Acetobacter spp* which has a well known acidification capacity desirable for production of cocoa beans and chocolate quality, although (Schawn and Wheal, 2004; Romero-Cortes *et al*., 2013; Liliane *et al*., 2015). Ouattara *et al*. (2008) isolated both *Acetobacter spp* and *Gluconobacter* species,the fermentation profiles obtained in this study were similar with respect to speed, microbial succession, and yield of metabolites to that recorded by (Daniel *et al*., 2009; De vuyst, 2010; Pereira *et al*., 2012; Samagaci *et al*., 2016; Odilon *et al*., 2017).

The dynamics of microbial population during natural and controlled fermentation showed that yeasts, lactic acid bacteria and acetic acid bacteria were the dominant micro organisms isolated during cocoa beans fermentation. Only yeast and acetic acid bacteria were observed significantly at the beginning of the fermentation, in succession at concentration 1.8 x 10^7(cfu\ml) and 2.1 x 10^7 (cfu\ml) for natural fermentation and 1.8 x10^7(cfu\ml) and 2.6 x10^7(CFU\ml) for controlled fermentation. Also the addition of yeast, LAB and AAB starters accelerated the concentration of LAB, it was observed that the concentration of LAB reached 1.7x10^7(cfu\ml) at 12hour of the controlled fermentation Table 3, whereas at the same time no LAB was observed in the natural fermentation as shown in Table 2.

The results in Table 2 showed that the yeast, lactic acid bacteria and acetic acid bacteria populations increased slowly and reached maximum of 6.1x10^7(cfu\ml), 4.4x10^7(cfu\ml) and 5.4x10^7 respectively at day 3-4 for the natural fermentation while the Yeast, lactic acid bacteria and acetic acid bacteria populations increased and reached maximum of 7.2x10^7(cfu\ml), 6.0x10^7(cfu\ml) and 6.1x10^7(cfu\ml) respectively at day 2-3 for controlled fermentations as shown in Table 3.

Table 2: Dynamics of microbial population during natural fermentation of cocoa beans

Time (hours)	**Natural (cfu/ml)**		
	(SDA)	(MRS)	(AAB)
0	2x10^6	NG	1.1 x10^7
12	1.8x10^7	NG	2.1 x10^7
24	2.4 x10^7	1.8 x10^7	3.3 x10^7
36	4.1 x10^7	2.4 x10^7	3.9 x10^7
48	6.9 x10^7	3.2 x10^7	4.3 x10^7
60	6.5 x10^7	4.5 x10^7	5.1 x10^7
72	6.1 x10^7	4.4 x10^7	5.4 x10^7
84	6.0 x10^7	2.3 x10^7	4.8 x10^7
96	4.5 x10^7	1.5 x10^7	2.2 x10^7
108	3.9 x10^7	5 x10^6	1.7 x10^7
120	3.1 x10^7	3 x10^6	8 x10^6
132	2.8 x10^7	2 x10^6	9 x10^6
144	1.8 x10^7	2 x10^6	7 x10^6

Key: NG= No growth, SDA=Sabouraud Dextrose Agar, MRS= Mann Rogosa Sharpe, AAB= Acetic Acid Bacteria

Table 3: Dynamics of microbial population during controlled fermentation of cocoa beans

Time (hours)	Controlled (cfu/ml)		
	(SDA)	(MRS)	(AAB)
0	$2x10^6$	NG	$1.2\ x10^7$
12	$1.8x10^7$	$1.7\ x10^7$	$2.6\ x10^7$
24	$2.9\ x10^7$	$2.5\ x10^7$	$3.9\ x10^7$
36	$4.1\ x10^7$	$3.1\ x10^7$	$4.5\ x10^7$
48	$6.9\ x10^7$	$5.9\ x10^7$	$6.1\ x10^7$
60	$6.5\ x10^7$	$6.1\ x10^7$	$5.9\ x10^7$
72	$7.2\ x10^7$	$6.0\ x10^7$	$6.1\ x10^7$
84	$7.0\ x10^7$	$5.9\ x10^7$	$5.7\ x10^7$
96	$6.6\ x10^7$	$5.4\ x10^7$	$5.2\ x10^7$
108	$5.9\ x10^7$	$4.9\ x10^7$	$4.9\ x10^7$
120	$5.5\ x10^7$	$4.1\ x10^7$	$4.2\ x10^7$
132	$5.1\ x10^7$	$3.9\ x10^7$	$3.9\ x10^7$
144	$4.9\ x10^7$	$3.6\ x10^7$	$3.3\ x10^7$

Key: NG= No growth, SDA= Sabouraud Dextrose Agar, **MRS=** Mann Rogosa Sharpe, **AAB=** Acetic Acid Bacteria

Mean results for proximate analysis of cocoa bean seed during natural and controlled fermentation

The mean results for proximate analysis of cocoa bean seed during natural and controlled fermentation are shown in Figures (1-6). Proximate analysis shows the values of the macronutrients in food samples. The Moisture, Ash, Crude fiber, Crude protein, total Lipid and total Carbohydrate were analyzed for both natural and controlled fermentation.

The cocoa bean of the natural fermentation had final moisture content of 11.40% at day 6 while that of the controlled fermentation had final moisture content of 11.20%, as shown in Fig. 1; unfermented cocoa bean had higher moisture content of 14.30% as shown in Table 1.

Fermentation introduced significant variation in the moisture levels (Fig. 1). The moisture content of a food gives an indication of the extent to which the nutritive value of the material can be maintained i.e. its shelf life, low moisture content is therefore required for a longer shelf life. Moisture levels were significantly lower ($p<0.05$) in both natural and controlled fermented cocoa beans than in the unfermented beans (Table1), and this may be ascribed to the initial higher moisture levels of unfermented bean samples. The results obtained are similar to those reported by Afoakwa *et al*. (2011).

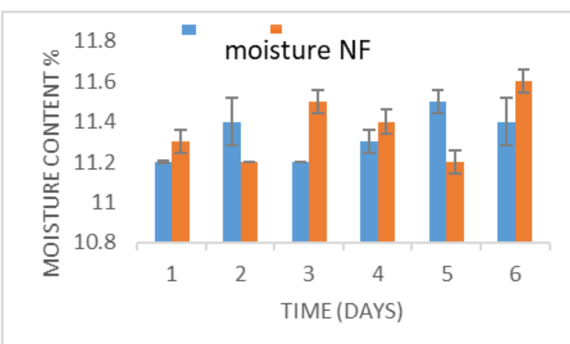

Fig 1: Moisture content of cocoa bean during natural and controlled fermentation

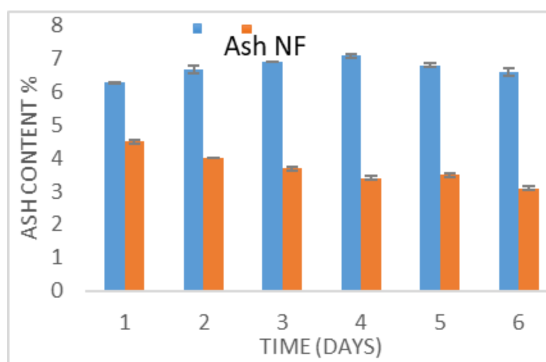

Fig. 2: Ash content of cocoa bean during natural and controlled fermentation

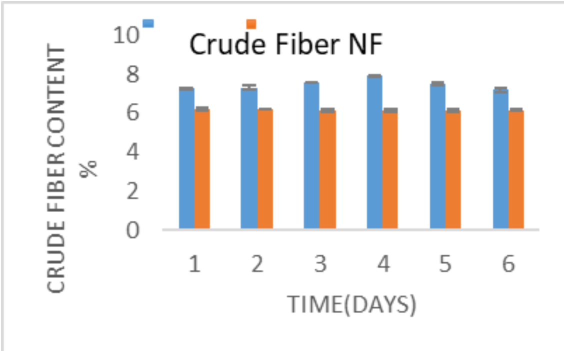

Fig. 3: Crude fiber content of cocoa bean during natural and controlled fermentation

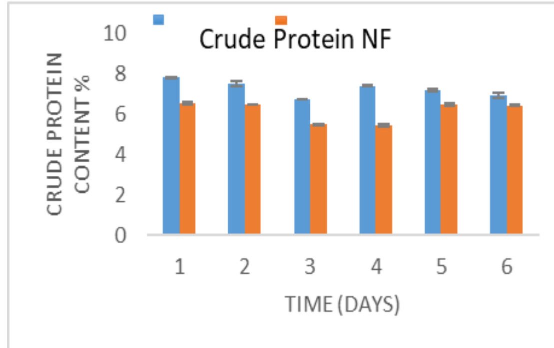

Fig. 4: Protein content of cocoa bean during natural and controlled fermentation

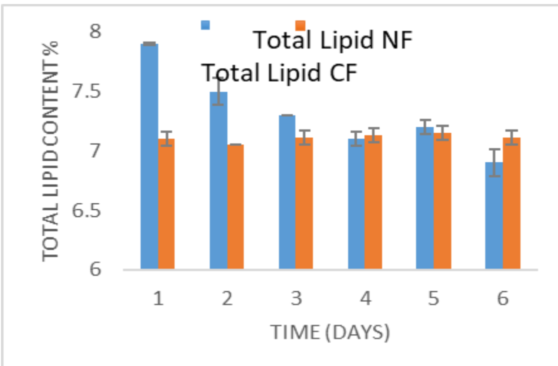

Fig. 5: Lipid content of cocoa bean during natural and controlled fermentation

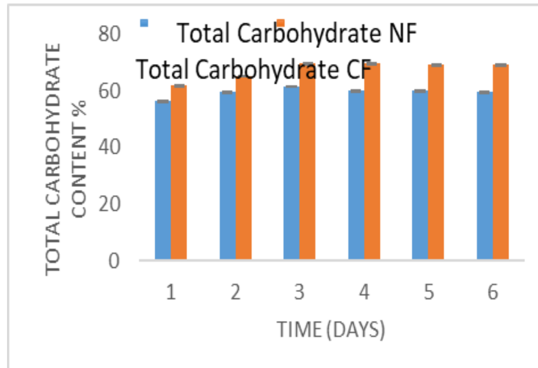

Fig. 6: Carbohydrate content of cocoa bean during natural and controlled fermentation

Key: Blue bar show results obtained during natural fermentation **(NF)**, Orange bar also showed results obtained during controlled fermentation (**CF)**

Also, the ash content of the controlled fermented cocoa beans decreased significantly ($p<0.05$) than that of the natural fermentation, with a value ranging from 3.10-4.50% and 6.28-7.10% respectively as shown in Fig. 2, but the unfermented cocoa bean had an ash content of 6.29% as shown in Table 1. The addition of microbial starter caused a decrease in the ash content (inorganic minerals) of the cocoa beans during the controlled fermentation (Fig. 2) with values ranging from (3.10-4.50%). Ash analysis is the burning away of organic minerals leaving the inorganic minerals, there was faster depletion of inorganic minerals in the controlled fermentation than in the natural fermentation leaving more organic minerals in the controlled fermented beans. Also, the body needs more organic minerals than inorganic minerals. Since organic minerals are gotten from plants and animals, cocoa beans are a good source of plant organic minerals. The decrease recorded in this study is similar to findings by Afoakwa *et al*. (2011) who recorded significant decrease in ash content with values ranging from 3.48-2.92%.

There was slight decrease in the crude fibre content with the controlled fermentation. Crude fibre content ranged from 7.20 – 7.90% for the natural fermentation and 6.12-6.20% for the controlled fermentation as shown in Fig. 3. The result recorded in this study is similar to that of Ndife *et al*. (2013) who also recorded reduction in crude fibre content with values ranging from 2.34-3.16%.

There was significant ($P<0.05$) decreases in Crude protein (Fig. 4) with values ranging from (5.45-6.52%) with the controlled fermentation. The result recorded in this study is similar to that reported by *Afoakwa et al*. (2011) who also recorded significant decrease in crude protein content with values ranging from 6.10-7.37% and in contrast to literature values of 15.2-19.8% reported by Afoakwa *et al.* (2008). The observed decreases in protein content in the cocoa bean with controlled fermentation might be due to protein breakdown during the curing process which occurred partly due to hydrolysis of amino acids and peptides and partly by conversion to insoluble forms by the action of polyphenols as well as losses by diffusion (Afoakwa *et al.* 2008).

The lipid content ranged from 6.90-7.90% for the natural fermentation and 7.05- 7.15% with the controlled as shown in Fig. 5. The fat content of the beans as observed in this study with values ranging from (7.8-9.1%) was similar to values of (10.05 to 12.65%) recorded by Ndife *et al*. (2013) and lower than values of (50.40% and 53.35%) reported by Afoakwa *et al*. (2011) and Aremu *et al.* (1995), who reported a decrease in lipid content of the cocoa beans from 62.9% to 55.7% by the sixth day of fermentation. In this study, there was slight increase in lipid content in the controlled fermentation from day 4 (reduced fermentation time) and it remained relatively stable throughout the fermentation period, unlike the lipid content in the naturally fermented cocoa beans that reduced by the end of the fermentation. This suggests that the reductions in fat content in cocoa beans could be avoided by reducing fermentation time. Variations in the bean sizes could account generally for the observed relatively lower fat content obtained in this study.

In addition, total carbohydrate content of the cocoa bean with controlled fermentation ranged from (62.00-69.70%) while that of the natural fermentation ranged from (56.00-61.50%) as shown in Fig. 6. Carbohydrate content was significantly ($p<0.05$) higher in the controlled fermentation with values ranging from (62.5-69.9%) than in the natural fermentation with values ranging from (56.6-59.90%) (Fig.6.). This increase could be as a result of an apparent inverse relationship which exists between the levels of fat and total carbohydrate in fermenting cocoa, thus, converting the lipid to carbohydrate via gluconeogenesis, employing the glyoxylate cycle. It has been indicated that this pathway normally operates in microorganisms and germinating oil seeds (Afoakwa *et al.* (2011). The unfermented cocoa bean had a carbohydrate content of (56.6%) (Table1). An increase in carbohydrate content was also recorded by Afoakwa *et al*. (2011) from 15.47% to 24.93% and by Ndife *et al.* (2013) from 43.92% to 61.74%.

CONCLUSION

The addition of microbial starters into cocoa bean fermentation as well as environmental factors (pH and temperature) reduced the fermentation process (food processing time) from 6 to 3 days, influenced to varied levels the mineral composition which resulted in consistent decreases in ash and protein, slight increase in fat content of the cocoa beans, and abrupt increase in carbohydrate content, resulting to a cocoa bean seed with potentially better and desirable export quality. The addition of microbial starter seemed to be the fundamental for the improvement of cocoa bean fermentation quality, demonstrating further application of these strains.

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Evaluation of the Diverse Nutrients of *Lasianthera africana* Leaf

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KEYWORDS

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Carbohydrates,
Lasianthera africana
Proteins minerals
Proximate analysis,
Vitamins.,

ABSTRACT

A proximate analysis was conducted to evaluate the minerals, vitamins and macro-food molecules of endemic Lasianthera africana leaves in the natural forest of Nnamdi Azikiwe University, Awka. The results showed relatively low ash (6.40), crude protein (13.83%) and moisture content (9.14%) but high crude fibre (5.37%), fat (2.61%), carbohydrate (62.7%) and Energy Value (329.5k/cal).These suggested that it is an energy giving food source even though its relatively low protein but high in calcium (143.7mg) and iron (5.94), as well as Vitamins A(294.2±0.1ug/100g) and C (10.52±0.01mg/100g). The study indicates that leaves of this forest shrub constitutes a good source of carbohydrate, protein, minerals and vitamins that could augment as a source of food condiment for the teeming population particularly in the rural communities, with significant economic and nutritional challenges

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INTRODUCTION

The preponderance of leafy vegetables in the tropics has been a significant source of food nutrient and sustainable livelihoodin developing countries, especially asa none-wood timber forest produce (Sale *et al*, 2019; Egbonwole *et al*, 2018). This is attributable to the potentials of green leafy vegetable to augment for the inadequacies in vitamins and essential proteins often associated with the high in-take of carbohydrates in africa.*Lasiantheraafricana (E*ditan) is one of the top six commonly consumed green leafy vegetables bythe Efik and Ibibio ethnic groups of Nigeria in the South Eastern part of the country (Williams *et al*., 2009). It belongs to the family *Icacinacae*. It is called Nka- nka by the igbos, Editan by the Efik and Ibibio of southern Nigeria (Burkill H.M, 1985) It is a perennial shrub that reaches a height of 61-136cm (Hutchinson and Dalziel, 2000). Four local varieties among the Ibibios, have been reportedly distinguished by the taste, leaf colour and ecological distribution are well documented (Basseyet *al*.,2006). The varieties are “Afia” (white variety), “Obubit” (black variety), “Akai” (forest variety)and “Idim” (riverine variety). The leaf has been used since pre-historic time for preparing soup and traditional concoctions for the treatment of various ailments (Sofowora, 2009).

Ebana*et al*.(2006) reported that the leaves of *Lasiantheraafricana*are rich in chemical compounds such as alkaloids, flavonoids, saponins, anthraquinones, glycosides and tannins in the four Ethno-varieties (Bassey*et al*., 2006). One unique characteristic of *Lasiantheraafricana*leaf is thebitter taste that requires de-bittering prior to cooking.The petioles of the leaves are short, approximately 5 to 10mm long with slightly undulate margins. The leaf apex is acute or acuminate while the leaf base is acute or rounded. The leaves of Lasiantheraafricana have a mild and slightly repulsive odor.

The high ash content of vegetables is a determinant of its mineral content with a high percentage of ash content in leafy vegetables for some Nigerian vegetables ranging between 9.7%±0.1 - 18.6±0.1%(Asibey-Berko and Tayie, 1999;Lockeeth*et al*., 2000).Review of studies on crude protein determination showed that green leafy vegetables are potential protein source but of low value and due to low protein levels, high consumption is normallyrecommended for daily dietary allowance of protein (Roger *et al*., 2005). Studies reported byRoger *et al*. (2005) showed the percentage crude protein range of leafy vegetables to be between 17.22±0.05 to 22.16±0.04 %.The main aim of this study is to evaluate the nutritional composition of *Lasianthera Africana (*Editan) leaf in Unizik natural forest reserve.Therefore this study evaluated the minerals, vitaminsand macro-food molecules contents of *Lasiantheraafricanan (*Editan*)* leaf in view of the need to consistently augment these essential nutrient values that could lead to malnutrition in developing climes as Nigeria. Furthermore, information will be useful to nutritionists, foresters, botanist and health practitioners.

MATERIALS AND METHODS

Study Area

This work was carried out in the Department of Forestry and Wildlife natural forest of Nnamdi Azikiwe University Awka, Anambra State, between latitude 6.245º and 6.283ºN and longitude 7.115º and 7.122ºE, within the humid tropical rainforest Belt. The forest zone is characterized by shrubs, evergreen and deciduous trees species, thick undergrowth, open vegetative Lowland that is interspersed with oil palm trees and deciduous trees. It has an average annual rainfall of 1600-2000 mm. It has Mean annual temperature rangesbetween 27ºC and 35ºC (Richard, 2005).

Collection of samples

Samples of *Lasianthera africana* leaf were obtained from the natural forest of the Department of forestry and Wildlife, Nnamdi Azikiwe University Awka, Anambra State. The leaves of Nka-nka were identified by a professional Forester for its varieties and collected with the aid of a knife. The leaves were collected in the evening between the hours of 4 and 5pm when the plants have completed light stage of photosynthetic process for the day. The quantity of leaves was air-dried at an average room temperature of 27°C for seven days and then milled with a blender. The milled samples were further sieved with a 0.02mm pore size filter to obtain a fine powdery dust. The powdered test samples were stored in a dry, clean container with lid for laboratory analysis.

Proximate composition

The analysis was conducted at the Food Profiling Biotechnology Laboratory,National Root Research Institute (NRCRI) Umudike, Umuahia. The proximate analysis was carried out on the leaf of *Lasianthera africana.* The method that was used for the proximate analysis was official analytical Chemistry (AOAC, 2010).

Statistical Analysis

Analysis of variance (ANOVA) was carried out on the data obtained from the Laboratory using Genstat 12 edition.

RESULTS

Proximate content of Lasianthera africana

The result showed relatively low ash (6.4%), crude protein (13.83%) and moisture content (9.14%) but high crude fibre(5.37%),fat(2.61%),carbohydrate(62.7%) and Energy value (329.5k/cal).

Table 1: Proximate Analysis of *Lasianthera africana* (Editan)

MC (%)	CP (%)	CF (%)	FAT (%)	ASH Mg/100g	CHO Mg/100g	EV K/cal
9.15±0.04	13.83±0.02	5.37±0.02	2.61±0.01	6.40±0.08	62.7±0.08	329.5±0.19

Where,MC-Moisture Content, CP- Crude Protein, CF- Crude Fibre, CHO- Carbohydrate, EV-Energy value

Mineral composition of *Lasianthera africana*

The mineral composition is showed in Table 2. There was a high calcium content of 143.7±0.08mg/100g and Sodium (131.9±0.09mg/100g).It showed relatively low magnesium content of 38.08±0.05mg/100gand a high potassium content of 227.1±0.06mg/100g.For Iron, this result showed a relatively high iron content of 5.94±0.25mg/100g.

Table 2: Minerals composition analysis *Lasianthera africana* (Editan)

Calcium Mg/100g	Sodium Mg/100g	Magnesium Mg/100g	Potasium Mg/100g	Iron Mg/100g
143.7±0.08	131.9±0.09	38.08±0.05	227.1±0.06	5.94±0.25

Vitamin content of Lasianthera africana

Table 3 shows the vitamin compositions. There was a high Vitamin A content of 294.2±0.1ug/100g and

vitamin B1(0.757±0.03mg/100g). The vitamins B2 content of 0.61±0.01mg/100g and B3 content of 0.38±0.01mg/100g. Vitamins C was 10.52±0.01mg/100g and E(0.30±0.01mg/100g

Table 3: Vitamin composition analysis of *Lasianthera africana* (Editan)

VIT A ug/100g	VIT B1 Mg/100g	VIT B2 Mg/100g	VIT B3 Mg/100g	VIT C Mg/100g	VIT E Mg/100g
294.2 ±0.1	0.757±0.03	0.61±0.01	0.38±0.01	10.52±0.01	0.30±0.01

VIT: Vitamin; VITA (Retinol), VIT B1 (Thiamin), VIT B2(Riboflavin), VIT B3(Niacin), VIT C (Ascorbic acid).VIT E (tocopherol)

DISCUSSIONS AND RECOMMENDATION

The results generally revealed that the minerals, vitamins and Macro food molecules compositions of *Lasianthera africana* leaves gotten from Nnamdi Azikiwe University Natural Forest, Awka.The proximate analysis showed a moisture content of 9.147±0.08% which was relatively low but within the standard condition that can enhance shelf life during storage. This result is in agreement with Mohammed *et al.* (2020) and Yakubu*et al.* (2012) which states that reported the effect of high moisture content can cause spoilage and reduce the shelf life of the food plant materials. However, it also asserted that low moisture content could lead to significant taste of bitterness and loss of nutritional value probably due to poor hydrophilic responses that allows for intermediate hydrolysis that could minimize the bitterness. This state can worsen with dry climatic conditions especially in the dry season within the tropics where this trees species is endemic.

The Crude protein content was relatively high (13.83±0.02%) because the food materials have been proportionally required to provide crude protein more than 12% of their caloric value from proteins as shown by Illondu (2010). The result therefore reveals that Ethan may be good sources of protein particularly in the midst of poor intake of protein diets due to cost of dairy products in the region of study. The *Lasianthera africana* leaves could therefore be classified as rich in proteins and serve as substitutes for protein, especially among rural dwellers, with economic challenges. Proteins are building block units and the food protein is needed to make vital hormones, important brain chemicals, antibodies, digestive enzymes, and necessary elements for the manufacture of DNA.

However, the crude fiber content compared to result obtained by Oboh*et al.* (2018), Eromosele*et al.* (2012) and Ojinnaka*et al.* (2019) showed a low value of of 5.373±0.015%. It was also lower than the result obtained by Adesina *et al.* (2020) and Abdulrahman *et al.* (2015). This may not be unconnected with either the method of preparation or location of the plant, especially the ecological zone which play key role in species differentiation for shrubby trees species. But the fat content (2.61±0.01%) was similar to the result obtained by Owolabi *et al.* (2015) and Adetunji *et al.* (2019).

Furthermore, ash content was low (6.4±0.08mg/100g) compared to earlier results obtained by Omoregie *et al.* (2012) and ogbonna *et al.* (2014) probably due to the location of the plant or method of analysis . Carbohydrate content of 62.7±0.08mg/100g showed similar result obtained by Gbadamosi *et al.* (2015) but slightly differed from Olajide*et al.* (2017) perhaps as a result of variation in photosynthetic potentials owning to leaf arrangement as well as ecological adaptation traits. This invariably influenced the high energy value of 329.5K/cal which was higher than the result obtained by Olatunde *et al*. (2015) to suggest that *Lasianthera africana* leaves represent good sources of energy and fiber.

The mineral composition was high in calcium content (143.7±0.08mg/100g) when compared with the earlier results obtained by Akindele *et al.* (2010), Adeniji *et al*. (2018) Oyetayo *et al*. (2018) and Onwukaeme *et al.* (2011). Although the methods of preparation have been adduced as probable reason, the individual capacities of studied plant species in response to nutrient retention during early growth could be contributory. For Sodium, the result showed high sodium content of 131.9±0.09mg/100g. This result was higher than the result obtained by Odeyemi and Akinloye (2017) and Ajiboye *et al*. (2012). Magnesium was low magnesium content of 38.08±0.05mg/100g. this result was lower than the result obtained by Oluwole *et al.* (2018). Potassium composition was relatively a higher (227.1±0.06mg/100g) than the result obtained by Ajayi *et al*. (2015) while the Iron content, (5.94±0.25mg/100g) was lowerthan the result obtained by Oboh *et al.* (2017) and Akindahunsi *et al*. (2015). The minerals content in *Lasianthera africana was* K > Ca > Na > Mg >Fe with potassium (K) as the predominant mineral element detected while Fe^{2+} was the least detected minerals element. This finding confers significant food value to this Ethan as critical source of inorganic mineral elements such as potassium and calcium which are known to play vital roles in the maintenance of normal glucose-tolerance and the release of insulin from beta cells of islets of Langerhans that helps to control the glucose level of in humans.

The study also revealed *Lasianthera africana* as a rich source of Vitamins A, C, E, B1, and B2 and hence a probable effective value in the treatment of of common ailments as postulated by (Adenuga*et. al.*,2010). Although the *Lasianthera africana* leaf contains more vitamin B1 (0.76mg/100g) and vitamin E (0.30mg/100g),.the higher contents of Vitamins A and C which have been reported to avert the formation of cancer-causing N-nitrous compounds (Kaur and Kapoor, 2001) presents the study findings as critical to the search for readily available non-concomitant sources of antidotes in food plants for the combat of cancer in man. The high content of Ascorbic acid of Lasiantheraafricana indicates the leaves might be a source of vitamin C. Although there are variations in Lasiantheraafricana leaf vitamins composition, this finding is in line with that of (Nwaoguikpe, 2010) Proximate analysis of *Lasiantheraafricana*leaves has revealed that they are a rich source of essential nutrients, including carbohydrates, proteins, fiber, vitamins, and minerals. This suggests that the consumption of Lasiantheraafricana leaves could contribute to meeting the daily nutritional requirements of individuals.Overall, the findings of the proximate analysis of *Lasiantheraafricana*leaves suggest that they have significant potential as a source of both medicinal and nutritional benefits.

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An Overview of Thermal and Non-Thermal Food Processing and Preservation Methods

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ABSTRACT

Thermal food processing technology had been in existence since the creation of human but recently industries are beginning to adopt the use of non-thermal food processing technology due to the challenges associated with the former like high energy consumption, degradation of food nutritive contents and high operational cost. Basically, food processing techniques are used to pasteurize, preserve taste, retain or improve nutrient contents and increase shelf life of food on storage. However, there is an increased awareness for the consumption safe and high nutritional food which has led to consumers' demand for processed food to retain natural flavour, pigment, safe, high nutritive value with an extended shelf life long enough for sales and home storage before consumption. These demands led to the continuous advancement in food processing industry to design techniques capable of retaining nutritive quality and organoleptic properties of food requiring little or no heat energy to process. In addition to the known novel processing methods like freeging, freeze-drying, ohmic heating and microwave, there is an increasing interest in developing other novel methods to achieve better food sterilization and preservation which includes high hydrostatic pressure process (HHP), pulsed electric field (PEF), cold plasma technology (CP). However, the later can lead to oxidation of lipids and loss of colour and flavour based on time of exposure. Therefore, this short review presents an overview of thermal and non-thermal food processing technologies with the underlining principles, uses and limitations of few of them.

INTRODUCTION

Food processing industry is one of the most important industry in Nigeria for its ability to create and empower populace and most importantly provide edible food for the masses to quench hunger, provide nutritional requirements and serve as supplement for some degenerative health diseases. Approaches or processes adopted in transforming raw materials to a finished product by the industry are referred to as *food processing*. Food processing techniques commonly adopted in the ancient time includes heating, sun drying, salting, soaking and fermentation. These processing techniques are required to eliminate toxins, deactivate pathogenic bacteria, prolong shelf life and make food stable and safe for consumption (Jongyingcharoen and Ahmad, 2014).

Primarily, the food industries processes food for safety, taste and stability (Jongyingcharoen and Ahmad, 2014; Chacha, *et al*., 2021). However, recently, due to modernization and awareness on the need to consume food with significant nutritive value, consumers demand for fast food, high nutritional quality, safety, satisfactory sensory properties and extended shelf life have increased (Bagchi, 2008). Meanwhile, techniques such as grilling and smoking are known to affect the nutritional physiology of food and are also linked to some health hazards like bronchitis and cancer (Oz *et al*., 2016; Oz, 2020). In a bid to meetup with consumers' demand, prevent the detrimental effects of some food processing techniques and preserve the original properties of food, researchers and processing industries have proffered new techniques referred to as non-thermal technologies (Jongyingcharoen and Ahmad, 2014).

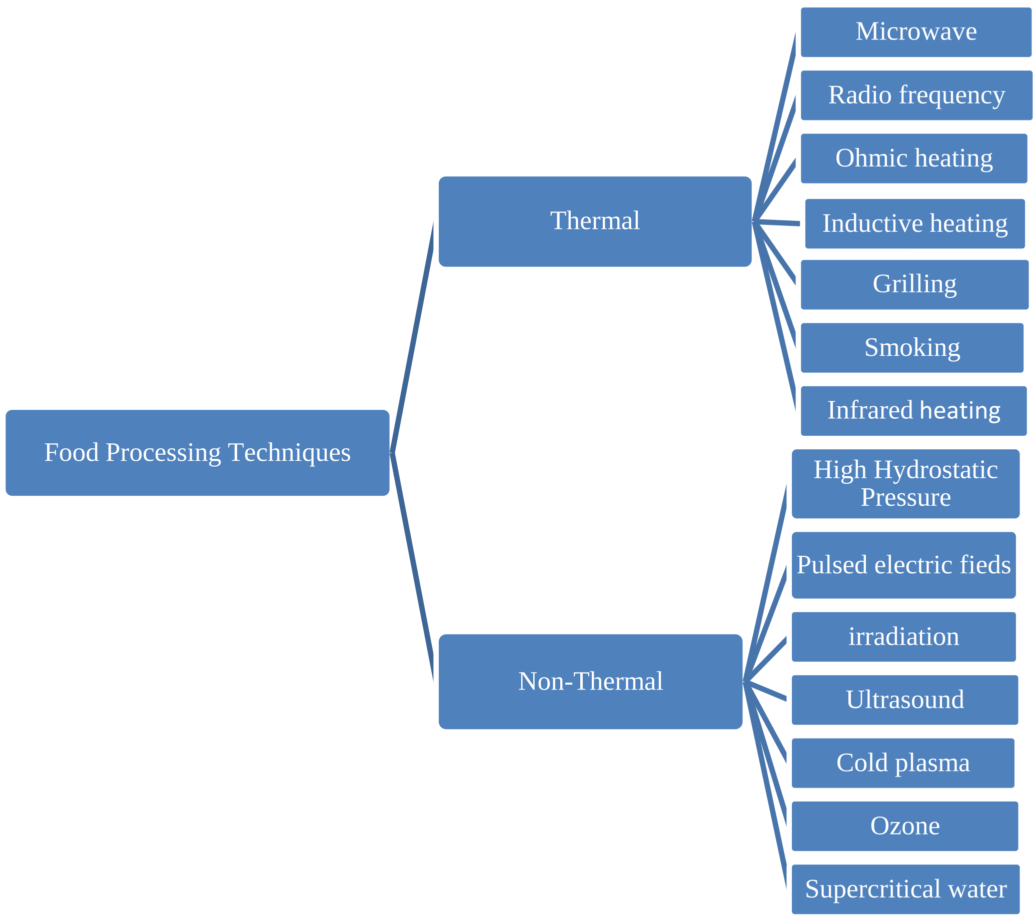

Figure 1: Food processing techniques
Source: Fozia *et al*., 2018

NOVEL TECHNOLOGIES

Before the innovation of novel technology, heating, smoking, salting and fermentation processing methods were the major techniques used in food preservation (Jongyingcharoen and Ahmad, 2014). However, these methods have their peculiarities. For instance, heating is fast and noble for its ability to retard microbial growth and prolong shelf life, but there is a limit to which this can be used in preserving fruit and vegetable products because it denatures vitamins, flavour compounds and pigments of food (Ryley and Kajda 1994; Rawson *et al*., 2011; Gao *et al*., 2016). The novel food technology is broadly divided into two (thermal and Non-thermal technologies) as presented in Figure 1.

Thermal Food Technologies

Thermal food technique is reliable and commonly adopted by food processors to minimize the microbes in food and extend the shelf life of food (Jongyingcharoen and Ahmad, 2014). These thermal processes are generally conducted at high temperatures to ensure food safety which in-turn cause detrimental effects on heat labile components like the nutrient contents, organoleptic properties and even texture of food (Knockaert *et al*., 2012; Zhong *et al*., 2019). These thermal processes can lead to the formation of carcinogenic substance which are detrimental to human health. Though, these toxicants are dependent of the kind, time and extent of heat treatment (Oz *et al*., 2016; Oz, 2020). As a result of the considerable damage caused by thermal methods, novel heating alternatives that can offer quicker heating rate to reduce damages and adverse reactions on food were devised. These techniques include microwave, radio frequency, ohmic heating and inductive heating (Fig. 1).

Effect of heat on microorganisms

Heating is a preservative technique applied during food processing to extend shelf life and increase food safety by eliminating microbes and reducing enzymatic activities of food (Tewari and Juneja, 2008) This is achieved by limiting enzymatic activities and enzyme-controlled micro-organisms. During this process, food is heated to such a temperature high enough to destroy the same percentage of contaminating micro-organism (independent of the number present initially). This is however time dependent. This time is referred to as Decimal Reduction Time (D-value) which is the time required at a giving temperature to kill 90% of contaminating micro-organism (to reduce their number by a factor of 10) (Fellows, 2000; Sebnem, *et al*., 2019). A food substance is believed to have high heat resistance when the D-value is high. Therefore, D-values of micro-organisms differ from specie to specie. z-value is the slope obtained after drawing the graph of D-value collated at different temperatures| (called Thermal Death Time-TDT) bearing in mind that the destruction of micro-organisms is time dependent and can be achieved more rapidly at higher temperature. Therefore, z-value is the relationship between an organism's resistance to different temperatures. Hence D and z-values are used to express the heat resistance of micro-organism and its temperature dependence respectively.

Table 1: **Thermal properties of selected nutritional and sensory components of foods in relation to heat-resistant enzymes and bacteria**

Component	Source	pH	$^{Z}(^0C)$	D_{121} (min.)	Temperature range (^{0}C)
Thiamin	Carrot puree	5.9	25	158	109-149
Thiamin	Pea puree	Neutral	27	247	121-138
Thiamin	Lamb puree		25	120	109-149
Lysine	Soya bean meal	-	21	786	100-127
Chlorophyll a	Spinach	6.5	51	13.0	127-149
Chlorophyll a	Spinach	Neutral	45	34.1	100-130
Chlorophyll b	Spinach	5.5	79	14.7	127-149
Chlorophyll b	Spinach	Neutral	59	48	100-130
Anthocyanin	Grape juice	Neutral	23.2	17.8*	20-121
Betanin	Beetroot juice	5.0	58.9	46.6*	50-100
Carotenoids	Paprika	Neutral	18.9	0.038*	52-65
Peroxidase	Pea	Neutral	37.2	3.0	110-138
Peroxidase	Various	-	28-44	-	-
Clostridium botulinum	Various	>4.5	5.5-10	0.1-0.3*	104
spores type A + B Bacillus stereothermophilus	Various	> 4.5	7-12	4.0-5.0	110+

* *D* values at temperatures other than 121ºC.
Source: Fellows, 2000

The heat resistance of micro-organisms considering certain variables cannot be categorically stated as a large number of factors are responsible to their resistance. Some of these factors are listed below.

1. Specie of micro-organism: Species and strains have varying heat resistance
2. Adopted Incubation condition while growing cells or spores: For instance, spores produced at high temperatures have more resistance than those produced at lower temperatures. Age of culture is another factor affecting heat resistance and culture medium (mineral salt and fatty acids greatly affects the heat resistance of spores).

Condition of heat treatment: factors like pH, water activity, components of food and growth media and incubation conditions of food while heating are great determinants of heat resistance. Pathogenic and spoilage bacteria are more heat resistant when the pH of a food substance is around 7.0. also, the water activity influences the heat resistance of vegetative cells. Fats, proteins and high concentrations of sucrose increases the heat resistance of microbes while sodium chloride do not have significant influence on the heat resistance (Fellows, 2000).

Effects of heat on nutritional properties of food

Most nutrients and organoleptic properties are potent at low temperature. For this reason, unit operations like sorting, distilling, freezing, mixing and cleaning do not have effect on the nutritional contents of food. Conversely, unit operations that intentionally separates the component of foods affect their nutrition quality compared to its raw material. Though, some operations involving unintentional separation can lead to the loss of some water-soluble vitamins, sugars and minerals. These commonly happens during blanching, drip losses from roast or frozen foods. Heating causes major changes in the nutritional properties of foods like what is experienced in the coagulation of protein and gelatinization of starch to improve their digestibility and elimination of the phytochemicals (Fellows, 2000). For instance, the trypsin inhibitor in legumes are destroyed. However, heating also deplete the protein content of food by losing some amine compounds and destroying the heat labile vitamins and promotes the oxidation of lipids (Ryley and Kajda, 1994).

Non-thermal Technologies

Non-thermal food processing technology are techniques used for food processing which requires less heat or done without applying heat (Troy *et al*., 2016; Hernandez-Hernandez, *et al*., 2019; Bhattacharjee., *et al*., 2019). Non thermal processing techniques have shown a variety of advantages over the thermal methods for their effect on the nutritive values of food and health. Non-thermal technology has been effective in extending the shelf life of food, inactivate microbes and food growth rate. The non-thermal methods include high hydrostatic pressure (HHP), cold plasma (CP) and pulse electric field (PEF). (Barbosa-Canovas *et al*., 1998).

Table 2: **Naturally occurring pigments in foods**

			Stability to the following			
Pigment	**Typical source**	**Oil or water soluble**	**Heat**	**Light**	**Oxygen**	**PH change**
Anthocyanine	Fruits	Water soluble	High	High	High	Low
Betalaines	Beetroot	Water soluble	Moderate	High	High	High
Bixin	Seed coat of Bixa orellena	Oil soluble	Moderate	Low	High	-
Caramel	Heated sugar	Water soluble	High	High	High	High
Carotenes	Leaves	Oil soluble	Moderate-low	Low	Low	High
Chlorophylls	Leaves	Water soluble	High	High	High	Low
Curcumin	Turmeric	Water soluble	Low	Low	Low	-
Norbixin	See Bixin	Water soluble	Moderate-low	Low	High	-
Oxymyoglobin	Animal	Water soluble	Low	=-	High	Low
Polyphenols	Tea leaf	Water soluble	High	High	High	High
Quinones	Roots, bark	Water soluble		Moderate	-	Moderate
Xanthophylls	Fruits	Water soluble	Moderate	High	High	Low

Source: Zapsalis and Beck (1985); Coultate (1984).

The choice of non-thermal processes is preferred over processes like fermentation because they can be used for the preservation and modification of liquids and semi-liquid rather than transforming foods in order to preserve or modify them (Mertens and Knorr, 1992). Using high hydrostatic pressure or high-intensity electric-field pulses, whole foods, micro- and/or macro-ingredients can be modified, for example gelatinization can be improved. High hydrostatic pressure and high-intensity electric-field impulses can also be used to induce stress, for example to increase the biosynthetic activities of micro-organisms, cell cultures or algae.

High hydrostatic pressure (HHP)

High Hydrostatic Pressure is a food processing technique done at ultra-high pressure to preserve and sterilize food (Rendueles 2011; Rastogi 2013). During this process, a pressure ranging from 100 and 600MPa is applied uniformly and instantly with a little variation in temperature. The temperature increases at 3^0C per 100MPa. to sterilize food substances, inactivate microorganisms without altering the flavour and nutrient with increased shelf-life (Rendueles, 2011). This method is considered safe as chemical reactions or carcinogens are not formed, ensures the inactivation of pathogenic bacteria and it does not affect the structure of protein and fat molecules. The pressure depletes the microbial cells while the existing covalent bond remains intact (Considine *et al*., 2008; Rastogi 2013).

Pulsed electric field process (PEF)

This is a non-thermal process where microorganisms are inactivated while the main nutrient of the food is retained. It is used for the sterilization of heat labile fluids and semisolids like juice, milk and liquid eggs in food industry (Ohlsso and Bengtson, 2002; Donsi *et al*., 2010; Mathys etal., 2013). This method is universally acceptable because it saves time, consume less energy, flexible, extends shelf life and retain nutritional contents more than novel thermal method (Arroyo, 2012). In principle, the electroporation may be reversible or irreversible- what happens in the reversible case is that the temporary pores formed traps desired constituents on the cell membranes while the irreversible causes permanent destruction to (distort the osmotic equilibrium of) the cell membrane which is often employed in the process of microbial inactivation and increase yield (Dukic-Vukovic *et al*, 2017). Pulse electric operates by exposing the tissue to an electric field for short high voltage pulses in the range of 10-80KV/cm to render the cell membranes more permeable (through a process called electroporation) (Sale and Hamilton, 1967; Zimmermann, 1986; Zhang *et al*., 1995; Pal, 2017; La Pena, 2019)**.**

The limitation of this method is that bacteria and moulds are resistant to it even at high intensity. This limitation may result in serious food hazard because it may alter the sterilization process. Since dielectric breakdown may occur when this method is applied on foods having bubbles, it is advised to apply it to food without air bubbles and low electrical conductivity (Arrayo *et al*., 2012).

Cold plasma technique (CP)

Cold plasma technique is a non-thermal technology which uses energetic, reactive gases to inactivate contaminating microbes on food and packaging material with minimal processing. It is the high-energy gas created when an electric current passes through a gas. This food processing technology unique for its surface sterilization and disinfection. Therefore, it is commonly used for the preservation of agricultural products in recent years (Misra *et al*., 2014). This method is simple, consumes less time, environmental friendly, economical and can be used for a wide range of food processing (Pankaj *et al*., 2018). Pigments of food may be affected during this process due to chemical reactions (Ali *et al*., 2021). However, original colour of food can be retained if the time of exposure to treatment is reduced (Pankaj *et al*., 2018).

Cold plasma process has to do with the combination of ions, UV photons, electrons, reactive species which constitute plasma state including those generated from oxygen. The cold plasma reaction does produce chemically active compounds like active nitrides and oxides cleavage some bonds and causes chemical modification on the side chains. These modifications include those of tryptophan, tyrosine, aromatic ring of phenylalanine and cysteine which may cause changes in protein structure (Surosky *et al*., 2019). Food substances are exposed to the oxygen generated reactive species to destroy the structural component of the microbial cells.

CONCLUSION

There is no doubt that heating is still the most commonly used technique for food preservation and sterilization. However, human must come to terms that the nutritional component of food must be retained rather than the benefit of preservation alone. Therefore, there is the need for the adoption of novel preservation technologies with options to produce high quality food with and lengthened shelf life. The introduction of non-thermal technologies is expected to produce better products than those of the conventional methods. The likelihood of adopting these novel technologies will be higher if the safety of their product are guaranteed with high quality product. The application of a combination of these technologies would not be a bad idea because it will broaden the application of novel technologies especially when the operation is done at about room temperature.

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Production and Evaluation of Flakes from Rice (*Oryza sativa*) and Kidney Bean (*Phaseolus vulgaris*) Flour Blends

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KEYWORDS

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ABSTRACT

This study evaluated breakfast flaked samples produced from rice and kidney bean flour blends. The rice grains were sorted, winnowed, washed, soaked, drained, dried, milled, and sieved, whereas, the kidney bean seeds were sorted, cleaned, boiled, drained, dehulled, washed, dried, milled, and sieved. The rice and kidney bean flours were blended in the ratio of 100:0, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80 and 10:90 of rice and kidney bean. The blended flours were weighed, mixed, heated, aged, cut, toasted, cooled and packaged to obtain the flaked samples. The three best samples from the sensory evaluation of breakfast flake samples (60:40, 30:70, 10:90) were analysed for proximate composition using standard methods. The data obtained were statistically analysed using SPSS and means were separated at 0.05 level of significance. The sensory properties of the breakfast flake samples ranged from 6.07 to 7.53 for colour, 5.67 to 7.80 for taste, 6.20 to 7.13 for texture, 6.20 to 7.00 for flavour and 5.27 to 6.87 for overall acceptability. The breakfast flake samples produced were all acceptable, although sample A (60:40) was preferred most in terms of overall acceptability scores of 6.87±0.73. The results of the proximate composition of the samples showed that moisture ranged from 3.35 to 11.77%, protein 13.95 to 20.61%, ash 1.99 to 3.25%, fibre 1.66 to 4.67%, lipid 6.01 to 6.08% and carbohydrate 53.69 to 69.91%, respectively. It was observed, therefore, that the blends of the rice and kidney bean flour in breakfast flakes making should not exceed 50% of kidney bean flour substitution.

INTRODUCTION

The word “breakfast” is a compound of "break" and "fast" which literally means “breaking the fast” from the last meal or snack of the previous day. Breakfast is the nutritional foundation or the first meal of the day (Afeiche *et al*., 2017). In developing countries, particularly sub-Saharan Africa, breakfast meals for both adults and infants are based on local staple diets made from cereals, cassava and potato tubers. However, the most widely eaten breakfast foods are cereals (Baltar *et al*., 2018). Breakfast cereals can be referred to as foods obtained by swelling, grinding, rolling or flaking of any cereal (Sharma and Caralli, 2014). They can be categorized into traditional (hot) cereals that require further cooking or heating before consumption and ready-to-eat (cold) cereals that can be consumed from the box or with the addition of milk (Fast, 2000; Tribelhorn, 1991).

According to Jones (2023), instant and ready-to-eat (RTE) flakes facilitate independence because of their ease of preparation which means that children and adolescents can be responsible for their own breakfast or snacks. Such foods may need to be reconstituted, pre-heated in a vessel or allowed to thaw if frozen before consumption, or they may be eaten directly without further treatment (Usman *et al*., 2015). However, it is still rare to find flakes made from legumes. Onweluzo and Nnamuchi (2009) indicated that most cereals are limited in some essential amino acids especially threonine and tryptophan. Though cereals are rich in lysine, they cannot effectively provide the nutrients required by the body, especially in the morning when the supply of nutrients from the previous day is exhausted. Cereals can however, be supplemented with most oil seeds and legumes which are rich in essential amino acids particularly the sulphur-containing amino acids (Kanu *et al*., 2017).

MATERIAL AND METHOD

Source of Raw Materials

The raw materials; rice grains, kidney bean seeds and other ingredients (sugar, salt, milk and vanilla) that were used in the study were purchased from Eke Market, Ekwulobia in Aguata Local Government Area of Anambra State, Nigeria.

Sample Processing

Preparation of Rice Flour

The rice flour was prepared following the method described by Eyenga *et al.* (2020) with modifications. One kilogram (1 kg) of rice grains were winnowed to remove the extraneous materials, washed, and soaked in distilled water for 8 h at room temperature (28°C). The rice was removed from water and dried at 60°C for 16 h to a moisture content of 20%. Then, the rice was milled in a regular disc attrition mill (dry milling) before completely drying the flour to 10% moisture and then pulverized to fine flour. The dried powder was sieved using a 60 mesh stainless sieve in order to bring the particle sizes to uniform at 60 mm, packaged and stored in a refrigerator until used.

Preparation of Kidney Bean Flour

The preparation of kidney bean flour was done according to the method of Manonmani *et al*. (2014) with slight modification. Two kilograms (2 kg) of the kidney bean seeds were sorted out, washed and boiled for 30 min. It was drained, washed, and then soaked in clean portable water for 10 h. The kidney beans were drained and dehulled manually by the aid of rubbing between palms. The dehulled kidney bean was later dried in hot air oven at 60ºC for 20 h. Then, the dried seeds (1 kg) was finely mill in disc attrition mill, sieved with 60 mm mesh sieve and stored at 4ºC in air tight containers until needed for further use.

Formulation of Flour Blends

The rice and kidney bean flours were thoroughly mixed together in the ratios of 90:10, 80:20, 70:30, 60:40,50:50, 40:60, 30:70, 20:80, 10:90 in a Kenwood blender (specify model, country of origin and year) to produce composite flours while 100:0 of rice: kidney bean was used as control. The composite flours produced were separately packaged in covered plastic containers, labelled and stored in a refrigerator at about 10^0C until needed for the production of breakfast flakes.

Recipe for the Production

The ingredients used were 500 g of each flour samples, and in each case 30 g of sugar, 4 g of salt, 6 g of milk flavour, 10 ml of vegetable oil and 750 ml of water.

Production of Breakfast Flakes

The breakfast flakes samples were prepared using the method described by Mbaeyi-Nwaoha and Uchendu (2016). The composite flour was poured in a plastic bowel and small quantity of water (20 mL) was added so as to have a binding effect, sugar and salt were added to improve the taste. The mixture was heat-treated by steaming at 120°C for 10 min and cooled. Then the treated mixture was allowed to age at a temperature of 4°C for 6 h. The semi-dried products were cut with a sharp knife, placed back into the oven for further drying and toasted at 280°C. Thereafter, the flakes products obtained were removed from oven and allowed to cool at room temperature (28°C). On cooling, the toasted breakfast flakes were packaged individually in covered plastic containers labelled and kept in a refrigerator at 10^0C until needed for analysis. Breakfast flakes made from 100% rice flour was similarly produced and used as a control.

Proximate Composition of the Samples

The Standard procedures of the Association of Official Analytical Chemist (AOAC, 2012) were used for the analysis of moisture, ash, fat, and crude protein contents. The carbohydrate content was determined by difference (AOAC, 2012).

Sensory Evaluation

The rice and the composite flour breakfast flakes produced were cooled for 2 h at room temperature and evaluated sensorially by a panel of twenty (20) semi-trained consumer panellists consisting of staff and students of the Department of Food Science and Technology, Federal Polytechnic Oko, Anambra, Nigeria. The breakfast flakes samples were made into porridge, separately coded and served to the panellists in white plastic plates of similar sizes. The panellists were asked to taste, assess and score the samples using a Nine (9) Point Hedonic Scale where 9 represents extremely like and 1 represent extremely dislike for the following attributes; colour, texture, flavour, taste, and overall acceptability. A cup of drinking water was also provided to each panellist to rinse his or her mouth after testing each sample to avoid residual effect. The panellists were told to evaluate and score each of the samples based on their preference and acceptability.

Statistical Analysis

The data generated was subjected to One-Way Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS, version 23) software (2015). Means were separated using Duncan New Multiple Range Test (DNMRT) at $p<0.05$. Values were reported in results as means ± standard deviation (SD).

RESULTS AND DISCUSSION

The Proximate Composition of Rice-kidney bean flour flaked samples

The result of the proximate composition of the breakfast flake samples produced from rice and kidney bean flour blends are as presented in Table 2.

Table 1: Proximate composition of the samples

Samples	Moisture (%)	Protein (%)	Ash (%)	Fibre (%)	Lipid (%)	Carbohydrate (%)
A	$5.53^{b}\pm0.03$	$13.95^{b}\pm0.00$	$1.99^{c}\pm0.01$	$2.54^{b}\pm0.00$	$6.08^{a}\pm0.03$	$69.91^{a}\pm0.01$
B	$3.55^{c}\pm0.00$	$17.83^{c}\pm0.04$	$2.74^{b}\pm0.06$	$1.66^{c}\pm0.01$	$6.04^{a}\pm0.06$	$68.18^{b}\pm0.03$
C	$11.77^{a}\pm0.03$	$20.61^{a}\pm0.01$	$3.25^{a}\pm0.01$	$4.67^{a}\pm0.01$	$6.01^{a}\pm0.00$	$53.69^{c}\pm0.06$

Data are mean ± standard deviation (SD) of duplicate determinations. Values in the same column bearing different superscripts differed significantly ($p<0.05$).

Keys: A = 60% Rice and 40% Kidney bean flours, B = 30% Rice and 70% Kidney bean flours and C = 10% Rice and 90% Kidney bean flours.

The Table 2 showed that the moisture content of the flaked samples ranged from 3.55±0.00 to 11.77±0.03%. The sample C had the highest value (11.77%), while sample B had the least value (3.55%). The results showed that the samples differed significantly ($p<0.05$) from each other. The moisture content of the flaked samples increased with corresponding increase in the percentage addition of kidney bean flour. This could be attributed to the differences in the composition of the individual raw materials. The values of 3.55 to 11.77% obtained in this finding were in agreement with the reported findings of 5.42 to 6.13 % by Edima-Nyah *et al*. (2020) in breakfast cereal made from maize, soybean and unripe banana. The breakfast flakes generally had low moisture content which implied that they could have an extended shelf-life except the sample C whose value was above 10%. Mbaeyi-Nwaoha and Uchendu (2016) also observed low moisture content of breakfast cereals made from blends of acha and fermented soybean to be within the range of 4.71 to 9.88%.

The protein content of the flaked samples ranged from 13.95±0.00 to 20.61±0.01%, with samples C (20.61%) having the highest value, while sample A (13.95%) had the least value. The results showed that the samples differed significantly ($p<0.05$) with each other. The protein content of the samples increased with increase in the percentage substitution of the rice with kidney bean flour. This increase could be attributed to the high protein content of kidney bean, as a legume grain compared to rice, a cereal grain. Kidney bean had been reported to be a good source of protein and several researchers have also reported increase in the protein contents of a wide range of products-substituted kidney bean flour (Thani *et al*., 2018). The values 13.95% to 20.61% obtained in this research are within the range of of 15.68% to 18.26% recorded by Okafor and Usman (2013) for breakfast cereals made from maize, African yam bean and defatted coconut breakfast cereal. The high protein in sample C indicates the effect of supplementing legumes in breakfast cereals (Mbaeyi-Nwaoha and Uchendu, 2016).

The ash content of the samples ranged from 1.99±0.01 to 3.25±0.01%. It was observed from the results that that ample C (3.25%) had the highest ash content, while sample A (1.99%) had the least ash content. The ash content of the samples differed significantly ($p<0.05$) from each other. Furthermore, there was steady increase in the ash content of the breakfast cereal with increased substitution of the kidney bean flour. Okafor and Usman (2013) reported that the ash content of breakfast cereals made from maize, African yam bean and defatted coconut ranged from 1.97% to 2.05%. The ash content gives an overall estimate of total mineral elements present in the food (Adeyeye *et al.*, 2020). The high percentage of ash in sample C indicates that the product was possibly rich in mineral, maybe because of higher percentage of kidney bean that reportedly contain high mineral composition (Agustina *et al*., 2013).

The fibre content of the samples ranged from 1.66±0.01 to 4.67±0.01%, with sample C (4.67%) having the highest fibre content, while sample B (1.66%) had the least. The result showed that the samples differed significantly ($p<0.05$) from each other. The value (1.66-4.67%) of fibre content of the samples obtained in this study were in agreement with the value (2.11-4.25%) reported by Edima-Nyah *et al*. (2020) in breakfast cereal made from maize, soybean and unripe banana. Fibre is needed to assist in digestion and keep the gastro-intestinal tract healthy (Slavin, 2013).

The lipid content of the samples ranged from 6.01±0.00 to 6.08±0.08% with sample A (6.08%) having the highest value, while sample C (6.01%) had the least value. The result showed that there were no significant ($p>0.05$) differences in the lipid content of the samples. The value (6.01-6.08%) of fibre content obtained in this research are lower than the value (14.08-18.13%) reported by Usman *et al*. (2015) in breakfast cereal made from local rice, soybean and defatted coconut flour blends.

The carbohydrate content of the samples ranged from 53.69±0.06 to 69.91±0.01%. The result showed that sample A had the highest value (69.91%), while sample C had the least value (53.69%). There were also significant ($p<0.05$) differences in the carbohydrate content of the samples. The carbohydrate content of the samples decreased drastically with increase in the percentage substitution of kidney bean flour. This could be attributed to the low composition of carbohydrate in legume compared to cereals (Tujoo, 2020). The observed values (53.69-69.91%) of carbohydrate obtained in this research were in line with the values (62.44-66.48%) reported by Edima-Nyah *et al*. (2020) in breakfast cereal made from maize, soybean and unripe banana. Mbaeyi-Nwaoha and Uchendu (2016) stated that breakfast cereals made from acha and fermented soybean paste had carbohydrate content that ranged from 60.96% to 64.53%.

The Sensory Properties of the Samples

The results of the sensory properties of the breakfast flake samples produced from rice and kidney bean flour blends are presented in Table 1.

Table 2: Sensory results of the Rice-kidney bean flour flaked samples

Samples	Colour	Taste	Texture	Flavour	Overall acceptability
A	$7.53^{a}\pm0.97$	$7.80^{a}\pm0.55$	$7.13^{a}\pm0.51$	$7.00^{a}\pm0.64$	$6.87^{a}\pm0.73$
B	$6.67^{b}\pm0.80$	$6.13^{b}\pm0.51$	$6.27^{b}\pm0.58$	$6.80^{b}\pm0.55$	$6.13^{b}\pm0.73$
C	$6.07^{c}\pm0.58$	$5.67^{c}\pm0.96$	$6.20^{b}\pm0.41$	$6.20^{c}\pm0.41$	$5.27^{c}\pm0.58$

Data are mean ± standard deviation (SD) of duplicate determinations. Values in the same column bearing different superscripts differed significantly ($p<0.05$).

Keys: A = 60% Rice and 40% Kidney bean flours, B = 30% Rice and 70% Kidney bean flours and C = 10% Rice and 90% Kidney bean flours.

The results of the sensory properties of the breakfast-flake samples made from rice and kidney bean flour blends are presented in Table 1. From the Table, the colour scores of the flakes ranged from 6.07±0.58 to 7.53±0.97. The sample A had the highest mean scores and rated by the panellists as very much acceptable whereas sample C had the least mean colour scores of 6.07 and rated by the panellists as slightly acceptable. There were significant ($p<0.05$) differences among the samples. The results of this research are similar to the reported findings of 6.30-7.70 by Calderon *et al*. (2022) in breakfast cereal produced from wheat, amaranth and orange flesh sweet potato flour blends. The result showed that colour values decreased with increased addition of kidney bean flour in the samples. The values obtained were lower than the reported findings of 7.43-7.93 by Shrivastava and Chakraborty (2018) in breakfast cereal produced from fermented chickpea and wheat flour blends.

The taste scores of the breakfast cereals ranged from 5.67 to 7.80. The sample A had significantly ($p<0.05$) the highest mean score and rated by the panellists as very much acceptable. Conversely, the sample C had significantly ($p<0.05$) the least mean score and rated by the panellists as slightly acceptable. The values obtained for the taste was similar to the reported findings of 6.10-8.69 by Bibiana *et al*. (2014) in breakfast cereal produced from wheat, maize and orange flesh sweet potato flour blends. The taste values decreased with increases in quantity of kidney bean flour in the samples. This reduction in taste could be attributed to kidney bean beany flavour.

The texture scores ranged from 6.20 to 7.13. It was observed that sample A had significantly ($p<0.05$) the highest mean scores and rated by the panellists as moderately acceptable, while the sample C had the least mean texture scores of 6.20 and rated by the panellists as slightly acceptable. There were no significant differences ($p>0.05$) between samples B and C. The results of the textural score are similar to the reported findings of 6.10 to 7.29 by Chinma *et al*. (2015) in breakfast cereals produced from rice bran and wheat flour blends. The texture values also decreased with increased percentage levels of kidney bean flour in the samples. This reduction in texture can be attributed to the absence of gluten of kidney bean flour.

The flavour scores of the samples ranged from 6.20 to 7.00. The sample A had the highest flavour score of 7.00 and rated by panelists as moderately acceptable, whereas sample C had significantly ($p<0.05$) the least flavour score of 6.20 and rated by the panelists as slightly acceptable. The results of scores of flavour of this research are similar to the reported findings of 6.20 to7.00 by Bourre *et al*. (2019) in breakfast cereals produced from split yellow pear flour and wheat flour blends. The breakfast cereal produced with sample A was more acceptable in terms of flavour compared with other samples. This could be that higher percentage of rice flour than kidney bean in breakfast cereals production would be better.

The overall acceptability scores of the samples ranged from 5.27 to 6.87. The sample A had significantly ($p<0.05$) the highest overall acceptability score of 6.87 and was rated by the panellists as moderately acceptable, whereas sample C had significantly ($p<0.05$) the least overall acceptability scores of 5.27 and was rated by the panellists as neither acceptable nor unacceptable. The results of the overall acceptability scores decreased with increased percentage levels of substitution of kidney bean flour. The decrease in overall acceptability score could be attributed to beany flavour The findings of this research are in line with the reported findings of 5.17 to 7.23 by Fendri *et al*. (2022)in breakfast cereals produced from wheat, chickpea and broad bean pea flour blends.

CONCLUSION AND RECOMMENDATIONS

The incorporation of different proportions of kidney bean flour into rice flour in the formulation of breakfast flakes drastically influenced the proximate and sensory properties of the formulated breakfast cereal products. The proximate composition of the samples showed that the increase in kidney bean flour addition resulted to subsequent increase in moisture, protein, ash and crude fibre contents, while lipid and carbohydrate contents decreased drastically. The sensory properties revealed that sample A (Breakfast flake made with 60% rice and 40% kidney bean flour) was the most acceptable to the panellists. The result also showed that all the formulated breakfast flakes were equally acceptable because they were generally rated high by the judges. In effect, the use of these nutrient-dense food materials would help to increase their cultivation and utilization in formulation of a wide range of ready-to-eat breakfast cereals that could serve as cheap sources of nutrients in Nigeria and other developing nations of the world.

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Roles of some Innovative Non-Thermal Processing Techniques on Food Quality and Safety

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ABSTRACT

New food processing methodologies have emerged in response to consumers' increasing demand for food products that are not only safe, delicious and minimally processed but also possess an extended shelf-life with consistent quality. The evolving lifestyle trends, characterized by a heightened interest in nutritionally-rich foods, bioactive compounds and overall sensory quality, have presented significant challenges to the food processing industry, driving the need for the development of novel and innovative food processing techniques. Conventional methods like pasteurization and commercial sterilization have long been used in the food industry for their efficacy in preserving foods through the eradication of harmful microorganisms and enzymes. However, the elevated temperatures generated by these methods can often lead to detrimental effects on food constituents, resulting in compromised organoleptic quality and diminished nutritional value. Hence, the need for novel non-thermal food processing techniques which can safeguard the overall quality attribute of food products with an extended shelf-life while ensuring total food safety becomes necessary. These innovative techniques include high-pressure processing, pulsed electric field, cold plasma treatment, ultrasound and hydrodynamic cavitation stand out among others, thus, exerting considerable influence on consumer health and representing major advancements in food processing. This review intends to furnish essential insights into various novel non-thermal food processing techniques, elucidating their preservative mechanisms, efficacy and suitability across diverse food categories and their impact on the food safety.

INTRODUCTION

Recent advancements in food processing techniques have been driven by consumer preferences for health-promoting foods rich in nutritional and nutraceutical values (Hameed *et al*., 2018). While the traditional focus of food processing methods was primarily on ensuring food safety and extending shelf life, contemporary consumer expectations have evolved. The production of safer food alone is no longer sufficient; therefore, consumers now seek products with substantial nutritional attributes, bioactive compounds and appealing sensory properties (Knoerzer *et al*., 2016). The attributes of food, including taste, texture, appearance and nutritional value, are significantly influenced by the processing methods employed (Knoerzer *et al*., 2016). Meanwhile, microorganisms, being the primary agents of food spoilage and contamination, are targeted by various food preservation techniques. The approaches employed by the food industry typically involve either microbial inactivation or the inhibition of microbial growth. Besides, conventional heat-based methods of reducing harmful microorganisms such as mild heat treatment, pasteurization, and in-container sterilization can negatively impact taste, nutritional content and appearance (Knoerzer *et al*., 2016). In contrast, the emergence of innovative non-thermal processing technologies has led to innovative processing techniques that prioritize improved quality and safety. The adoption of these non-thermal treatments is driven by several factors such as their milder processing conditions and environmental friendliness. These methods reduce reliance on solvents and organic chemicals, thus, contributing to a more sustainable approach to food processing (Basak and Annapure, 2022). With consumers increasingly demanding natural, nutrient-rich food products devoid of preservatives and additives, there has been a swift rise in the development of innovative non-thermal technologies to meet these preferences (Knorr *et al*., 2011).

Non-thermal or minimal processing techniques offer the advantage of preserving foods without subjecting them to significant heating, thus preserving their nutritional integrity and sensory attributes. These novel technologies have the potential to extend the freshness of foods while retaining their natural flavours and colours. Such technology results in products of improved quality and consumer appeal. Consequently, these techniques have gained significant attention from food manufacturers seeking novel processing methods (Brennan and Grandison, 2012). The advent of such innovative technologies strikes a delicate balance between safety and minimal processing, addressing both economic constraints and the demand for superior quality (Tokusoglu, 2015).

Moreover, these advancements contribute to environmental sustainability by minimising power and water consumption, consequently lowering the carbon and water footprint associated with food processing. In this way, innovative technologies play a vital role in fostering both environmental stewardship and food security (Knoerzer *et al*., 2015).Gao *et al*. (2016) reported that food components responsible for colour, flavour and taste are particularly sensitive to heat, making thermal processing prone to altering the quality of commercial food items and impacting their overall acceptability. As a result, there has been a quest for alternative methods to thermal food processing that can produce safer products with enhanced quality, nutritional content, and sensory properties. Thus, motivating food experts to delve into alternative inactivation techniques. The novel processing techniques include high-pressure processing, ultrasound extraction, pulsed electric fields, cold plasma and hydrodynamic cavitation which offer promising avenues for food processing that mitigate the detrimental effects associated with thermal methods while maintaining and enhancing product quality and nutritional value.

INNOVATIVE NON-THERMAL FOOD PROCESSING TECHNIQUES

High-pressure processing technology

High-pressure processing (HPP) emerges as a promising non-thermal preservation method, offering an effective substitute to traditional food preservation techniques for enhancing the safety and shelf life of perishable foods (Balasubramaniam and Farkas, 2008). This technique is characterized by non-thermal pasteurization which subjects products to pressures typically ranging between 300–600 MPa for durations of about 10 minutes. Notably, HPP boasts several advantages over traditional thermal processing methods, including abbreviated process times, which minimize heat-induced damage, and the preservation of product attributes such as flavour, texture, colour, and vitamins (Hameed *et al*., 2018). The HPP technology demonstrates efficacy in inactivating pathogenic and spoilage microorganisms (bacteria, yeast, mould and viruses), its effectiveness against bacterial spores and enzymes is limited (Marszałek *et al*., 2017). Various factors such as microbial species, food composition, pH and water activity, influence the efficiency of microbial inactivation by HPP (Zhang *et al*., 2017). This technique finds application in the processing of numerous liquid and semi-solid foods as well as fruit juices, jellies, purees and smoothies (Nayak *et al*., 2017). Nevertheless, the current adoption of HPP is impeded by high capital investment requirements and limited throughput (Chang *et al*., 2017).

Pulsed electric field technology

Puled electric field technique (PEF) involves subjecting the food to a pulsed high-voltage field for less than 1 second, serving as a method of food preservation. This is famous for its capacity to neutralise bacteria in liquid-based food items at reduced temperatures. Comparative studies indicate that PEF processing offers superior retention and strong ability of biologically active compounds such as phenolic compounds, carotenoids and flavonoids to remain stable during storage when compared to thermal processing. It finds industrial applicability in certain liquid products, particularly functional foods, nutraceutical products and juices, while closely resemble freshly squeezed products, particularly regarding aroma profile (Morata *et al*., 2017).The PEF technology shows promise as an alternative to thermal techniques in the pasteurization and sterilization of liquid foods. This can be attributed to its ability to maintain the nutritional value, sensory characteristics, safety and overall products' quality at lower operational costs. To enhance efficacy, PEF can be combined with additional processes such as mild thermal treatment or pH and water activity control (Khouryieh 2021). Studies suggest that integrating PEF treatment with moderate temperatures and an antimicrobial agent is effective against both gram-positive and gram-negative pathogenic bacteria can significantly improve process efficiency, reduce the number of pulses, and outlet temperature, and lead to substantial energy cost savings (Aruda *et al*., 2021).

The efficacy of PEF in microbial inactivation depends on various factors including the intensity of the electric field, number of pulses, pulse duration, pulse waveform, and temperature (with 50 – 60°C resulting in increased microbial inactivation), as well as the conductivity of the product. However, foods with high conductivity (salt content), as well as liquid products containing particulates, are considered unsuitable for PEF treatment. Additionally, the lifecycle stage of the target microorganisms also influences PEF lethality, with rapidly growing and dividing populations being the most susceptible, while those in stationary or lag phases exhibit some resistance (Dukić-Vuković *et al*., 2017). PEF technology has demonstrated successful application in the pasteurization of fluid foods like juices, milk, yoghurt, soups, and liquid eggs. However, PEF use is limited to food products without air pockets and having minimal electrical conductivity. Ensuring proper treatment requires that the largest particle size in the liquid be smaller than the gap of the treatment region in the PEF chamber (Hameed *et al*., 2018).

Cold plasma technology

Cold plasma (CP) is classified as another state of matter distinct from solids, liquids and gases which can exist in either thermal or non-thermal forms according to the conditions in which it is produced. As a non-thermal treatment, it has the potential for protein modification and has already been recognized as an innovative method for altering the content of carbohydrates, lipids and proteins in food (Jadhav and Annapure, 2021; Basak and Annapure, 2022). While thermal plasmas require significant power, such as high temperature and pressure conditions, non-thermal plasmas utilize considerably less power, often generated by electric or magnetic discharges and obtained at lower pressures, thereby attracting significant industrial interest. Although relatively underexplored, CP has been utilised in sanitizing the surfaces of fresh fruits and vegetables, liquid products (juices), food equipment surfaces (Misra and Roopesh, 2019). Recognized as a sustainable method, CP has been identified for its environmentally friendly approach to improving seed germination, decontaminating food-contact surfaces, modifying food ingredients, and inactivating enzymes (Bourke *et al*., 2018). Additionally, CP requires minimal use of solvents and chemicals, and leaves no residue, therefore, ensuring a clean label for the treated food or ingredient (Misra and Roopesh, 2019).

Cold plasma technology emerges as an effective alternative to thermally based microbial inactivation methods, exhibiting comparable microbial inactivation properties against major pathogens while exerting minimal or no effect on the nutritional or other quality aspects of the product. However, the potency of CP processing can be influenced by cell density, with upper cell layers serving as physical barriers to underlying cells, particularly in complex bacterial multilayer structures like biofilms, hence, impacting the practical application of the technique in the food sector (Misra *et al*., 2014). Its suitability for treating heat-sensitive food products stems from the fact that ions and uncharged molecules gain minimal energy, thereby, remaining at low temperatures (Pankaj *et al*., 2018).The rising demand for improved food safety and quality, while maintaining nutritional and sensory attributes, has sparked greater attention towards innovative low-temperature food processing methods. These emerging technologies primarily rely on physical processes utilizing ambient or moderately elevated temperatures and short treatment times to inactivate microorganisms. The efficacy of these processes is largely influenced by the properties of the food matrix, applying a universal approach to their application may be challenging. Further research is warranted to establish and expand the industrial applications of these technologies, overcoming potential barriers such as high capital costs that could impede industrial adoption (Komitopoulou 2024).

Ultrasound technology

Ultrasound (US) emerges as a promising, sustainable and cost-effective alternative to traditional food processing methods. This approach offers numerous advantages by enhancing food quality, preserving food, reducing processing time and facilitating process monitoring (Arruda *et al*., 2021). As a non-thermal technology, its main objective is to prolong the shelf life of food products while minimizing temperature to preserve nutritional characteristics such as texture, colour, taste and aroma, similar to fresh food (Zhang *et al*., 2018).

Ultrasound technology is recognized as a green food processing technique with the potential to enhance mass and energy transfer processes, making it one of the technologies that enables food processing with lower energy and water consumption, thereby promoting more sustainable and environmentally friendly processing methods (Chemat *et al*., 2017). In the food industry, high-powered ultrasound applications operate within the range of 20-100 kHz, particularly in systems where a liquid or gaseous medium (such as air) is used to propagate ultrasound waves (Bermudez-Aguirre *et al*., 2011). However, the scope of ultrasound applications extends beyond this, encompassing cleaning, atomization, homogenization and emulsification, defoaming, drying and freezing (Astráin-Redín *et al*., 2021).

Recent research has focused on ultrasound's potential to enhance the nutritional value and organoleptic qualities of food (Charoux *et al*., 2017). This technology facilitates mass and energy transfer processes, enabling the formation of infusions at lower temperatures (around 30 ^{0}C) with higher total polyphenol, carotenoid, and anthocyanin contents (Ciudad-Hidalgo *et al*., 2020). Moreso, US assists in the elimination of naturally occurring compounds in foods that may be harmful to human health, such as oligosaccharides from pulses or heavy metals from edible crabs (Antunes-Rohling *et al*., 2018). During dehydration, US minimizes the loss of bioactive constituents and improves the appearance of dehydrated products (Charoux *et al*., 2017).Furthermore, US facilitates the extraction of functional compounds from foods (pectins, gums, cellulose, alginates and carrageenans) which influence structure, stability and viscosity to food products (Singh *et al*., 2020; Laurora *et al*., 2021). It also enhances the extraction of protein, which can be used to enrich foods with low protein content or serve as functional additives like foam or emulsion stabilizers (Jain and Anal, 2016; Lafarga *et al*., 2018).

Hydrodynamic cavitation technology

Hydrodynamic cavitation (HC) involves the formation, expansion and abrupt collapse of bubbles, generating high pressures ranging from 100– 5000 bar and temperatures between 727 – 9727^{0}C for mere fraction of seconds. According to Gogate (2011), HC represents an innovative and underexplored non-thermal technology in food processing. It appears more physically effective and energy-efficient compared to ultrasound treatment. This technology holds promise in non-thermal food processing by potentially eliminating microorganisms, reducing enzyme activity and preserving essential nutritional and physicochemical properties (Shalini *et al*., 2023).The HC technology serves various purposes, including creating stable emulsions, homogenizing food constituents and extracting food components like polyphenols, essential oils, and pigments (Shalini *et al*., 2023). Furthermore, HC finds utility in water treatment, biodiesel, and biogas production (Shalini *et al*., 2023). This phenomenon can be induced either by mechanically rotating an object through a liquid or by fluid passage through a constriction, leading to increased velocity at the expense of local pressure (Huang *et al*., 2013). The constriction creates massive gas bubbles that collapse violently downstream, generating potent mechanical waves and high-speed micro-jets (Kuldeep *et al*., 2016). The collapse of cavities produces highly reactive hydroxyl radicals, which can be harnessed for various applications.

This novel technology is recognized as a clean and advantageous technology platform, characterized by the absence of additional chemicals, compactness, inline reactors, and low costs. In the food industry, HC is pivotal in extraction, processing, and sterilization. Various high-acid fluid foods, such as tomato juice, apple juice, and skim milk, have been processed in HC reactors for commercial sterility (Hammed *et al*., 2018). Research indicates that HC generates adequate destructive forces to deactivate bacteria, yeast cells and heat-resistant bacterial spores. The main advantage lies in its ability to achieve lower operating temperatures for sterilization, enabling the safe processing of acidic fruit juices, salad dressings, and milk at reduced temperatures, thereby preserving superior product quality. Employing hydrodynamic cavitation as a processing technology allows for minimal heat treatment of fluid foods while extending shelf life, retaining heat-labile nutrients and flavour components which results in superior products that align with consumption trends (Hameed *et al*., 2018).

CONCLUSION

The emergence of novel non-thermal food processing technologies characterized by improved quality and safety has led to significant innovations in processing techniques. The consumer preferences, research and development efforts have also led to the development of novel techniques such as high-pressure processing, pulsed electric field, ultrasound, cold plasma and hydrodynamic cavitation, which represent cutting-edge advancements in food processing. These innovative technologies have played a pivotal role in enhancing the bioactivity of functional components, food quality and safety. Their increasing applicability is driven by their significant health impacts, leading to a reduction in consumer complaints. It is anticipated that soon, traditional thermal processing methods will be largely replaced by innovative food processing techniques. Consequently, there is a concerted effort to develop more environmentally sustainable production systems to ensure the production of safe and high-quality food products.

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