Current innovation in Agriculture Science

An international peer-reviewed journal

Volume 3 Issue 1 January 2026

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Published by
Indian Society of Agricultural Science & Technology for Rural Empowerment (ISATRE), Raichur
Quarterly Journal | www.ciasjournal.com

CURRENT INNOVATION IN AGRICULTURE SCIENCE

An international peer-reviewed journal

Frequency: **QUARTERLY** – January, April, July, October

CURRENT INNOVATION IN AGRICULTURE SCIENCE
Volume 3, Issue 1 January 2026

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Current Innovation in Agriculture Science
Vol. 3, Issue 1, pp. 752-762
Research Article
ISSN (E): 3048-6009

Artificial intelligence applications in layer poultry farming for sustainable development in Delta State, Nigeria

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Received: 15 April 2025 | Accepted: 19 November 2025

DOI: https://doi.org/10.65791/cias.71

ABSTRACT

Poultry farming remains a vital agribusiness in Delta State, Nigeria, yet its growth is derailed by high disease pressure, fluctuating feed costs, unstable electricity, and inefficiencies in farm operations. Emerging evidence and innovations suggest that Artificial Intelligence (AI) technologies, ranging from computer vision systems for egg grading and disease monitoring to precision feeders, water controllers and climate-smart housing, can address these constraints and promote sustainable development. This study examined poultry farmers' perceptions of the adoption of AI applications in layer farming, focusing on their potential benefits, operational efficiency, and adoption barriers. Using a descriptive survey design, data were collected from 30 layer poultry farmers across Delta State, and analyzed using mean scores and standard deviation. According to the findings, AI is often seen as advantageous for lowering veterinarian expenses, avoiding mortality, promoting operational efficiency, and improving egg grading. Farmers were also aware of AI's potential to boost environmental sustainability and generate jobs. However, issues with its dependability in water and biosecurity applications, digital infrastructure, and pricing still exist. The findings complement previous research showing AI's revolutionary impact on agriculture, but they also underscore the necessity of encouraging laws, financial aid, and capacity training. All things considered, AI offers prospects for sustainability and efficiency in layer farming; yet, adoption necessitates removing financial and physical obstacles.

KEY WORDS: *Artificial intelligence*; *Layer poultry farming*; *Efficiency*; *Sustainability*; *Delta State.*

1. Introduction

A crucial component of Nigeria's agricultural landscape, poultry farming supports rural communities, generates jobs, and offers a significant source of high-quality protein in the form of meat and eggs. In particular, Delta State's favorable climate and robust agricultural foundation make layer poultry farming, which concentrates on rearing chickens for egg production, essential. Nigeria's expanding population has increased demand for eggs, making it essential to enhance the sustainability and production of layer poultry farming. Disease outbreaks, ineffective feed management, labor-intensive procedures, and environmental issues are just a few of the many difficulties the Delta State poultry industry faces, all of which jeopardize the long-term viability of the industry there. Modernizing and optimizing layer poultry farming operations is made possible by the advent of

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Artificial Intelligence (AI) technologies (Hamadani *et al*., 2024).

AI, which simulates human decision-making through intelligent systems and algorithms, has been used more and more in agriculture to boost output, cut waste, and increase efficiency. These technologies, which can be modified to satisfy the particular requirements of layer farming, include robots, computer vision, machine learning, and data analytics (Leong *et al*., 2025). AI-powered monitoring systems, for example, may follow the activity and health of poultry in real-time, allowing for early disease identification and a decrease in fatality rates. In a similar vein, AI-based automated feeding systems can maximize feed distribution, guaranteeing that hens get enough nutrients while reducing waste and expenses (Taleb *et al*., 2024). In addition to increasing production efficiency, Delta State's layer poultry farming has embraced AI, which is consistent with sustainable development ideals. The goal of sustainable farming is to strike a balance between social justice, environmental conservation, and economic viability. Precision farming methods powered by AI can maximize resource use to lower emissions and waste, among other environmental effects. AI can also help farmers make better decisions by giving them data-driven insights on market demands, production predictions, and flock management (Chand *et al*., 2024). Profitability can be increased while encouraging resource-saving behaviors for the coming generations.

Research on the use of artificial intelligence (AI) in agriculture, particularly in poultry farming, shows that it is becoming more and more relevant in fostering sustainability, production, and efficiency. AI has been incorporated into livestock management systems worldwide to address issues with environmental sustainability, feeding, disease prevention, and production efficiency (Kazembe and Mkandawire, 2024). Despite the substantial potential impact, there are currently few empirical studies conducted in Delta State and Nigeria. Globally, empirical research has shown how Artificial Intelligence (AI) may revolutionize poultry farming, especially in improving sustainability, disease detection, egg production, and farm automation. By using machine learning algorithms to identify respiratory sounds in poultry houses, Liu *et al*. (2020) made it possible to identify diseases like Newcastle disease early on in the field of disease detection and health monitoring. Similarly, Islam *et al*. (2025) demonstrated that AI models based on images could distinguish between healthy and ill birds with an accuracy rate of over 90%. However, Momah *et al*. (2024) noted that poor veterinary care and delayed diagnosis continue to cause significant death rates among poultry producers in the South-South region of Nigeria, particularly in Delta State. According to these results, AI-enabled monitoring systems have the potential to greatly lower losses and enhance regional sustainability.

Applications of AI in egg production and quality control have drawn attention, in addition to illness management. According to Yang (2023), grading eggs can be automated using computer vision and deep learning models, guaranteeing consistency in size, weight, and quality while reducing labor expenses and human error. According to Abanikannda and Leigh (2012), Nigerian small-scale farmers do not have access to contemporary grading equipment, which results in ineffective pricing and marketing strategies. This suggests that layer poultry farmers in Delta State, where market integration is still difficult, may become more profitable and competitive using AI-driven

egg quality evaluation. Research demonstrates that AI improves productivity and decreases waste in agricultural operations and automation. AI-powered sensors that controlled humidity and temperature enhanced animal welfare and feed efficiency (Sajid *et al*., 2024). Similarly, AI decision systems-assisted automated drinkers and robotic feeds guaranteed accurate resource use. However, the majority of Nigerian poultry farms still mostly rely on manual feeding and watering, which raises labor costs and reduces production (Chukwuka, 2024). This demonstrates the potential for implementing AI technologies in Delta State, where smallholder producers who want to increase productivity dominate the chicken industry.

Research further emphasizes AI's contributions to social, environmental, and economic consequences from a sustainability standpoint. AI-enabled precision farming eliminates environmental contamination and feed waste, according to Vetrivel *et al*. (2024). Adoption issues still exist, nonetheless, particularly in poorer nations. According to Ahmed *et al*. (2024), the main obstacles to AI adoption in Nigeria include high technological costs, low farmer awareness, and inadequate infrastructure. In Delta State, these constraints are compounded by limited access to electricity, digital tools, and extension services, making technology transfer and farmer training critical for adoption. Empirical data demonstrate that AI greatly enhances farm automation, illness detection, and egg production, all of which contribute to the sustainability of poultry farming. Notwithstanding the significant advantages, Delta State's layer poultry industry has obstacles in integrating AI due to a lack of technical experience, infrastructure constraints, high technology costs, and farmers' reluctance to embrace new innovations. In order to promote sustainable development goals, it is imperative to look into how AI applications might be applied locally. This study aims to investigate the many AI technologies that are pertinent to layer poultry farming, evaluate their possible effects on sustainability and production, and pinpoint solutions for adoption obstacles in Delta State.

2. Material and Methods

This study uses a quantitative methodology based on a descriptive survey design to assess Artificial Intelligence (AI) applications in layer poultry farming and their contribution to sustainable development in Delta State, Nigeria. Ten (10) layer poultry farms in Delta State make up the population: Caritana Farms, Oatvana Farms Nigeria Ltd, Crown Farms Limited, Ajanla Farms, Elimor Farms Nigeria Ltd, Cynthia Poultry Farm, Flourish Farms, Ifeezendo Agro Ventures, and Dandani Farms. The farm serves as the analytical unit. A sample size of 30 individuals was determined. Three (3) knowledgeable employees per farm, *viz.*, the farm manager, veterinary/animal health officer, and operations supervisor, were asked to provide data, which was then combined at the farm level to increase reliability.

An observation checklist (to confirm the presence and functionality of AI tools like sensors, CCTV/computer vision, automated feeders, drinkers, climate controllers, egg graders, and biosecurity infrastructure), a structured questionnaire (covering demographics, extent of AI adoption, disease management, egg production and quality, operations automation, sustainability outcomes, and adoption barriers), and a record extraction sheet (to capture farm Key Performance Indicators (KPIs) over the last 12 weeks, including

mortality rate, eggs per hen housed, percentage of cracked eggs, feed use, and energy downtime) are the three complementary instruments that will be used to gather data for the study. The instruments were subjected to content validation through expert review (poultry health, agri-tech/AI, and research methods specialists), and a pilot test was conducted on farms outside the sampling frame to refine clarity. Reliability was checked using Cronbach's alpha (≥0.70) for multi-item constructs, with weak items adjusted or removed. For data collection, permission was obtained from farm management, informed consent was sought from participants, and questionnaires were administered to 3 staff per farm. On-site visits will also include completion of observation checklists and extraction of relevant records. Data were entered promptly, with double-entry verification to minimize errors. Collected data were managed and analyzed using SPSS/Stata/R. An AI Adoption Index and a Sustainability Index will be computed, and analysis will involve descriptive statistics, visual summaries, and non-parametric correlation (Spearman) to explore relationships between AI adoption and sustainability outcomes.

3. Results

The results in **Table 1** show that respondents mostly agreed that artificial intelligence (AI) technologies can enhance or support disease detection and management in layer poultry farming, with a grand mean of 3.19 (SD = 0.99). The highest agreement was on the view that AI-based health monitoring reduces veterinary costs (M = 3.57, SD = 0.88), highlighting its economic advantage. Similarly, respondents agreed that AI could assist in early disease detection and reduce poultry fatality rates (M = 3.30 each). However, perceptions were less robust on AI's role in improving farm biosecurity (M = 2.93) and addressing the challenge of prompt disease

Table 1: Mean and Standard Deviation Scores of Response on the benefits of artificial intelligence technologies to enhance disease detection and management (N=30)

S/N	Statement	SA	A	D	SD	X	SD
1	Compared to conventional techniques, AI technology (such as sensors and image recognition) can assist in the early detection of layer farming diseases.	15	11	2	2	3.30	0.86
2	Fatality rates in Delta State layer farms can be decreased by implementing AI-enabled technologies.	19	4	4	3	3.30	1.04
3	For layer farms, AI-based health monitoring would reduce the expense of veterinarian care.	23	3	2	2	3.57	0.88
4	Layer farm's overall biosecurity can be enhanced by implementing AI techniques for disease detection.	10	13	2	5	2.93	1.03
5	In layer farming, one of the main issues that AI can solve is the lack of prompt disease diagnosis.	12	6	7	5	2.83	1.13
	Grand Mean/SD					3.19	0.99

SA − Strongly Agree, A − Agree, D − Disagree, SD − Strongly Disagree, X − Mean, SD − Standard Deviation, N − Total Number of Respondents, S/N − Serial Number

diagnosis (M = 2.83), with higher variability in responses. The findings suggest that while AI is recognized as beneficial for cost reduction and mortality prevention, Layer farmers remain cautious about its broader applications in biosecurity and timely disease identification.

The data presented in **Table 2** indicate that respondents generally agreed that AI can improve quality control, grading, and egg output in sustainable layer farming, with a grand mean of 3.24 (SD = 0.93). The highest agreement was on the need for AI in reducing human error and costs in egg sorting and packing (M = 3.37, SD = 0.98) and in boosting daily egg production (M = 3.33, SD = 0.91). Respondents also recognized AI's potential to increase marketability and compliance with standards (M = 3.30). Improving egg sizes and quality through AI-based grading (M = 3.13) and supporting small-scale farmers (M = 3.07) received slightly lower ratings, suggesting some reservations about broader accessibility and impact. The results demonstrate that layer farmers view AI as a useful tool for increasing productivity, efficiency, and competitiveness in the production of eggs, even though smaller producers still face difficulties.

Furthermore, the interpretation in **Table 3** reveals that respondents generally agreed that AI-driven automation can enhance efficiency in feeding, watering, and overall farm operations, with a grand mean of 3.23 (SD = 0.95). The highest agreement was on the role of AI-powered daily operation automation in reducing reliance on physical labor (M = 3.47, SD = 0.96) and optimizing feed-to-egg conversion ratios (M = 3.37, SD = 0.75), highlighting AI's potential to improve productivity and reduce human effort. Incorporating AI into farm management also received strong support (M = 3.27). Concurrently, reducing feed waste with AI-powered feeders (M = 3.17) and ensuring a steady water supply (M = 2.90) scored lower, indicating mixed perceptions

Table 2: Mean and Standard Deviation Scores of Response on how artificial intelligence (AI) can improve quality control, grading, and egg output for sustainable layer farming (N=30)

S/N	Statement	SA	A	D	SD	X	SD
1	Egg size and quality can be consistently improved with AI-based grading systems.	14	9	4	3	3.13	0.99
2	In the sorting and packing of eggs, automated AI technologies lower human expenses and errors.	20	3	5	2	3.37	0.98
3	Using AI technologies can boost a hen's daily egg production.	17	8	3	2	3.33	0.91
4	Layer farms can increase the marketability of their eggs and fulfill market criteria with the use of AI applications.	15	11	2	2	3.30	0.86
5	Small-scale farmers find it difficult to compete with large-scale growers in the absence of AI-based grading systems.	11	13	3	3	3.07	0.93
	Grand Mean/SD					3.24	0.93

SA− Strongly Agree, A − Agree, D − Disagree, SD − Strongly Disagree, X − Mean, SD − Standard Deviation, N − Total Number of Respondents, S/N − Serial Number

Table 3: Mean and Standard Deviation Scores of Response on how layer poultry farmers in Delta State can increase the efficiency of their feeding, watering, and general farm operations with AI-driven automation (N=30)

S/N	Statement	SA	A	D	SD	X	SD
1	In layer farms, feed waste can be decreased with AI-powered automated feeders.	17	4	6	3	3.17	1.07
2	AI-powered water control systems guarantee a steady and sufficient supply of water for layers.	10	12	3	5	2.90	1.04
3	In layer poultry farming, feed-to-egg conversion ratios can be optimized with AI technologies.	15	12	2	1	3.37	0.75
4	AI-powered daily operation automation lessens reliance on physical labor	22	2	4	2	3.47	0.96
5	The efficiency of production would be greatly increased by incorporating AI techniques into farm management	16	8	4	2	3.27	0.93
	Grand Mean/SD					3.23	0.95

SA− Strongly Agree, A − Agree, D − Disagree, SD − Strongly Disagree, X − Mean, SD − Standard Deviation, N − Total Number of Respondents, S/N − Serial Number

about the reliability of these systems. The findings stipulate that farmers view AI automation as a pathway to improved efficiency, cost savings, and productivity, though concerns remain about consistent water management applications.

Lastly, the result in **Table 4** shows that respondents generally agreed that AI has strong potential for layer poultry farming in Delta State but also faces significant obstacles, with a grand mean of 3.17 (SD = 0.98). The highest mean was recorded for AI's role in promoting environmental sustainability by reducing waste and pollution (M = 3.30, SD = 1.00), followed closely by the ability to create new skills and employment opportunities for youth (M = 3.27). Respondents also acknowledged that AI adoption could support sustainable development with adequate training and government support (M = 3.20). However, high equipment costs (M = 3.17) and weak infrastructure, especially unsteady electricity and limited digital facilities (M = 2.93), were identified as major barriers. The findings specify that while farmers recognize the transformative benefits of AI, successful adoption relies on addressing affordability and infrastructural challenges through supportive policies and capacity-building initiatives.

4. Discussion

The findings of the study indicate that layer farmers in Delta State have a generally favorable but cautious opinion of AI's contributions to poultry production. Respondents consistently indicated in all four tables that artificial intelligence (AI) has clear economic and productivity benefits, especially in lowering mortality, improving grading and packing, reducing veterinary costs, and optimizing feed

efficiency. However, they are still skeptical of AI's dependability for specific biosecurity and resource-management tasks and are worried about cost and infrastructure limitations. **Table 1** (disease detection and management) demonstrates that respondents were less convinced of AI's role in improving biosecurity and enabling timely diagnosis (M = 2.93 and 2.83, respectively), but they did strongly associate AI with cost savings and lower mortality (highest mean = 3.57 for reduced veterinary costs; M = 3.30 for reduced fatalities and early detection). It is consistent with Petrović *et al*. (2024) in their applied studies that show high accuracy of computer-vision and sensor systems in controlled or well-resourced settings but report variability when deployed under heterogeneous smallholder conditions (e.g., droppings-based or vision-based detection systems that perform very well in experimental datasets). This pattern reflects confidence in economic outcomes but reluctance to trust diagnostic robustness in field contexts. Also in support is recent research by Xu *et al.* (2025), which suggests that non-invasive computer vision techniques, for instance, demonstrate encouraging early-warning capabilities but emphasize that sensor placement, data representativeness, and edge processing power all affect field performance.

Two ramifications emerge. First, farmers' trust in AI to lower veterinary costs aligns with the technology's ability to prevent serious epidemics and treatment frequency through early identification. Second, the decreased trust in biosecurity and diagnostics probably stems from real-world issues that impair diagnostic timeliness and reliability in actual deployments, such as power outages, noisy surroundings, and a lack of local maintenance. The larger precision-livestock literature documents these contextual limits and highlights that to provide consistent, real-time benefits, algorithmic accuracy must be matched by strong on-farm systems architecture. As can be

Table 4: Mean and Standard Deviation Scores of Response on the potential and obstacles related to implementing AI technology in layer poultry farming (N=30)

S/N	Statement	SA	A	D	SD	X	SD
1	The use of AI in layer poultry farming could give young people in Delta State access to new skills and employment opportunities	15	10	3	2	3.27	0.89
2	By lowering waste and pollution in the production of poultry, AI technology can support environmental sustainability	18	6	3	3	3.30	1.00
3	One of the main obstacles to layer producers' adoption of AI equipment is its high cost.	17	6	2	5	3.17	1.13
4	In Delta State, the adoption of AI technology is restricted by inadequate digital infrastructure and erratic electricity supplies	10	11	6	3	2.93	0.96
5	Adoption of AI can greatly aid in the poultry industry's sustainable development with the right training and government backing.	14	10	4	2	3.20	0.91
	Grand Mean/SD					3.17	0.98

SA− Strongly Agree, A − Agree, D − Disagree, SD − Strongly Disagree, X − Mean, SD − Standard Deviation, N − Total Number of Respondents, S/N − Serial Number

seen from **Tables 2** and **3** (quality control, grading, and egg output), respondents believe AI automation would increase productivity and decrease human error (**Table 2** grand mean = 3.24; **Table 3** grand mean = 3.23). The high degree of agreement that AI improves feed conversion (M = 3.37) and lowers sorting/packing mistakes (M = 3.37) is consistent with research of Sajid *et al*. (2024) on smart sensors and robotics in poultry farming; applied demonstrations where automated feeders and vision systems provide uniform grading and precisely metered nutrition, increasing uniformity and conversion ratios. According to their experimental research, when used correctly, AI-driven grading and automated feeding can both boost per-bird output and decrease human error.

Respondents, however, showed less faith in AI-controlled water systems (**Table 3**, M = 2.90) and in the steady increase in egg size and quality (**Table 2**, M = 3.13). These concerns are understandable given that resource-delivery systems (water, micro-dosing feed) rely heavily on consistent energy, calibrated sensors, and prompt maintenance, all of which are not always present on small farms. Similar limitations are highlighted in the literature on precision agriculture for smallholders: many sensor or actuator systems function well theoretically but falter in the absence of supply chains, maintenance services, or dependable electricity (Mizik, 2022). Therefore, even though automation promises to increase productivity, farmers' decreased confidence in water control and certain quality outcomes represents real implementation difficulties in settings with limited infrastructure.

Table 4 (socio-economic potential and barriers) shows that farmers acknowledge the potential of AI to provide employment/skill possibilities for young (M = 3.27), as well as environmental benefits (M = 3.30), which is consistent with the research of Patil *et al*. (2024). However, they also cite cost (M = 3.17) and inadequate digital/electric infrastructure (M = 2.93) as significant barriers. These conclusions are substantially supported by regional evaluations of the adoption of precision agriculture, which consistently point to high upfront expenditures, restricted financial resources, and infrastructure deficiencies (such as connectivity and electricity) as the main obstacles facing smallholders in Africa and comparable regions (Khaspuria *et al*., 2024). Without subsidies, customized financing, and investments in rural digital infrastructure, smallholder adoption of AI is expected to lag, concentrating gains among farms with greater resources, according to several policy evaluations (Bagri *et al*., 2024). Respondents to the study also emphasized the need for government support and training (M = 3.20). This is consistent with previous policy literature of Patil *et al*. (2024), which encourages public-private partnerships, capacity building, and targeted financial assistance to scale up the adoption of AI in agriculture in an equitable manner. Programs that combine hardware subsidies, specialized training, and extension services, according to analysts, can hasten adoption while reducing the possibility that AI could exacerbate structural disparities between smallholder and commercial producers (Amuda & Rahman, 2024).

Three statements that cut across the four tables are synthesized. First, in line with the global body of research on the main factors influencing the adoption of agricultural technologies, farmers primarily value AI for its economic and operational benefits, such as lower costs, lower

mortality, less labor demands, and increased feed efficiency. Second, when technology needs to function reliably in challenging or under-resourced environments (biosecurity diagnostics, water control), trust gaps arise. According to the literature, these trust gaps are caused by both service ecosystem flaws and technical fragilities in the field, such as sensor drift and edge computing restrictions. Third, policies and academic research on smallholder precision agriculture directly support the conclusion that widespread adoption will require multifaceted support, including financial mechanisms to reduce entry costs, investments in rural electrification and connectivity, and extensive training and localized technical support.

5. Conclusion

Despite AI promises of quantifiable improvements in cost savings, mortality reduction, grading consistency, and operational efficiency, Delta State layer farmers' confidence is hampered by practical adoption barriers such as cost, infrastructure, and service capacity, particularly for tasks requiring consistent, reliable field performance (such as water management and biosecurity diagnostics). It will need a combination of institutional, financial, and technological action to convert favorable impressions into long-term, equitable adoption in Delta State, a strategy that is repeatedly advised by the literature today.

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Current Innovation in Agriculture Science
Vol. 3, Issue 1, pp. 763-771
Research Article
ISSN (E): 3048-6009

Carcass and organs weight of finished broiler chicken fed diets containing air-dried Pawpaw (*Carica papaya*) leaf meal as an additive

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Received: 22 May 2025 | Accepted: 28 November 2025

DOI: https://doi.org/10.65791/cias.72

ABSTRACT

The study was conducted at the poultry unit of the Teaching and Research Farm, Rufus Giwa Polytechnic, Owo, to evaluate the effect of air-dried pawpaw (*Carica papaya*) leaf meal on the carcass and organ characteristics of finished broilers. Ninety-nine (99) Ross 308 broiler chicks were used for the experiment. The birds were brooded for three weeks and later assigned to three dietary treatments in a completely randomized design, with 33 birds per treatment and three replicates of 11 birds each. The dietary treatments consisted of a control diet (T_1) with 0% pawpaw leaf meal, T_2 with 5 g kg^{-1} inclusion, and T_3 with 10 g kg^{-1} inclusion. The feeding trial lasted four weeks, during which feed and water were provided ad libitum. Data collected were analyzed using analysis of variance, and treatment means were separated using Duncan Multiple Range Test. Results showed that birds fed 10 g kg^{-1} air-dried pawpaw leaf meal (T_3) recorded the highest live weight, dressed weight, and most carcass cuts compared to the control. However, organ weights such as liver, heart, lungs, kidney, gizzard, and abdominal fat were generally higher in birds fed the control diet. The study concluded that inclusion of air-dried pawpaw leaf meal improved carcass yield but did not enhance organ development. It is therefore recommended that pawpaw leaf meal can be used as a feed additive in broiler diets, while further studies should explore other processing methods to improve both carcass and organ performance.

KEY WORDS: *Poultry*; *Weight*; *Finished broiler*; *Diets*; *Air-dried*

1. Introduction

Nigeria's population is growing at an estimated annual rate of about 3.2%, which exceeds the growth rate of food production, put at roughly 2.0% per year (National Bureau of Statistics, 2013). The disparity between the rate of food production and population growth has resulted in a shortfall in the supply of food, leading to a widening gap between domestic food production and the total demand. This has necessitated an increase in food imports and a significant rise in food prices. Consequently, widespread hunger and malnutrition have become evident in the country (Alabi and Isah, 2012).

According to Adeniji and Balogun (2002), the solution to the issue of low consumption of animal protein among the typical Nigerian is to enhance the production of highly efficient animals with a short time between generations, such as poultry, pigs, rabbits, sheep, and goats. To enhance this

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condition, it is imperative to promote the production of poultry, particularly broilers. In addition to its short generation interval and prolificacy, Sola-Ojo *et al*. (2013) found that poultry offers a significant return on investment within a short period of time. It also requires relatively minimal capital for investment and is well accepted in various culinary traditions.

The importance of poultry to the national economy cannot be overstated, as it has gained popularity among small-scale farmers who have made significant contributions to the country's economy. Poultry accounts for around 15 percent of Nigeria's total yearly protein consumption, with each person consuming an average of 1.3 kg of poultry products per year (Ologbon and Ambali, 2012). The poultry sector has become increasingly significant in enhancing employment prospects and the production of animal food in Nigeria. Many countries are now rejecting the use of synthetic feed additives or antibiotics as growth promoters in meat production due to the related health hazards for humans and animals (Gonzalez and Angeles, 2017). The use of phytobiotics, phytogenic feed additives, phytochemical feed additives, and herbal supplements or ingredients as dietary supplements is increasingly being explored as substitutes for synthetic growth promoters (Fallah *et al*., 2013; Oloruntola *et al*., 2018).

Parts of several plants that are of medicinal interest had been employed as supplements and or component in poultry production to achieve various goals of performance and health relevance (Oloruntola *et al*., 2016; Oloruntola and Ayodele, 2017; Oloruntola *et al*., 2018). One of the phytogenic feed additions gaining significance in poultry feeding to increase their performance and boost their immunological response is pawpaw whose leaf has been previously identified by Oloruntola *et al*. (2018) as a natural source of papain, chymopapain A and B, and papaya peptidase A. Papain is proteolytic and thus capable of increasing protein digestion (Oloruntola *et al*., 2018).

Pawpaw is a plant endemic to tropical America. It is popular in the tropics and sub-tropics because of its easy cultivation, rapid growth, quick economic returns and easy adaptation to varied soils and climates (Olubode *et al*., 2016). Pawpaw latex contains proteolytic enzymes papain, chymo-papain A and B, and papaya peptidase A (Olubode *et al*., 2016) and chitinase enzyme (Savon, 2005). In addition, the papaya leaf contains broad-spectrum phytochemicals including alkaloids and phenols. Phenolic compounds exhibit significant antioxidant activity and free radical scavenging capability, with the mechanism of blocking enzymes involved for reactive oxygen species generation (Kahkonen *et al*., 2001). The antibacterial, antifungal, antiviral, neuroprotective and antifertility effects of papaya have also been shown (Kadiri *et al*., 2016). It is conceivable that the nutritional and phytogenic potentials of the papaya leaf could be exploited as a growth enhancer in broiler chicken feed.

Broiler production gives employment and steady income within the shortest time because to its fast growth and shorter production cycle. However, reasonable return may be assured only when produced at minimum cost, because net profit is a function of gross return and cost of production. Though minimum cost of production is desirable to gain higher return, care must be given so as not to be too strict so that the goal of creating soft, supple and good quality meat is not compromised. According to Asghar *et al*. (2000), reduced cost of

production and higher returns are significant criteria for higher profit in broilers.

It is a general understanding that feed constitute the most and costly input in any livestock operation; notably poultry. Thus, any considerable reduction in the cost of feeds will greatly reduce the entire cost of production and raise the profit margin of the farm. Due to restriction on feed additives (Gonzalez and Angeles, 2017), the priority of nutritional research is shifted towards identifying non-conventional sources and natural replacement feed additives that are locally available with low human needs. One of such natural alternative feed additives sources that might be employed to lower the high cost production in poultry diets is the pawpaw leaf (*Carica papaya*) meal.

2. Material and Methods

2.1 Experimental site

The experiment was carried out at the poultry unit of the Teaching and Research Farm, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria the school is located in Owo, Ondo State, the state is situated at the South West part of Nigeria which was derived at savannah zone with an annual mean temperature of 30% and relative humidity of 80%. Area is 330 mm above sea level.

2.2 Sources and preparation of the test ingredient

The pawpaw leaves were harvested fresh within the institution; the leaves were air-dried under a shade avoiding the rays from sunlight after which the leaves were milled into powdery form.

2.3 Experimental animals and design

Ninety nine (99) day old Ross 308 strains of broiler chicks were procured from a reputable and reliable hatchery (Agrited) at Ibadan, the birds were brooded for three weeks after which they were divided into three (3) treatments with 33 birds per treatment and each treatment have three (3) replicates containing eleven (11) birds. The birds were housed in well ventilated pens while the experimental diets were given to them *ad libitum* throughout the experiment which lasted for four (4) weeks.

2.4 Experimental diet

Three dietary treatments (T_1-T_3) were formulated using air-dried pawpaw leaf meal as an additive (**Table 1**).

Treatment 1, (T_1) was control diet, with no inclusion of air-dried pawpaw leaf meal.

Treatment 2, (T_2) contains 5 g kg^{-1} inclusion of air-dried pawpaw leaf meal.

Treatment 3, (T_3) contains 10 g kg^{-1} inclusion of air-dried pawpaw leaf meal.

2.5 Data collection

Carcass weight: At the end of the experiment, the birds were fasted overnight, one bird was randomly selected from each replicate and weighed the following prior to slaughtering. The birds were slaughtered by using sharp knife on the jugular vein, after slaughtering the birds were defeathered, eviscerated and the respective weights were taken. The live, dressed, wings, thigh, drumstick, breast, back, head, neck and shank weight were taken.

Table 1: Percentage (%) composition of the experimental diets

Ingredients (%)	Control – Treatment 1 0% APLM	Treatment 2 5 gram APLM	Treatment 3 10 gram APLM
Maize	57.40	57.40	57.40
SBM	18.00	18.00	18.00
Wheat Offal	5.00	5.00	5.00
PKC	5.00	5.00	5.00
GNC	8.00	8.00	8.00
Fish meal	1.00	1.00	1.00
Bone meal	3.00	3.00	3.00
Lime Stone	2.00	2.00	2.00
Salt	0.30	0.30	0.30
Premix	0.30	0.30	0.30
Total	100	100	100
Calculated analysis			
M.E(kcal/kg)	2899.17	2899.17	2899.17
Crude Protein (%)	19.30	19.30	19.30
Crude fat (%)	5.05	5.05	5.05
Crude fibre (%)	4.34	4.34	4.34

M.E.: Metabolisable Energy, APL: Air-dried Pawpaw Leaves, PKC: Palm Kernel Cake, GNC: Groundnut Cake, SBM: Soyabean Meal

*Premix contains *Vit. A 4000000IU; Vit.D 800000IU; Vit.E 40000mg; Vit.K_3 800mg; Vit.B_6 5000mg; Vit.B_{12} 250mg; Niacin 6000mg; Panthothenic acid 20000mg; Folic acid 200mg; Biotin 8mg; Maganaes300000mg: Iron 80000mg; Zinc 20000mg; Cobalt 80mg; Iodine 4000mg; Selenium 40mg; Chlorine 8000*

Organ characteristics records: After evisceration the organs; liver, spleen, lung, heart, gallbladder, pancreas, proventiculus, kidney, gizzard and abdominal fat were weighed and recorded.

The value of the parameters were expressed as percentage of live weight

Percentage (%) live weight = $\frac{Parameter\ Weight}{Live\ Weight} \times 100$

$Y_{ij}=\mu+T_i+\sum_{ij}$

2.6 Statistical analysis

Data obtained was subjected to analysis of variance (ANOVA) in a complete randomised design using SAS (2015) significant mean was separated by Duncan's multiple range test (Duncan, 1955) in all 5% confidence level was set to test statistically. Significant component to variance mean value and standard error was estimated using the following experiment model Where:

Y = Output yield

μ= Population mean

Ti= Effect of air dried pawpaw leaves

∑ij= Residual error.

3. Results

3.1 Effect of air-dried pawpaw leaf meal on carcass weight of broiler chicken

The results showed no significant ($p > 0.05$) effect across all the parameters studied (**Table 2**). The highest live weight (2333.33 g) was recorded in treatment 3 (10 g inclusion of APLM), while the lowest (2050.00 g) was observed in the control (no inclusion of APLM). Similarly, for dressed weight, the highest value (1620.00 g) was recorded in treatment 3, whereas the lowest (1410.00 g) was noted in the control diet. In the case of wings, the highest weight (9.47 g) was observed in the control, while the lowest (8.69 g) was recorded in treatment 3. For thigh weight, the highest (12.45 g) and lowest (11.85 g) values were recorded in treatment 3 and treatment 2 (5 g inclusion of APLM), respectively. Drumstick weight was highest (9.80 g) in treatment 3 and lowest (9.19 g) in treatment 2. Breast weight followed a similar trend, with the highest value (25.56 g) in treatment 3 and the lowest (21.17 g) in treatment 2. Back weight was also highest (14.16 g) in treatment 3 and lowest (11.99 g) in treatment 2. For head weight, treatment 3 recorded the highest value (2.52 g), while treatment 2 recorded 2.26 g. Neck weight was highest (4.81 g) in treatment 3 and lowest (3.81 g) in treatment 2. Likewise, shank weight was highest (3.80 g) in treatment 3 and lowest (3.40 g) in treatment 2.

3.2 Effect of air-dried pawpaw leaf meal on organ weight of broiler chicken

There was no significant ($p > 0.05$) effect on all the parameters measured except for the proventriculus (**Table 3**). The proventriculus showed a significant ($p < 0.05$) effect, with the highest weight (0.52 g) recorded in the control (no inclusion of APLM) and the lowest weight (0.41 g) observed in treatment 2 (5 g inclusion of APLM). For the liver, treatment 2 recorded the highest weight (2.04 g), while treatment 3 (10 g inclusion of APLM) showed the lowest weight (1.61 g). In the case of the spleen, both the control and treatment 2 recorded similar weights (0.13 g),

Table 2: Carcass weight of finished broilers fed air-dried pawpaw leaf meal as additive

Parameters (%)	Treatment 1 Control (no inclusion of APLM)	Treatment 2 5 g inclusion of APLM	Treatment 3 10 g inclusion of APLM	SEM
Live weight	2050.00	2066.67	2333.33	86.67
Dressed weight	1410.00	1453.33	1620.00	55.10
Wings	9.47	9.20	8.69	0.26
Thigh	12.45	11.85	12.79	0.38
Drumstick	9.68	9.19	9.80	0.28
Breast	24.25	21.17	25.56	1.52
Back	13.11	11.99	14.16	0.35
Head	2.36	2.26	2.52	0.07
Neck	4.54	4.12	4.81	0.18
Shank	3.54	3.40	3.80	0.26

abc: means on the same row with different superscript differs significantly ($p<0.05$).
SEM: Standard error of mean
APLM: Air-dried pawpaw leaf meal

which were higher than that of treatment 3 (0.10 g). For the lungs, the control had the highest weight (0.60 g), whereas treatment 3 had the lowest (0.37 g). Heart weight was highest (0.43 g) in both the control and treatment 2, while the lowest (0.37 g) was observed in treatment 3. The gall bladder showed the highest weight (0.17 g) in the control and the lowest (0.14 g) in treatment 3. For the pancreas, the highest weight (0.25 g) was recorded in the control, while both treatment 2 and treatment 3 showed the lowest weight (0.21 g). Kidney weight was highest (0.40 g) in the control and lowest (0.34 g) in treatment 3. Similarly, gizzard weight was highest (1.75 g) in the control and lowest (1.54 g) in treatment 3. Abdominal fat was also highest (1.77 g) in the control and lowest (0.88 g) in treatment 3.

4. Discussion

In carcass weight, the result shows increase in all parameters measured as the inclusion of the air-dried pawpaw leaf meal increases except for wings where the result shows highest weight in no inclusion of pawpaw leaf meal, which is in consonance with the research work of Banjoko *et al*. (2020), whose result shows that the increase in the inclusion levels of pawpaw leaf meal contribute to the weight of carcass cut parts. Also the results of earlier researchers such as Bolu *et al*. (2009); Oloruntola *et al*. (2018) also corroborate with the result of this research which showed relative increase in the parameters measured in the treatments with pawpaw (*Carica papaya*) leaf extract compare with treatment with no papaya leaf extract, and is also in agreement with the result of Moshood and Odunsi (2018), which shows increase in parameters measured in the treatments with inclusion of papaya latex compared to those without inclusion. The superior value revealed across parameters in treatment 3 with 10g inclusion of APLM is an indicator that meat yield from same treatment (treatment 3) is higher than meat yield from other treatments

Table 3: Organ weight of finished broilers fed air-dried pawpaw leaf meal as additive

Parameters (%)	Treatment 1 Control (no inclusion of APLM)	Treatment 2 5g inclusion of APLM	Treatment 3 10g inclusion of APLM	SEM
Liver	1.87	2.04	1.61	0.12
Spleen	0.13	0.13	0.10	0.01
Lungs	0.60	0.40	0.37	0.04
Heart	0.43	0.43	0.37	0.02
Gall bladder	0.17	0.15	0.14	0.01
Pancreas	0.25	0.21	0.21	0.01
Proventiculus	0.52^{a}	0.41^{b}	0.44^{ab}	0.02
Kidney	0.40	0.35	0.34	0.05
Gizzard	1.75	1.69	1.54	0.12
Abdominal fat	1.77	1.53	0.88	0.19

abc: means on the same row with different superscript differs significantly.($p<0.05$)
SEM: Standard error of mean
APLM: Air-dried pawpaw leaf meal

which shows satisfactory in the weight of the carcass of broiler chicken fed with higher inclusion of air-dried papaya leaf meal, this commemorate with the work of Onyimonyi and Ernest (2009), whose results shows increase in meat yield as the inclusion of PLM increases across the treatment, hence, the use of air-dried papaya leaf meal as additive can be used in the pursuit of optimal performance in the carcass weight of broiler chicken. This result shows that in the nearest future there will be general acceptability of the inclusion of air-dried pawpaw leaf meal in broilers diet to optimise meat treatment.

This result shows no significant ($p<0.05$) effect in all parameters measured except for proventiculus, which is significantly higher at the treatment without the inclusion of papaya leaf meal in their diet compared to the treatments with the inclusion of air-dried papaya leaf meal, this result however shows that the treatment without the inclusion of air-dried papaya leaf meal has the highest weight in all parameters measured except for liver which had its highest weight at treatment 2, compared to the treatment which had the highest inclusion of air-dried papaya leaf meal which had the least weight. Also treatment 2 with 5% inclusion of air-dried papaya leaf meal has same weight in spleen and heart with the treatment with no inclusion of air-dried papaya leaf meal which is not in agreement with the result of Oloruntola *et al* (2018) in his findings, which shows that in all his organ parameters (kidney, liver, heart, lung and gizzard) measured, treatment with highest inclusion of papaya leaf meal had the highest weight compared to treatments without papaya leaf meal but indicates slight agreement with the research of Moshood and Odunsi (2018), whose result shows increase in the organ (gizzard and liver) parameters measured at the treatment with the highest inclusion of papaya latex compared to those without such inclusion, but shows decrease in weight of other organs (kidney, lung and heart) measured in treatment with the highest inclusion of papaya latex compared to the treatment without inclusion of papaya latex which is an indicator that much more research work or findings need to carried out so as to find out the most effective processing means that ensures maximum profit through organ weights.

5. Conclusion

The research finding showed that feeding of finished broiler birds with air-dried papaya leaf as additive favoured the performance of carcass weight but, could not favour organ weight compared to the other feed without air-dried papaya leaf. Since air-dried papaya leaf did not produce the desired result in optimizing better performance level of carcass and organs weight of finished broiler, it is recommended that the use of papaya leaf meal in increasing ration be used, as well, other papaya parts such as papaya bark, papaya seeds and fresh papaya flower should be investigated so as to determine a better performance level of carcass and organ weight of finished broiler.

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Current Innovation in Agriculture Science
Vol. 3, Issue 1, pp. 772-785
Research Article
ISSN (E): 3048-6009

Navigating a crisis: How the 2023 cash scarcity shaped household consumption in Ondo State, Nigeria

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Received: 28 May 2025 | Accepted: 04 December 2025

DOI: https://doi.org/10.65791/cias.73

ABSTRACT

Economic history frequently reveals how societies tolerate and adjust during financial crises. The year 2023 was critical for Nigeria due to severe cash scarcity, which went beyond inconvenience and significantly upset citizens' daily lives. In an increasingly digital and cashless economy, shortages of physical currency raise dire concerns about household consumption behavior. This study examines the effects of cash scarcity on spending patterns, financial behavior, savings, and the adoption of alternative payment methods among Nigerian households. The study used primary data collected from 180 respondents and employed statistical tools such as frequency and percentage distributions, tables, charts, mean statistics, and correlation analysis. The findings reveal that cash scarcity affected the consumption behavior of a significant proportion (88.9%) of respondents, altering spending patterns and limiting the ability to meet essential needs. Major factors contributing to the scarcity included inflation (mean = 3.52), political instability (mean = 3.13), counterfeiting (mean = 3.11), and challenges within the banking sector (mean = 3.09). Results further indicate that 75.0% of households experienced reduced savings and investment, while 92.8% reported increased reliance on alternative payment methods, leading to heightened financial stress. Common coping strategies adopted by households included reducing non-essential spending (72.8%) and modifying shopping habits (60.6%), with only 1.7% reporting no impact. The study underscores the importance of effective currency management and responsive fiscal and monetary policies. It recommends targeted social interventions, investment in digital financial infrastructure, flexible budgetary frameworks, inflation control measures, and regulatory reforms within the banking sector. Promoting financial inclusion, particularly in rural areas, is essential to ensure resilience during similar crises. Overall, the study highlights the need for coordinated policies to mitigate the immediate effects of cash scarcity while fostering long-term economic stability.

KEY WORDS: *Financial crises*; *Cash scarcity*; *Households*; *Consumption behaviour*; *Spending pattern*

1. Introduction

Nigeria, often referred to as the "Giant of Africa," has a rich economic history characterized by both promising growth and significant challenges (Sohn, 2020). Its journey from independence in 1960 to the present has seen various economic phases and transitions. Following independence, Nigeria experienced strong economic growth during the 1960s and 1970s, largely driven by the

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discovery of oil in the Niger Delta and the oil boom of the 1970s (Thomas *et al.*, 2022). While oil revenues generated unprecedented wealth, they also entrenched overdependence on oil, corruption, and weak economic diversification (Ezeogidi, 2020). The volatility of global oil prices exposed Nigeria to recurrent economic shocks, notably during the 1980s oil glut, which resulted in fiscal deficits and economic contraction (Rasheed, 2023). Structural Adjustment Programs introduced in the late 1980s sought economic reform but imposed significant social costs on citizens. The return to democratic governance in 1999 renewed optimism for economic stability, supported by reforms and growth in sectors such as telecommunications (Lueders, 2024). However, political instability, corruption, and regional unrest persisted. Banking sector crises in the 1980s and 1990s revealed deep systemic weaknesses, prompting comprehensive reforms including bank recapitalization, stricter regulation, enhanced supervision, and deposit insurance through the Nigeria Deposit Insurance Corporation (Azétsop *et al.*, 2020). These reforms strengthened financial resilience, encouraged foreign participation, and restored confidence in the banking system.

A major turning point occurred with the fuel subsidy removal in 2012, which triggered nationwide protests and economic disruption (Isyaku and Hamza, 2023). While intended to reduce fiscal burdens and redirect funds toward development, the policy led to sharp increases in fuel prices, inflation, and cost of living pressures (Abubakar *et al.*, 2023). Although a partial subsidy was reinstated after public outcry, the episode intensified debates on governance, fiscal responsibility, and accountability. Nigeria faced another severe challenge during the 2016–2017 recession, driven primarily by declining oil prices, structural inefficiencies, and limited economic diversification (Yamoah, 2023). The recession led to GDP contraction, rising inflation, and increased unemployment. Concurrently, a currency crisis caused significant depreciation of the naira, escalating import costs and reducing purchasing power. Policy responses included exchange rate controls, fiscal austerity, and efforts to diversify the economy, though the effects lingered beyond the recession (Matallah, 2022).

The 2023 cash scarcity marked a recent and transformative economic episode, characterized by shortages of physical currency amid a growing shift toward digital finance (Ghana, 2023). Banking infrastructure challenges, currency management issues, and broader economic instability intensified the crisis. Households adapted by embracing electronic payments, altering spending and savings behaviors, and relying more on digital platforms. While this accelerated financial innovation, it also exposed vulnerabilities within the informal economy. In this era of increasingly digital and cashless economies, the scarcity of physical currency raised pivotal questions about the dynamics of household consumption behavior in the face of such adversity (Naeem, 2023). This research embarks on an exploration of the multifaceted landscape shaped by the 2023 cash scarcity in Nigeria, seeking to shed light on its causes, consequences, and the strategies adopted by households to navigate this challenging terrain. The aim is to discern how the scarcity of cash influenced not only the spending patterns of households but also their broader financial behaviors, from savings practices to the adoption

of alternative payment methods (Li *et al.*, 2021). Through a comprehensive analysis, we seek to offer insights into the unique economic realities that unfolded during this period and their enduring impacts on the financial behaviors of Nigerian households.

The significance of this research extends beyond its immediate empirical contribution. The 2023 cash scarcity was not merely an economic event but also a profound social and institutional challenge that disrupted livelihoods, altered financial practices, and accelerated Nigeria's transition toward digital financial systems (Otame, 2023; Akata, 2022). Understanding household responses to this crisis offers valuable insights into adaptive capacity, vulnerability, and resilience in developing economies. Moreover, the findings provide critical evidence for policymakers, financial institutions, and development practitioners seeking to design effective social protection mechanisms, strengthen financial inclusion, enhance regulatory frameworks, and improve crisis-response strategies. For businesses and financial service providers, insights into changing consumption patterns and payment preferences offer guidance for strategic planning, service innovation, and product development.

By situating household behavior within the broader context of macroeconomic instability, financial sector reform, and digital transformation, this study contributes to the growing body of literature on economic shocks and household welfare in emerging economies. It bridges a critical gap by offering empirical evidence from Nigeria's 2023 cash scarcity, thereby enriching scholarly discourse on financial resilience, consumption adaptation, and crisis management.

The broad objective of this study is to assess the effects of the 2023 cash scarcity on households' consumption behavior in Ondo State, Nigeria. The specific objectives are to:

(i) examine the extent of the 2023 cash scarcity on household consumption behavior;

(ii) analyze the factors contributing to the cash scarcity;

(iii) investigate the effects of cash scarcity on household consumption patterns and financial behavior; and

(iv) explore the coping strategies adopted by households during the cash scarcity period.

2. Material and Methods

2.1 Study population and sampling technique

The population of this study is comprised of households in Ondo State, Nigeria. A multi-stage sampling technique was used for this study, giving rise to a total sampling size of one hundred and eighty (180) respondents.

2.2 Source of data

Data for this study was collected through the use of a well-structured questionnaire.

2.3 Data analytical techniques

Data were analyzed using frequency, percentage, table, charts, mean statistics, and correlation analysis.

3. Results and Discussion

3.1 Extent of the cash scarcity of 2023 on households' consumption behavior

Awareness of respondents about cash scarcity of 2023

According to the statistics shown in **Fig. 1**, 98.9% of respondents were aware of the nationwide cash scarcity problem that occurred in Nigeria in 2023. The pervasive effects of the cash shortage are highlighted by this high awareness rate. It implies that this problem had a major impact on the people of Ondo State, Nigeria. This high level of awareness draws attention to how serious the situation was and how it could affect people's ability to support themselves and their businesses. These results are in line with those of Ani *et al*., 2024, who found that 97.9% of participants knew about the cash shortage and the redesign policy.

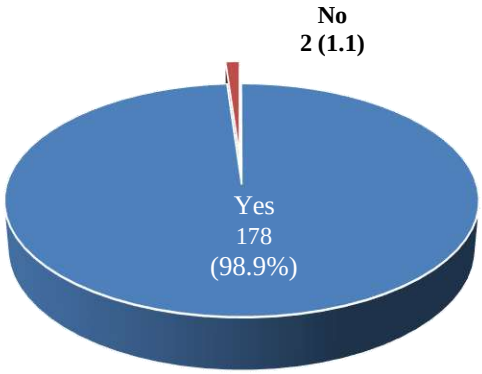


Fig. 1: Percentage distribution of respondents on awareness of respondents about cash scarcity of 2023

3.2 Challenges/difficulties encountered when accessing physical cash during the cash scarcity period

The results in **Table 1** show that the respondents identified and ranked the difficulty in finding ATMs with cash (84.4%) as the most significant challenge experienced in the study area. "Having to wait in long queues to withdraw cash" (53.3%) was the second-ranked problem. Respondents noted that the major frustrations during this period were the long queues and extended waiting times at banks or ATMs to access cash. Banks imposing withdrawal limitations or running out of cash (47.2%) was another major difficulty. Many respondents highlighted that the withdrawal and transaction thresholds set by the banks were particularly challenging. The worry for one's personal safety when handling or withdrawing cash came in last on the list of challenges (6.1%). This indicates that safety concerns were not a major issue for respondents, possibly because they were withdrawing less cash and thus were less worried about security threats associated with cash handling.

3.3 Effect of the cash scarcity of 2023 on households' consumption behavior

The findings displayed in **Fig. 2** demonstrate that a sizable segment of participants (46.7%) concurred that their consumption pattern was somewhat impacted by cash scarcity, necessitating certain modifications. Furthermore, 25.6% of respondents said that the lack of cash had a significant influence on their purchasing habits, leading to significant adjustments and difficulties. This implies that the respondents' purchasing patterns were significantly impacted by the cash scarcity, most likely as a result of their dependence on cash to cover everyday expenses. On the other hand, 10.0% of the participants stated that the lack of cash had a substantial influence on their consuming habits, leading to considerable modifications. 11.1% of respondents claimed the event had no discernible impact on their consumption habits, while 6.7% reported a minor but manageable impact.

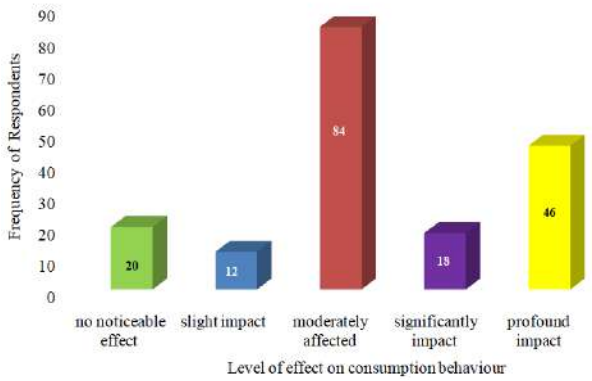


Fig. 2: Percentage distribution of respondents on perceived level of effect of Cash Scarcity of 2023 on household consumption behavior

3.4 Effect of the cash scarcity of 2023 on households' spending pattern

The results shown in **Fig. 3** indicate that a substantial number of respondents (38.3%) agreed that the cash shortage led to a significant increase in their household spending due to higher prices or increased expenses, while 22.8% reported a moderate increase in household spending as a result of the cash dearth. Additionally, 30.6% believed that the cash scarcity led to a moderate decrease in their household spending as they adjusted their expenses.

This implies that the scarcity noticeably affected the spending patterns of the respondents, causing various adjustments and changes in how they managed their finances, especially given the challenges of accessing cash during this period.

Furthermore, 4.4% of the respondents reported that their household spending was significantly reduced, and only 3.9% claimed that the currency scarcity had no noticeable effect on their spending patterns.

These findings clearly indicate that the cash scarcity event in 2023 had varying impacts, both positive and negative, on the households in the study area.

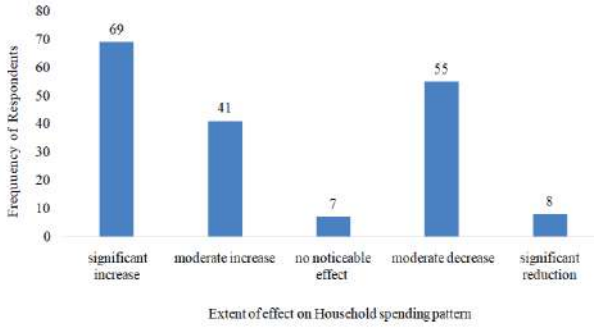


Fig. 3: Percentage distribution of respondents on perceived level of effect of Cash Scarcity of 2023 on household spending pattern

Table 1: Challenges/difficulties encountered when accessing physical cash during the cash scarcity period

Difficulties encountered when accessing physical cash	Frequency	Percentage	Rank
Difficulty finding ATMs with cash.	152	84.4	1st
Having to wait in long queues to withdraw cash.	96	53.3	2nd
Banks running out of cash or imposing withdrawal limits.	85	47.2	3rd
Difficulty in reaching ATMs or banks due to transportation problems.	80	44.4	5th
ATM machines running out of cash while you were in the queue.	84	46.7	4th
Concerns about personal safety while withdrawing or handling cash.	11	6.1	6th

Source: *Field survey, 2024*

3.5 Effect of the cash scarcity of 2023 on households' ability to meet essential needs

Furthermore, **Fig. 4** illustrates the various effects that the cash scarcity in 2023 had on households' ability to meet basic needs. The results showed that the statement "the cash scarcity significantly affected our ability to meet essential needs, leading to major challenges in accessing food, healthcare, or education" was the most agreed upon, with 43.3% of respondents supporting it. Additionally, 24.4% of respondents admitted that their ability to meet essential needs was moderately affected due to the cash scarcity, resulting in some difficulties.

These findings clearly demonstrate that the cash scarcity caused significant hardship and stress for Nigerian residents, particularly in accessing basic and essential needs such as food and healthcare. The limited or constrained access to cash, coupled with some outlets and stores demanding payment in cash only, greatly impacted their ability to meet these essential needs.

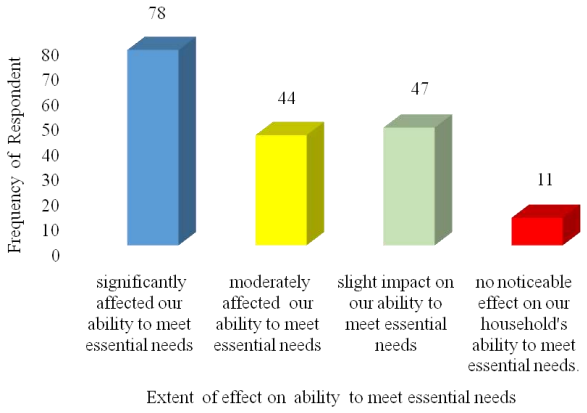


Fig. 4: Percentage distribution of respondents on perceived level of effect of Cash Scarcity of 2023 on ability to meet essential needs.

3.6 Factors contributing to the cash scarcity of 2023

The opinions of the respondents regarding the several issues they believe have contributed to the cash scarcity in 2023 are displayed in **Table 2**. All respondents agreed that the primary cause was inflation ($\bar{x}$ = 3.52). This implies that the public believes that a significant contributing factor to the cash scarcity is the inflation of goods and services. Because it was an election year, the political atmosphere in the nation during this time probably contributed to the significant perception that political instability was the second largest factor ($\bar{x}$ = 3.13). Many conjectured that Nigerian political deals played a role in the cash shortage, bolstering the claim made by Akinlo *et al.* (2022) that there is a direct and adverse correlation between political instability and economic growth in Nigeria. This is also consistent with the finding of Adamaagashi *et al.* (2023) that there is a direct correlation between political conflict and economic inequality, where economic inequality is defined as differences in wealth, income, and assets between various persons or groups. Counterfeiting ($\bar{x}$ = 3.11) and problems with the banking system ($\bar{x}$ = 3.09) were two other causes that were found to be significant drivers of cash scarcity in 2023. This emphasizes how decision-makers and financial systems influenced the incident, highlighting the indisputable shortcomings and difficulties these parties faced during the cash scarcity situation.

3.7 Perceived overall rating of household's economic wellbeing before and after the 2023 cash scarcity

The respondents' assessments of their household's financial well-being before and after the cash

Table 2: Factors contributing to the cash scarcity of 2023

Factors	SD	D	N	A	SA	Mean
Inflation	24 (13.3)	21 (11.7)	22 (12.2)	64 (35.6)	49 (27.2)	3.52*
Political Instability	36 (20.0)	55 (30.6)	6 (3.3)	15 (8.3)	68 (37.8)	3.13*
Counterfeiting	36 (20.0)	32 (17.8)	41 (22.8)	19 (10.6)	52 (28.9)	3.11*
Banking Sector Issues	39 (21.7)	40 (22.2)	26 (14.4)	15 (8.3)	60 (33.3)	3.09*
Government Regulations	48 (26.7)	30 (16.7)	38 (21.1)	13 (7.2)	51(28.1)	2.94*
Cybersecurity Incidents	53 (29.4)	38 (21.1)	26 (14.4)	12 (6.7)	51 (28.3)	2.83*
Economic Policies	46 (25.6)	61(33.9)	12 (6.7)	15 (8.3)	46 (25.6)	2.74*
Financial System Stability	43 (23.9)	54 (30.0)	6 (3.3)	62 (34.4)	15 (8.3)	2.73*
Exchange Rate Fluctuations	64 (35.6)	19 (10.6)	27 (15.0)	54 (30.0)	16 (8.9)	2.66*
Currency Circulation and Supply	79 (43.9)	16 (8.9)	12 (6.7)	55 (30.6)	18 (10.0)	2.54*
Hoarding Behavior	60 (33.3)	26 (14.4)	60 (33.3)	12 (6.7)	22 (12.2)	2.50*
Informal Economy	74 (41.1)	37 (20.6)	25 (13.9)	36 (20.0)	8 (4.4)	2.26**
External Shocks	73 (40.6)	41 (22.8)	29 (16.1)	25 (13.9)	12 (6.7)	2.23**
Geographic Factors	85 (47.2)	34 (18.9)	31 (19.4)	10 (5.6)	20 (11.1)	2.14**
Supply Chain Issues	81 (45.0)	35 (19.4)	31 (17.2)	23 (12.8)	10 (5.6)	2.14**
Natural Disasters	102 (56.7)	7 (3.9)	31 (17.2)	30 (16.7)	10 (5.6)	2.11**
Consumer Behavior	79 (43.9)	44 (24.4)	35 (19.4)	7 (3.9)	15 (8.3)	2.08**
Seasonal Factors	96 (53.3)	21 (11.7)	31 (17.2)	22 (12.2)	10 (5.6)	2.05**

Source: *Field survey, 2024*

Note: * connotes main contributory factor; ** connotes minor contributory factor

scarcity event of 2023 are contrasted in **Fig. 5**. The findings indicate a substantial disparity in the evaluations, with almost 100 participants asserting that their financial security was significantly worse following the incident, in contrast to 65 who assessed it as significantly worse before the incident. Given that the respondents experienced considerable hardship during this time due to limited access to cash, it appears that the cash scarcity had a large detrimental effect on their financial wellness. The proportion of respondents who thought their economic welfare was better before the cash scarcity (35 respondents) and those who thought it was better after the cash scarcity (51 respondents) also differed noticeably. The fact that a small percentage of respondents said they felt their economic wellbeing had increased after the event suggests that some people were able to use adaptive tactics to get through the challenging time and keep or even improve their economic wellbeing in spite of the national crisis.

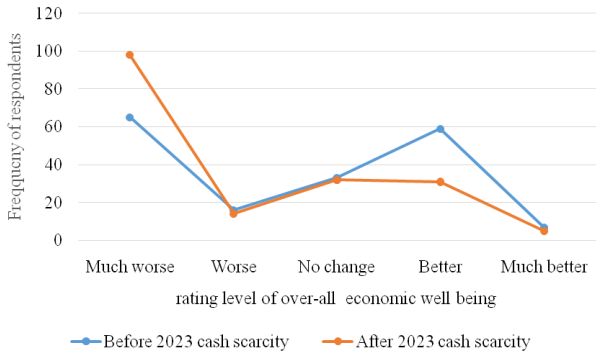


Fig. 5: Perceived overall rating of household's economic wellbeing before and after the 2023 cash scarcity

3.8 Cash scarcity influence on household's savings and investment strategies

The majority of respondents (75.0%) agreed that cash scarcity affected their household savings and investment strategies, according to the results shown in **Fig. 6**. This implies a connection between financial decisions on investments, savings, and cash availability. These results are consistent with those of Lingyan *et al.* (2021), who discovered that cash availability, or financial accessibility, is a significant indicator that has an impact on private investment and its linked control variables in both positive and negative ways.

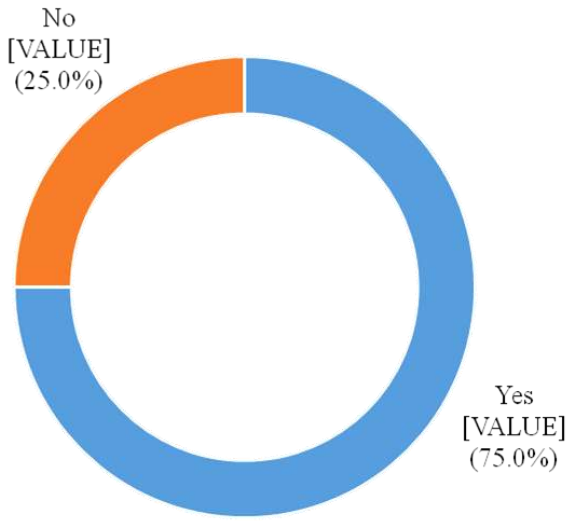


Fig. 6: Did the cash scarcity influence your household's savings and investment strategies?

3.9 Utilization of alternative payment methods, such as mobile money or electronic transfers, during the cash scarcity

During the cash shortage, the majority of respondents (92.8%) stated that they made use of other payment methods, including electronic transfers or mobile money (**Fig. 7**). This suggests that, at the time, the populace relied on alternate payment methods, including bank apps, mobile money, and e-channels. Interviews, however, indicated that this tactic only somewhat reduced the challenges brought on by the scarcity. Certain retailers and service providers mandated cash payments due to their inability to wait for confirmation delays resulting from financial institutions or network problems.

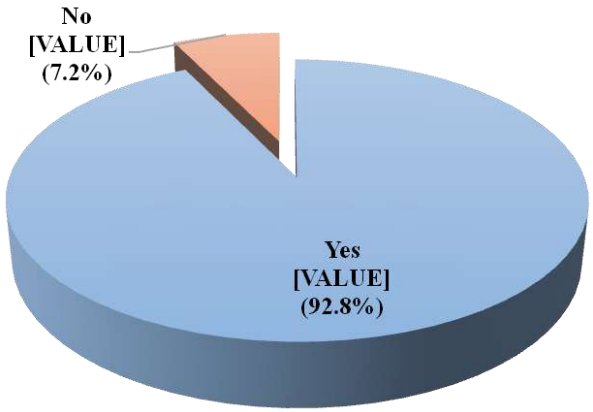


Fig. 7: Percentage distribution of respondents based on utilization of alternative payment methods, such as mobile money or electronic transfers, during the cash scarcity

The degree to which the cash shortage generated financial stress within homes was examined to further investigate how it affected households in the study area. According to the results, while 29.4% and 21.1% of respondents said that cash scarcity had a major and very substantial financial burden on their households, respectively, 33.3% of respondents agreed that it created moderate financial stress. 3.3% of respondents stated they did not experience any financial hardship as a result of the cash constraint, while the remaining

few respondents (12.8%) stated it had a minor impact (**Fig. 8**). This finding indicates that 84.8% of the households polled were highly impacted by cash scarcity, with 50.5% reporting significant to very significant stress. Implications include, potentially unstable economic conditions, decreased consumption, and heightened vulnerability among affected households.

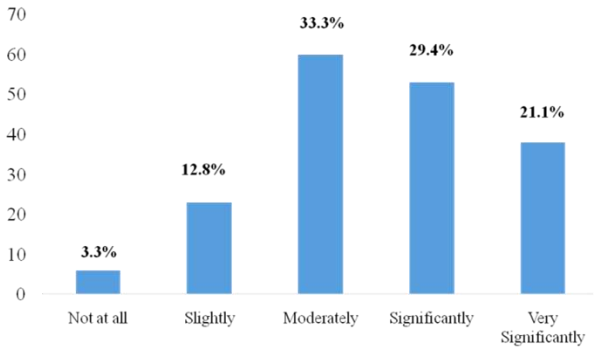


Fig. 8: Distribution of respondents by levels of financial stress faced within household due to cash scarcity

3.10 Average monthly estimated household expenditures by categories

The result in **Table 3** shows that the respondents had spending on food as the highest ranked expenditure (₦39,985) they make in their households, while expenditures on education were ranked second with an average estimation of ₦31,492 monthly. Then closely linked to these two highly ranked expenditures were: utilities (₦22,724), housing (₦22,674), and transportation (₦14,0477). Households prioritize spending on food and education in Ondo State, Nigeria, indicating a commitment to human capital and fundamental needs. The significant expenditures for housing, transportation, and utilities, however, highlight other necessary costs. Insufficient funds might put access to utilities and education at risk, increasing financial stress and impeding socioeconomic growth. This would call for focused actions to lessen the negative consequences for livelihoods.

Table 3: Average monthly estimated household expenditures by categories

Categories of expenditure	Average estimated monthly value (in Naira)	Rank
Food	39,985	1st
Education	31,492	2nd
Utilities	22,724	3rd
Housing	22,674	4th
Transportation	14,077	5th
Health care	6967	6th
Entertainment	5082	7th

Source: *Field survey, 2024*

The results in **Fig. 9** show that many (63.3%) of the respondents agreed that they experienced a change in their household spending behavior. This suggests a discernible change in the way their households spend their money. This result is consistent with that of Gomes *et al*. (2021), who also noted variations in respondents' spending habits.

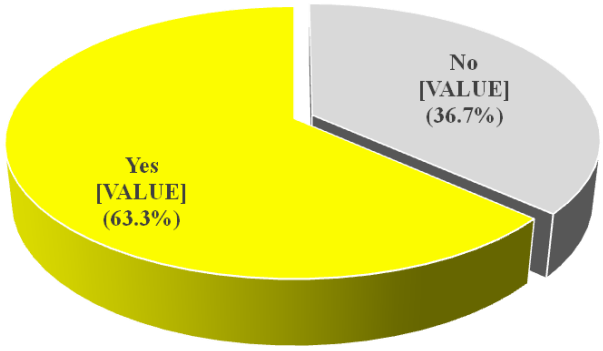


Fig. 9: Perceived change in household's spending behavior

3.11 The types of goods and services that your household typically purchases regularly

The research indicates that a majority (82.2%) of respondents spend their income on groceries. This implies that respondents prioritize spending on groceries, suggesting a fundamental emphasis on sustenance. This focus potentially leaves little room for other essential expenses or savings. Cash scarcity may exacerbate challenges in accessing nutritious food, leading to food insecurity and impacting overall household well-being and health (**Fig. 10**).

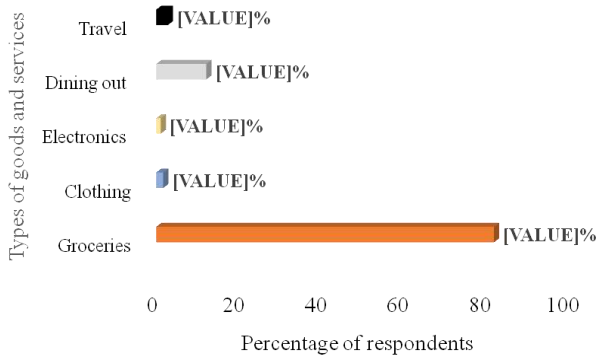


Fig. 10: Percentage distribution of respondents by the types of good and services households typically purchase regularly

3.12 Extent of external factors (such as economic conditions or policy changes) impact on household's consumption behavior

The results in **Fig. 11** indicate that 55.0% of respondents agreed that external factors significantly impact household consumption behavior, 25.0% felt the impact of external factors moderately, and 14.4% claimed that external factors like economic policies and policy changes have only a slight impact on their household consumption. Additionally, 4.4% of respondents believed external factors had a very significant impact, while only 1.2% claimed they had no impact at all.

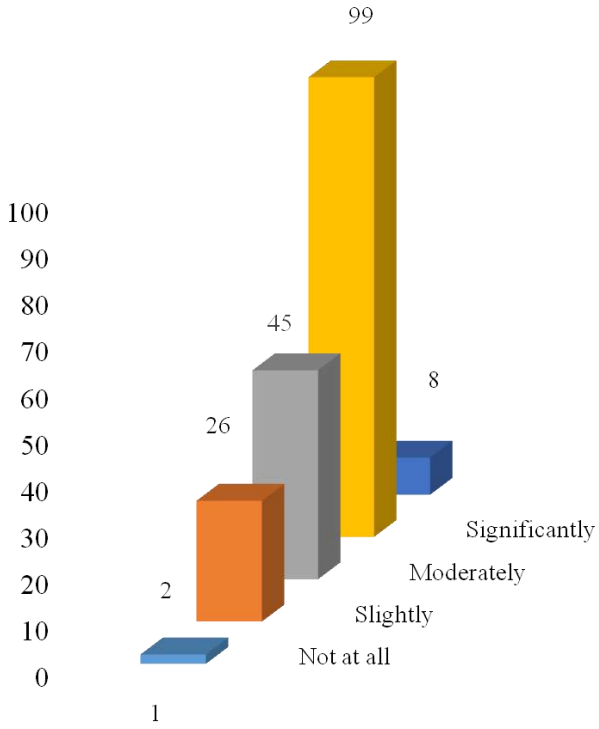


Fig. 11: Frequency distribution of respondents by their level of perceived impact of external factors on household's consumption behavior.

This implies that external factors, such as economic policy, affect household consumption in various ways, as 98.8% of respondents acknowledged feeling its impact, ranging from slight to very significant. These findings support those of Kim *et al*. (2021), who found a strong negative association between economic policy uncertainty and household consumption, particularly in areas such as food, transportation, communication, entertainment, and social interaction expenses. The results also align with

Madudova and Corejova's (2023) opinion that household consumption expenditure is a crucial measure of economic activity, reflecting the spending behavior of households and their purchasing power.

3.13 Strategies employed to cope with the cash scarcity of 2023

The results in **Table 4** reveal the strategies respondents used to cope with cash scarcity in 2023. It shows that 72.8% of respondents primarily reduced non-essential spending to lessen the impact of cash scarcity on their households and wellbeing. This indicates that respondents developed the habit of prioritizing essential needs and making opportunity-cost decisions.

A similar strategy that ranked second was changing shopping habits and frequency due to limited cash access. Additionally, 60.0% of respondents relied on digital payments to reduce the impact of cash scarcity on their households. This reliance on digital payments highlights the adaptation to available alternatives when cash is scarce.

3.14 Effect of adopted strategies on the household consumption behavior

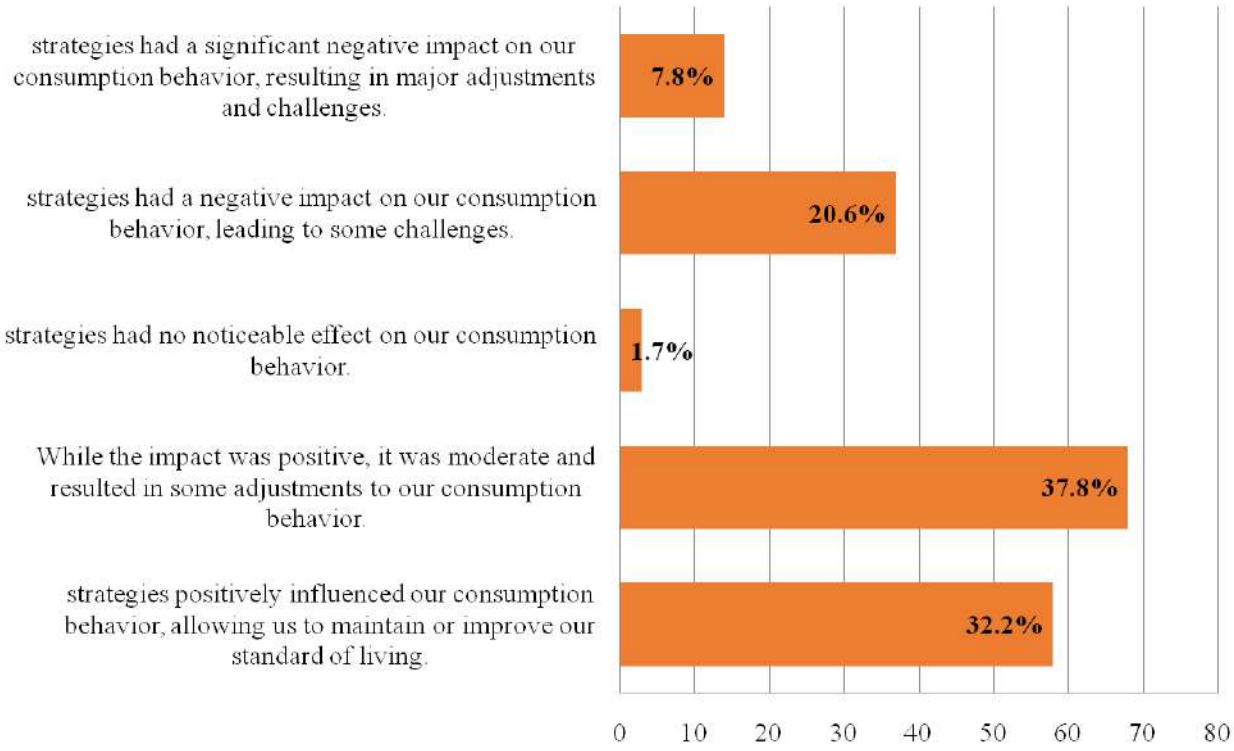
The results show that 37.8% of respondents reported that the strategies they adopted had a positive but moderate impact, resulting in some adjustments to their consumption behavior. Additionally, 32.2% agreed that the strategies they utilized positively influenced their consumption behavior, allowing them to maintain or improve their standard of living. This implies that the majority (70.0%) of respondents claimed that the strategies they adopted to combat the cash scarcity challenge in 2023 had a positive impact on their consumption patterns, helping them adapt and survive the hardship. However, a smaller percentage (28.4%) of respondents indicated that the strategies they used to cope with cash scarcity had a negative impact on their households. This could be due to a lack of capacity or resilience to effectively address the challenge or the use of unsuitable strategies, such as borrowing money they cannot repay, leading to negative effects on their household consumption behavior (**Fig. 12**).

Table 4: Ranking of the strategies employed to cope with the Cash Scarcity of 2023

Strategies	Yes		Rank
	Frequency	Percentage	
Reduced non-essential spending	131	72.8	1st
Changed shopping habits	109	60.6	2nd
Relied more on digital payments	108	60.0	3rd
Borrowed money	51	28.3	4th
Sought additional sources of income	47	26.1	5th
Increased savings	30	16.7	6th
Cut back on recreational activities	19	10.6	7th
Utilized government assistance programs	5	2.8	8th

Source: *Field survey, 2024*

Fig. 12: Percentage distribution of respondents by effect of adopted strategies on the household consumption behavior



4. Conclusion

The study provides empirical information on the assessment of the effects of the 2023 cash scarcity on household consumption behavior. Results showed that the cash scarcity had a noticeable effect on household consumption patterns and spending, causing significant financial stress. It indicated that political instability, inflation, and issues within the banking sector were contributory factors to this national crisis in 2023. The study also revealed that the majority of respondents devised several strategies to cope with the cash scarcity, with these strategies having varying degrees of effectiveness on their households and livelihoods. Additionally, the period witnessed widespread use of alternative payment methods, especially mobile payments and electronic channels, by the Nigerian populace. This adaptation highlights the resilience and resourcefulness of households in navigating economic challenges.

To mitigate these issues, the study suggests that Fiscal policies should include targeted social interventions, such as direct cash transfers or subsidies, to alleviate the immediate financial burdens on vulnerable populations. Increased focus on digital infrastructure investment to enhance alternative payment methods and reduce dependency on physical cash. This could be prioritized in government budgets to support smoother transitions during similar crises. There is a need for fiscal policies that provide flexibility in

budget allocations to respond swiftly to crises like cash scarcity. This includes emergency funds that can be quickly mobilized to support households and stabilize the economy. The study underscores the critical role of effective currency management. The Central Bank of Nigeria (CBN) needs to ensure adequate circulation of physical currency while promoting digital payment systems to prevent cash shortages. With inflation identified as a key factor contributing to cash scarcity, monetary policies must prioritize controlling inflation. This involves managing interest rates and employing other monetary tools to stabilize prices. Regulatory reforms aimed at improving the efficiency and resilience of the banking sector are essential. This includes ensuring banks are equipped to handle increased digital transactions and crises. Increased reliance on alternative payment methods during times of cash scarcity indicates a shift towards digital finance. Policies should aim at promoting financial inclusion, ensuring that all demographics, especially those in rural areas, have access to digital financial services. The study underscores the need for robust and responsive fiscal and monetary policies that address the immediate impacts of cash scarcity while promoting long-term economic stability and growth.

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Current Innovation in Agriculture Science
Vol. 3, Issue 1, pp. 786-794
Research Article
ISSN (E): 3048-6009

Effects of formal and informal land ownership systems on the economics of rice farming in Dakin kowa irrigarion scheme, Gombe State, Nigeria

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Received: 22 April 2025 | Accepted: 14 November 2025

DOI: https://doi.org/10.65791/cias.74

ABSTRACT

This study examined the effects of formal and informal land ownership systems on the economics of rice farming in Dadin kowa irrigation scheme. A multi-stage sampling procedure was adopted in the study and 312 respondents were selected randomly. Data were collected using questionnaires and analyzed with descriptive statistics and stochastic frontier production model. The findings revealed a mean household size of 10 persons, mean farming experience of 19 years, mean irrigation experience of 11 years, farm size of less than 1 hectare for formal system and more than 5hectares for informal system with a mean of 4 hectares and mean annual income of ₦78,093.25. The result further revealed the effect of land ownerships on the productivity of rice farming as, farm size ($P<0.01$), family labor ($P<0.01$), Hired labor ($P<0.01$), agrochemicals ($P<0.01$), organic fertilizer ($P<0.01$), seed ($P<0.01$) and rent ($P<0.05$) significantly influence the technical efficiency of rice farmers and their output, while, for informal system, farm size ($P<0.05$), Family labor ($P<0.05$), Agrochemical ($P<0.01$), Organic fertilizer ($P<0.01$) and Seed ($P<0.01$) significantly influences the technical inefficiency of rice farmers. The major constraints affecting rice production in the study area include; high cost of input (4.3), incident of pest and disease (3.4) and farmers/herders conflicts (3.2). It was concluded that rice production based on formal and informal systems is highly profitable. The study recommended that government and other relevant agencies should provide adequate security to cope the menace of farmers/herders clashes in the study area so as to allow farmers to maximize their productivity.

KEY WORDS: *Rice farming*; *Irrigation*; *Land ownership*; *Gombe State.*

1. Introduction

Land is a distinctive factor of production and is inclusive of all naturally occurring goods such as water, air, soil, minerals, flora and fauna that are used in the creation of products. Land is recognized as a primary source of wealth, social status, and power, the basis for shelter, food, and economic activities (Ayoola *et al.,* 2023). It is an institutional framework within which decisions are taken about the use of land, embodying that legal or customary arrangement whereby individuals or groups or organizations gain access to economic and social opportunities through land

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(Udo, 2003). The land system is also constituted by the rules and procedures which govern the right and responsibilities of both individuals and groups in the acquisition, use and control of land.

Nigeria has the ambition of diversifying her economy from crude petroleum dependency. The country also faces a looming food security crisis with a growing population that is increasingly dependent on imported foods. Insecure land tenure, scarcity of funds and credit, labour scarcity despite overall high unemployment and stagnant technology have crippled its further development. Until today, a wide range of policies, programmes and projects have had limited impact in ameliorating these problems. Given the choice, young people from the rural areas rather try their luck in urban centres. Climate change compounds the challenges confronting agriculture. The sector is dependent on the natural resource base and thus faces risks such as desertification, rising temperatures, changing rainfall patterns and sea level rise, leading to "degraded agriculture" and exacerbating conflict (Nwajiuba, 2020).

Rice (*Oryza sativa*) is a cereal which has become a staple food of considerable importance which is widely consumed in many countries of the world. In Nigeria, it one of the few food items whose consumption has no cultural, religious, ethnic or geographical boundary (Issa *et al.*, 2016). Rice accounts for over 20% of global calorie intake and has been an important food commodity for most people in Sub- Saharan Africa particularly, West African region. In Nigeria, rice has assumed a strategic position in the food basket of rural and urban households (Oyinbo *et al.*, 2013). As rice can provide a nation's population with nationally required food security minimum of 2,400 calories per person per day (Bamidele *et al.*, 2010). Many local dishes are prepared with rice because of its relative ease in terms of storage and preparation. In terms of local production, rice is now one of the main cereals produced by Nigerian farmers; it is cultivated in virtually all the agro-ecological zones of Nigeria. It covers both the upland and the swamps, depending on the variety (Mohammed, 2013). There is therefore dearth of literatures on the effect of formal and informal land ownership systems on rice productivity in Dadin-kowa irrigation scheme which is one of the largest rice-producing irrigated areas in the North-eastern Nigeria. Hence, this study aimed to improve the productivity and technical efficiency of rice farmers in Dadin-kowa irrigation scheme and to address the effects of land ownership systems on the economic performance of rice farming in Dadin-kowa irrigation scheme area of Gombe State. Addressing these challenges would be a step towards improving productivity of rice farmers in this area.

The broad objective of the study is to analyze the effects of formal and Informal land ownership systems on the economics of rice farming in Dadin-kowa irrigation scheme in Gombe State. While the specific objectives are to describe the socio-economic characteristics of rice farmers in the Dadin-kowa irrigation scheme; to determine the effect of land ownership on productivity of rice farming and to identify the constraints affecting rice production in the study area.

2. Material and Methods

2.1 The study area

The study was conducted in Yamaltu-deba Local Government Area of GombeState and Bayo Local government Area of Borno State. Gombe State lies between Latitude 10° 16' and 11° 00' North of the equator and Longitude 11° 00' and 11° 11' E of

the Greenwich meridian distance above the sea level within the Sudan Savannah ecological zone of Nigeria. It shares boundary with Bauchi in the west, Taraba and Adamawa in the south west, Borno in the east and Yobe in the north. Gombe State covers a land area of 158,998,569 m^2 with a population of 2,365,040 inhabitants based on 2006 National Population Commission (NPC) census with a 2.8 percent annual growth rate. The climatic condition of the State is characterized by two distinct season's dry and wet seasons. The wet season begins from April and ends in October, while the dry season starts in November and last up to March. The annual rainfall ranges from 600 mm to 1200 mm, with the minimum and maximum temperature of 22.7 °C and 33.5 °C, respectively. The major economic activities of the people are agriculture (farming and livestock production), trading and public service. Major irrigated vegetables grown in the State includes onion, spinach, amaranths, okra, tomatoes, pepper, pumpkins, cabbage, lettuce, water melon and sweet melon (DKIS, 2020).

2.2 Sampling procedure and sample size

A multistage sampling procedure was employed in the selection of rice farmers in Dadin-kowa irrigation scheme (**Table 1**). Stage 1: this involves the purposive selection of 2 Local Government Areas (LGAs) 1 from the Gombe State and another from Borno State. This is based on their participation in irrigated rice production and prevalence of water in the area. Stage 2: These involve purposive selection of 6 villages based on the intensity of rice farmers in the area. Stage 3: involve random selection of 15% rice farmers from the sample frame as provided by GSADP to make a total sample of 320 rice farmers.

2.3 Data collection

Primary data were collected using structured questionnaires. The structured questionnaires were administered to 320 rice farmers with the help of enumerators. The enumerators were well trained and a pre-test analysis was conducted in other to test the reliability of the instrument for data collection. Out of 320 questionnaires that were distributed, the total number of 312 questionnaires were completed, retrieved and were subjected to analysis.

2.4 Data analysis

Data were analysed using descriptive statistics to describe the socio-economic characteristics of rice farmers and constraints affecting rice production; while, the inferential statistics used the Cobb-Douglas functional form to determine the effect of

Table 1: Sample size selection plan

State	LGA	Community(s)	Sample Frame	Sample size (15%)
Gombe	Yamaltu-Deba	Dadin-kowa	410	62
		Yaranduwa	375	56
		Hinna	345	52
Borno	Bayo	Biriyel	378	57
		Jauro garga	315	47
		Garin dala	310	46
Total	2	6	2133	320

Source: DKIS, (2020)

land ownership on productivity of rice farming.

The explicit form of the model is as follows;

$$\ln Y_{ij} = \beta_0 + \beta_1 \ln X_{1ij} + \beta_{2l} n X_{2ij} + \beta_3 \ln X_{3ij} + \beta_4 \ln X_{4ij} + \beta_5 \ln X_{5ij} + \beta_6 \ln X_{6ij} + V_{ij} - U_{ij} \quad \ldots\ldots\ldots\ldots (1)$$

where;

ln = Logarithm to base e
Y_{ij} = Output of rice (kg)
X_1 = farm size (hectare)
X_2 = Family labor (mandays)
X_3 = Hired labor (mandays)
X_4 = Agrochemical (Litre/hectare)
X_5 = Inorganic fertilizer (kg/hectare)
X_6 = Seeds (kg/hectare)
X_7 = Cost of rent per season (₦)

3. Results and Discussion

3.1 Socio-economic characteristics of rice farmers

The result from **Table 2** revealed that the households had a minimum number of 2 persons and the maximum number of 44 persons with the mean of 10 persons. The large household size may serve as a source of cheap and readily available farm labor supply depending on the compaction and very likely increased output (Ndanitsa *et al.*, 2021). The finding agrees with Mustapha *et al.* (2012) and Olumba (2014) who reported that large family size could be as a result of polygamous nature of the rural farmers. He further opined that this could be linked to the fact that most rural farmers look at large household size as a good and economical way of maximizing farm returns by using family labor.

The result also revealed that the household had a minimum and maximum farming experience between 1 and 60 years, respectively, and had a mean of 19 years. Gomina (2015) and Ndanitsa *et al.* (2021) posited that farming experience is used as a measure of efficiency in management *i.e.* the more experience a farmer was, the more s/he had the ability to manage farm resources effectively and efficiency, which is expected to translate in to higher returns for entrepreneurs. The result further shows that majority of the farmers had mean experience of 11 years. The rice farmers in the study had a minimum and maximum irrigation experience between 1 and 60 years, respectively. The years of irrigation experience were reflected in more effective production capacity and high output level of rice. This finding is similar to that of Issa *et al.* (2016) who found high irrigation experience of 10 years and above among maize farmers.

The result of the analysis depicts that the minimum and maximum farm size used by rice farmers were 0.5 and 15 hectares with a mean of approximately 4 hectares. This implies that rice production in the study area is mainly practiced by small-scale farmers under formal system. The average farm size for formal land ownership system was less than 1 hectare, while for the informal land ownership system was 15 hectares. This result is in line with Mohammed (2015), Tijjani and Bakari, (2014) who reported that 85 percent of the farmers in the area are small-scale farmers cultivating less than five hectares of land. Similarly, the result revealed the minimum and maximum annual income of formal and informal rice farmers to be ₦100,000 and ₦1,100,000, respectively with an annual mean of ₦78,096.25. This implies that farmers earned low annual farm income which could be as a result of

Table 2: Descriptive statistics of socio-economic variables of rice farmers (n=312)

Variables	Minimum	Maximum	Mean	Std. Deviation
Household size	2	44	10.18	5.927
Farming experience	1	60	18.87	10.804
Irrigation experience	1	60	11.34	8.745
Farm size	0.5	15	3.76	1.950
Annual Income	100,000	1,100,000	78,096.25	835468.540

Source: Field survey, (2021).

constraints that associated with rice farming such as high cost of fertilizer, pest and disease, high cost of transportation, lack of improved seed varieties.

3.2 Effects of formal and informal land ownership on productivity of rice farming

The result of maximum likelihood estimate on efficiency of rice farmers revealed that for the formal system, farm size (P<0.01), family labor (P<0.01), Hired labor (P<0.01), agrochemical (P<0.01), organic fertilizer (P<0.01), seed (P<0.01) and rent (P<0.05) significantly influences the technical efficiency of rice farmers (**Table 3**). The coefficient of farm size was positive and statistically significant related to technical efficiency at (P<0.01), this implies that increase in farm size by 1%, the output of rice related to technical efficiency will increase by 0.9850. This implies that increase in farm size will increase the output of rice farmers.

The coefficient of family labor was positive and statistically significant related to technical efficiency at (P<0.01), this implies that the technical efficiency of rice farmers who used family labor is efficient to increase the output of rice farmers. This means that family labor was enough to boost rice production because they are adequate. This result disagrees with the findings of Kareem (2016); Shittu (2014) and Abaoba (2020) who reported that households are inefficient in terms of labor use. Similarly, the coefficient of hired labor was positive and statistically significant related to technical efficiency at (P<0.01), this indicated that the technical efficiency of rice farmers who also used hired labor tends to increase the output of rice farmers by 0.8097. This implies that increase in number of hired labor would increase the output of rice farmers. This means that, hired labor influences the yield of rice production as compare with family labor.

The coefficient of agrochemical was positive and statistically significant related to technical efficiency at (P<0.01), this implies that if the quantity of agrochemical increases by 1%, the output of rice farmers will increase by 0.1894 related to technical efficiency. This is so because insect pest infestation and weed were serious challenges facing rice farmers and efforts to eliminate insect pests and weed chemically will increase the output of rice farmers. This result emphasizes the importance of agrochemical in agricultural production and this is consistence with the finding of Aboaba (2020) who reported that there exist a relationship between agrochemical and the output of rice in Ogun State. The coefficient of organic fertilizer was positive and statistically significant related to technical

Table 3: Effect of formal and informal land ownership on the productivity of rice farming

Variables	Parameter	Formal		Informal	
		Coefficient	t-value	Coefficient	t-value
Constant	α_0	-11.2177	-20.7***	-21.473	-32.002***
Farm size	α_1	0.9850	6.0***	-0.702	-1.939**
Family labor	α_2	0.5560	5.1***	-0.123	-2.280**
Hired labor	α_3	0.8097	3.3***	-0.457	-0.637
Agrochemicals	α_4	0.1894	3.5***	-0.713	-4.130***
Organic fertilizer	α_5	0.9503	8.6***	-0.811	-5.465***
Seed	α_6	0.7727	2.9***	-0.511	-5.159***
Rent	α_7	-0.2446	-2.1**	-0.177	-1.193

Source: Field survey, (2021). Notes: ** and *** = 5% and 1% level of significance.

efficiency at (P<0.01), this implies that if the quantity of organic fertilizer increases by 1%, the output of rice farmers will increase by 0.9503. This indicated that the higher the quantity of organic fertilizer, the higher will be the output of rice farmers. The coefficient of seed was positive and statistically significant related to technical efficiency at (P<0.01), this implies that if the quantity of seed increases by 1%, the output of rice farmers will increase by 0.7727. This indicated that the higher the quantity of seed sown, the higher the output of rice. This result is in line with the findings of Ambali *et al.* (2012) and Okello *et al.* (2019) who reported a positive relationship between the quantity of seed and the output of rice. The coefficient of rent was negative and statistically significant related to technical efficiency at (P<0.05), this implies that if land rent cost increases by 1%, the total cost of land rent will decrease by 0.2446. This is so because land is a particularly vital resource used in production and any attempt to raise its rental cost will decrease the total production cost.

Furthermore, the result of maximum likelihood estimate on efficiency of rice farmers for informal system revealed that farm size (P<0.05), Family labor (P<0.05), Agrochemical (P<0.01), Organic fertilizer (P<0.01) and Seed (P<0.01) influences the output of rice farmers. The coefficient of farm size was negative and statistically significant at (P<0.05), this implies that 1% increase in the area under cultivation of rice will result in decreased output of rice by 1.939. This indicated that as the size of the farm increases, output of rice decreases and this result disagree with Ndanitsa *et al.* (2021) and Abdulahi (2021) who reported that farm size significantly determines the output of water melon and maize respectively at (P<0.01) in Niger and Katsina States, respectively. The coefficient of family labor was negatively significant at (P<0.05), this implies that 1% increase in family labor; the output of rice will decrease by 2.280. This means that, family labor was insufficient in production process of rice thereby decreasing the output of rice. The coefficient of agrochemical was negative and statistically significant at (P<0.01), this implies that 1% increase in agrochemical will result to decrease in output of rice by 4.130. This indicated that, increase in level of agrochemical in rice farms will lead to decrease in output of rice there by affecting the technical efficiency of rice farmers. The coefficient of organic fertilizer was negative and statistically

significant at (P<0.01), this implies that 1% increase in organic fertilizer will decrease the output of rice by 5.465. This means that organic fertilizer decreases the level of rice output if it is applied in abundant, it will destroy the rice plant thereby reducing the yield. The coefficient of seed was negative and significant at (P<0.01), this indicated that 1% increase in the quantity of seed sown will lead to decrease in output of rice. This implies that if the quantity of seed sown increases there will be overpopulation among the crops, competition will arise in terms of sunlight, air, water and fertilizer thereby harboring pests and diseases which will lead to decrease in output and yield of rice in the area. This will greatly affect the technical efficiency of rice output in the area.

3.3 Constraints affecting rice production

Table 4 shows the constraints affecting rice production in Dadin-kowa irrigation scheme. The result revealed that high cost of input, incident of pest and diseases and farmers/herders conflicts were the major challenges faced by rice farmers in the study area. Others include inadequate extension services, land fragmentation, inadequate storage facilities, land encroachment and high cost of labor were also some the challenges faced by rice farmers. These constraints are believed to have serious negative implication on farmer's production efforts and farm income due to their discouraging effects.

4. Conclusion

The study concluded that the major constraints affecting rice production in the Dadin-kowa irrigation scheme were the high cost of farm inputs, incidence of pests and diseases, and farmers–herders conflicts. Other challenges identified by farmers included inadequate extension services, land fragmentation, inadequate storage facilities, land encroachment, and high labor costs, all of which negatively affected production efforts and farm income. These constraints discouraged farmers and limited their productivity and standard of living.

Based on the findings, the study recommended that the government and relevant agencies should provide adequate security to address farmers–herders clashes in the study area, thereby enabling farmers to maximize productivity. It also recommended exploring alternative methods of

Table 4: Distribution of farmers according to constraints affecting rice production

Constraints	SA	A	UD	D	SD	Total	Mean
High cost of input	187	94	8	18	13	1384	4.3
Incident of pests and diseases	67	67	116	58	12	1079	3.4
Farmers/herders conflict	120	60	15	25	100	1035	3.2
Inadequate extension services	35	88	12	170	15	918	2.9
Land fragmentation	74	6	35	185	20	889	2.8
Inadequate storage facilities	60	83	13	50	114	885	2.8
Land encroachment	8	57	181	27	10	875	2.7
High cost of labor	70	37	50	29	134	840	2.6
Lack of access to credit facilities	14	45	32	179	50	754	2.4
Lack of processing facilities	52	36	45	32	155	758	2.4

Source: Field Survey, (2021).

land acquisition beyond inheritance to increase land available for rice cultivation and expand production. In addition, improving farmers' technical efficiency through credit facilities was suggested as a means of sustaining rice production. Finally, the study emphasized the need for timely provision of farm inputs and supplies such as machinery, improved seeds, agrochemicals, and fertilizers at affordable prices to enhance productivity, income, and the overall standard of living of farmers.

5. Acknowledgement

This is to acknowledge the financial support of Transforming Irrigation Management in Nigeria Project (TRIMING) to the conduct of this research. We equally, acknowledge the support and encouragement of the Research Panel of Experts (RPoEs) that lead to the successful completion of the study.

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Current Innovation in Agriculture Science
Vol. 3, Issue 1, pp. 795-808
Research Article
ISSN (E): 3048-6009

Influence of arable crop farmers' use of Climate-Smart Agricultural Practices on food security in North-Central Nigeria

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Received: 08 March 2025 | Accepted: 17 November 2025

DOI: https://doi.org/10.65791/cias.75

ABSTRACT

This paper examined the influence of arable crop farmers' use of Climate-Smart Agricultural Practices (CSAPs) on food security in North-Central Nigeria. Primary data were collected using a structured questionnaire, and a multistage sampling procedure was adopted to select 120 respondents. Data were analyzed using descriptive statistics, sigma scoring, mean score, and logit regression. The results revealed a mean age of 48.0 ± 5.7 years, a household size of 5.9 ± 1.6 members, farming experience of 18.0 ± 6.6 years, a farm size of 1.4 ± 0.6 hectares, and an annual income of ₦173,210 ± ₦ 5,000. The majority were male (92.3%), married (88.0%), had no secondary occupation (72.5%), had formal education (72.3%), and were members of associations (58.4%). The sigma scores on perceived effects of climate change indicated hotness (5.30), irregular rainfall (5.30), and yield reduction (5.08). In contrast, the mean scores of constraints to CSAPs' use included rainfed farming (2.93) and inadequate finance (2.90). The CSAPs most commonly employed were shifting planting schedules (5.02), mixed cropping (4.91), and planting cover crops (4.70). The influence of CSAPs on food security showed that sex (-0.5535), age (-0.0372), household size (-0.0413), education status (-0.4317), farming experience (-0.0620), and association membership (-0.0849) had significant negative effects. In contrast, secondary occupation (0.1894), farm size (0.2568), extension visits (0.3715), and total CSAPs used (0.3498) were highly significant positive determinants. Intensive CSA training and grant awards were recommended to enhance the effective use of CSAPs and improve food security.

KEY WORDS: *Climate-Smart Agricultural Practices (CSAPs)*; *Arable crop farmers*; *Food security*; *Nigeria*

1. Introduction

Agriculture has been recognized globally as a primary source of human life since it produces the food that humans need to survive. As an important industry that significantly contributes to local and global food security, job creation, and farmer income generation, it is carried out by many smallholder farmers in developing nations, including Nigeria, where it is rain-fed due to its dependence on rainfall, a key climatic factor (Pierre *et al.*, 2024). Other climatic factors that influence agriculture in a place include temperature, humidity, wind direction and speed,

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precipitation type, frequency, and amount, as well as solar radiation.

Note that it is not only climate elements that influence agriculture, but there is also an inter relatedness between the two (agriculture and climate). Agriculture has several ways in which it influences and is influenced by the environment, with the two having inverse, reversible, and reciprocal relationships. This is consistent with Wakweya (2023), who noted a nexus between agriculture and climate and Yilai *et al.* (2024), who identified a substantial dependency between agriculture and climate. For example, agriculture will flourish, and humans will reap the natural benefits of optimal production and productivity, including stable food supplies and food security, if climatic conditions are ideal and optimal (Wakweya, 2023). On one hand, vegetation (forest) can influence atmospheric elements such as rainfall and even absorb excess heat thereby influencing the weather condition of a place meaning that agriculture is a key carbon sink, in that agricultural perennial such as pasture, forests, fruit orchards and tea plantations can capture CO_2 from the atmosphere for/through photosynthesis (Yilai *et al.*, 2024).

Conversely, Yilai *et al.* (2024) stated that agriculture contributes to the emission of greenhouse gases (GHGs) such as methane (CH_4) from the metabolic activity of bacteria that produce methane, nitrous oxide (N_2O) from ruminant gastrointestinal fermentation and farmland soil nitrification and denitrification under nitrogen fertilizer application, and anthropogenic Non-CO_2 from the conversion of forest land to cropland. Others include agricultural activities such as machinery operations, fertilizer and feed inputs also indirectly increase the carbon footprint of agriculture via various pathways such as fossil fuel consumption, traditional and predominant method of clearing farmland by bush burning and the indiscriminate cutting down of trees for use as firewood and making charcoal all releases and increases the concentration of GHGs in the atmosphere which traps heat and contribute to global warming and consequently resulting into climate change (Onoja, 2023).

Long-term changes to temperature, precipitation, wind patterns, and other aspects of the Earth's climate system are referred to as climate change (Henri-Ukoha and Adesope, 2020). In Chepng'etich *et al.* (2024), the Intergovernmental Panel on Climate Change (IPCC) further defined climate change as the swift and unpredictable shifts in Earth's surface temperature and precipitation patterns that have made agricultural systems more vulnerable worldwide. They went on to say that, although the effects of climate change are felt globally, Sub-Saharan Africa (SSA) is expected to experience the most severe impacts on its food systems and agriculture. They claimed that this is due to the region's fragility, stemming from the fact that agriculture, the main driver of their economies, is largely dependent on rainfall and is therefore extremely vulnerable to climate change. This supports the position of Tabe-Ojong *et al.* (2023), who found that droughts, rising temperatures, and changes in rainfall patterns, including both increased and decreased rainfall, are examples of how climate change is affecting smallholder arable crop agriculture in many tropical locations.

It is worth noting that half the world consumes arable crops such as rice, yams, beans, maize, wheat, guinea corn and cassava, among others and in Nigeria, every household consumes them (Chima *et al.*, 2024). They added that the impact of a changing climate on arable crops is a

catastrophe shared by many countries of the Globe, especially Sub-Saharan Africa (SSA), including Nigeria, where biodiversity-based rice and cassava farming is facing extinction, especially in the northern part, where drought and flood disasters are destroying agrifood systems, causing food insecurity.

Food insecurity is when people are unable to meet their food needs. They may eat once a day but not know where they will get their next meal or that people experiencing severe food insecurity may have run out of food completely and go a day or more without anything to eat at all (Oxfam, 2025). Oxfam further explained that food insecurity is when only 1 in 11 people have access to food, and the Number of people globally without access to adequate food is 31%. Nigeria ranks ninth among the top 10 nations in the world with the greatest food crises, according to Onoja (2023). In 2019, more than five million individuals in Nigeria were affected, which accounted for 5% of the global total (Global Network Against Food Crises-GNAFC, 2020). According to the WFP 2024 report, in Action Aid Nigeria (2024), there were 100 million food-insecure Nigerians in Q1 2024, up from 66.2 million in Q1 2023. They added that out of these, 18.6 million are experiencing acute hunger, and as of March 2024, 43.7 million Nigerians are exhibiting crisis-level or above crisis-level hunger coping strategies. Food security is therefore essential for human existence, and this has been the reason why successive governments in Nigeria have attempted to address the food crisis and insecurity situation caused by other factors, until recently, climate change. Regrettably, the country has never come close to attaining this goal. In Nigeria, smallholder farmers are facing threats to their livelihoods and food security due to climate change, resulting in a growing decline in agricultural production, food accessibility, and financial stability. This has bolstered Wakweya's (2023) assertion that climate change has negative implications for food security.

Food security is when "all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food to suit their dietary needs and food preferences for an active and healthy life," (Tabe-Ojong *et al.*, 2023) and (Oxfam, 2025). The United Nations 2030 Sustainable Development Goals (SDGs) "Zero Hunger" target is seriously threatened by the world's population growth, which is predicted to surpass 9 billion people by 2050, even as climate change continues to threaten the ability to produce food (Yilai *et al.*, 2024). Food security as a concept encompasses four primary aspects: (a) Food availability, especially of local food, which must always be readily present on shop shelves and at market stalls. (b) Food access means having physical, social, and financial freedom to access food. (c) Food utilization, which occurs when people have access to wholesome, disease-free food in enough quantities to support an active and full life; and (d) Food stability, which occurs when the food supply is steady and consistent, and rising food costs and seasonal food shortages brought on by climate change do not jeopardize food security. Food security, therefore, is about ensuring that no one goes hungry and in practical terms, it means that the fundamental assurance of human survival is food security. Onoja (2023) cited Pachauri & Meyer (2014) as warning that African nations may see a 10% to 25% decrease in farm production if the required adaptation measures are not implemented. As an addendum, Pierre *et al.* (2024) noted that the two most significant issues of our day are food insecurity

and climate change; therefore, it is imperative to develop sustainable agricultural practices that mitigate the consequences of these two factors on agriculture.

To address these two challenges, **Fig. 1** clearly shows the World Bank and partners' resolution from the Seminar on Climate Change and Risk Management, where they developed Climate Smart Agriculture (CSA) to help farmers adapt to and mitigate climate change and address the interconnected challenges of food insecurity that has been made worse by climate change (World Bank, 2024 in Wanglin and Rahut, 2024).

Fig. 1: Climate-smart chart adapted from World Bank (2024) in Wanglin and Rahut (2024).

The concept of CSA was first proposed by the Food and Agriculture Organization of the United Nations (FAO) at the Hague Conference in 2010 (Yilai *et al.*, 2024), aiming to achieve the multi-win goals of increased food production, security, and income, as well as climate change mitigation and adaptation. As illustrated in **Fig. 1**, the three main goals of CSA are: (a) Increasing agricultural productivity sustainably by producing more and better-quality food without further taxing natural resources in order to increase incomes and improve nutrition security, particularly for the 75% of the world's poor who live in rural areas and depend primarily on agriculture for their livelihoods. (b) Developing resilience and adapting to climate-related hazards and shocks, such as droughts, pests, and diseases; and enhancing the ability to grow and adapt to longer-term pressures, such as more unpredictable weather patterns and increasing seasonal variability and (c) Reducing GHGs emissions from agriculture of the food system, avoid deforestation due to cropland expansion, and increase the carbon sequestration of plants and soils (World Bank, 2024 in Wanglin and Rahut, 2024).

Wakweya (2023) noted that climate-smart agriculture is now positioned as an exceptional perspective for meeting both global warming reduction and adaptation objectives while also ensuring/enhancing agricultural production and feeding people worldwide. The CSA is gaining recognition as a viable approach to mitigating the impact of climate change on the food security of farming households. Although the idea of CSA is still evolving, little research has been conducted on the connections between CSA and sustainable agriculture, and how CSA behaviors might be encouraged to achieve food security. Climate-smart agricultural practices and technologies (CSAPs) are a group of agricultural production-related practices that can "effectively adapt agriculture to climate change and reinforce agricultural production capacity" (Wanglin and Rahut, 2024).

Based on the foregoing, this paper investigated the influence of arable crop farmers' use of CSAPs on food security in North-Central, Nigeria. The purpose of the study was to;

i. describe the socio-economic characteristics of arable crop farmers.
ii. identify arable crop farmers' perceived effects of climate change;
iii. identify CSAPs used by arable crop farmers;
iv. identify constraints faced in the use of CSAPs by arable crop farmers; and,
vi. examine the influence of CSAPs usage on food security.

2. Material and Methods

The study was conducted in the North-Central zone of Nigeria, covering an area of 242,425 Km^2, comprising Kwara, Niger, Nasarawa, Plateau, Benue, and Kogi states, as well as the Federal Capital Territory (FCT). The research design used for this study was a descriptive survey. A multistage random sampling procedure was used as follows to obtain samples: a simple random sampling technique was used to select two states, namely Benue and Kogi State. Benue State is located at coordinates longitude 7° 47' and 10° 0' East and Latitude 6° 25' and 8° 8' North, and has a total area of 34,059 km^2, while Kogi State is in coordinates 'Latitude 7°30'N 8°10'N and Longitude 6°01'E 7°50'E and covers an area of about 29,833 km^2. The states are primarily rural and major arable crop production zones because nature has endowed them with suitable edaphic and climatic factors that are conducive to the growth of major arable crops. This may be the reason why most of the populace, including both males and females, young and old, were arable crop farmers until recently, when the prevailing effects of climate change negatively affected their livelihood activities, resulting in a food crisis. The researcher used the ADP structure to obtain the sample size as follows: Benue and Kogi States comprised three and four ADP zones, respectively, and two zones were selected from each state. These four zones comprised 42 blocks, out of which 50% (21 blocks) were selected. The selected blocks consist of 216 cells, from which 50% were randomly selected, resulting in 108 cells being obtained. Each selected cell comprised 10 contact farmers who were aware of and used CSAPs, from which 12.5% were selected, resulting in a total of 120 respondents used for this research. A structured questionnaire was used to collect data from respondents and was initially subjected to both face and content validity. The reliability of the instrument was assessed using the split-half method, yielding a reliability coefficient of 0.73. Data were analyzed using descriptive statistics, the sigma scoring method, mean scores from the Likert scale, ordinary least squares regression, and ordered logit regression models.

3. Results and Discussion

3.1 Awareness and perceived effects of climate change

Results in **Table 1** reported in sigma scores show that all (5.714) arable crop farmers were aware of climate change. Arable crop farmers' understanding of climate change is a crucial step in determining the actions to be taken to mitigate its effects. Their awareness may be due to personal observations and experiences of changes in weather factors, contact with extension services, interaction with other farmers, and information on weather forecasting from electronic and/or print media. This finding corroborates that of Jackson *et al.* (2021), who reported that farmers are aware of climate change, as evidenced by their experiences.

Perception is a cognitive process by which people interpret and make meaning of the sensory data

Table 1: Distribution of respondents' awareness and perceived effects of climate Change

Awareness and perceived effects of climate change		
Awareness	No. of Respondents	Sigma Score
Aware of climate change	120	5.714
Perceived effects of climate change		
Fluctuating/irregular rainfall	120	5.714
Frequent erosion/flooding	109	5.300
Yield reduction/poor yield	97	5.082
Increase weed infestation	94	5.026
High temperature/hot environment	120	5.714
Common pest infestation	92	4.986
Change in crop growing season	96	4.834
Draught/Water shortage	109	5.300
High cost of food/living	91	4.968
Food insecurity	89	4.472
Soil degradation	73	4.644

Source: *Computation from Field Survey, 2024*

they receive from their surroundings. The results on respondents' perception of the effects of climate change reported in sigma scores also in **Table 1** includes; fluctuating/irregular rainfall and Hot environment (5.714), frequent erosion/flooding and drought (5.300), yield reduction (5.082), increase weed infestation (5.026), common pest infestation (4.986), high cost of living (4.968), change in crop growing season (4.834), soil degradation (4.644) and food insecurity (4.472). This implies that respondents' perception of the effects of climate change is many and mostly negative. These findings are in tandem with similar researches that reported decline, fluctuating, inconsistent, irregular and uneven rainfall patterns, reduced growing season and increasing atmospheric temperature resulting into hot environment (Onyeneke and Madukwe, 2020), (Tajudeen *et al.*, 2022), (Tabe-Ojong *et al.*, 2023) and (Bruce and Oluyede, 2024) loss/decrease/failure in the yield/output of arable crops (Tabe-Ojong *et al.*, 2023), (Wanglin and Rahut, 2024), (Yann *et al.*, 2024) and (Yilai *et al.*, 2024), soil erosion and flooding (Araya and Adjaye, 2021) and (Tajudeen *et al.*, 2022), soil degradation/declining soil fertility (Nhemachena, 2022) and (Alakpa and Ogbe, 2024), outbreak / thriving of insects pests, draught, decrease in farm sales and income, high cost of living and food scarcity/insecurity (Orgu *et al.*, 2024) and (Pierre *et al.*, 2024).

3.2 The CSAPs used by arable crop farmers in the study area

Results in **Table 2** indicates the mean scores of CSAPs used by arable crop farmers in the study area which indicated; adjust/shift planting schedule (5.03), practice mixed/inter cropping (4.90), planting cover crops/leave crop leftovers (4.70), planting early maturing crops and practice minimum/reduced tillage (4.51), practice mulching (4.22), practice agroforestry (2.31), apply organic manure (2.22), practice crop rotation (2.11), reduced use of chemicals (1.72) and use irrigation (0.94).

Table 2: Distribution of respondents' use of CSAPs n=120

CSAPs use	Frequency	%	Mean score
Adjust/Shift planting schedule/calendar	120	100.0	5.03
Reduce the use of chemicals	041	34.2	1.72
Apply organic manure	053	44.2	2.22
Planting cover crops & leave crop leftovers	112	93.3	4.71
Practice minimum reduced tillage	107	89.2	4.51
Use irrigation	021	17.5	0.94
Practice agroforestry	056	46.7	2.31
Practice mixed cropping/ intercropping	118	98.3	4.91
Planting improved crop varieties (pest, disease, drought tolerant)	012	10.0	0.52
Practice mulching	101	84.2	4.22
Plant early maturing crops	109	90.8	4.51
Practice crop rotation	051	42.5	2.11

Source: *Computation from Field Survey, 2024*

These findings imply that, out of the twelve packages, only six were the most frequently used by arable crop farmers in the study area, meaning they use fewer CSAPs, and those used by them are related to their traditional practices.

These findings align with those reported in a related researches such as; planting variety and mixed/multiple crops / intercropping because different crops have different levels of resilience to weather variability, hence planting many crops could ensure that the farmer get some output in the face of extreme weather situations, shifting / modifying husbandry practices, use of organic fertilizers, practicing irrigation, mulching, crop rotation, change timing/date of planting, planting early maturing, pest/disease/drought resistant crop varieties and planting trees (Nhemachena, 2022), (Katz and Brown, 2022), (Tabe-Ojong *et al*., 2023), (Wakweya, 2023), (Onoja, 2023), (Alakpa and Ogbe, 2024), (Orgu *et al.*, 2024), (Yakasi, 2020), (Wanglin and Rahut, 2024) and (Liwei *et al.*, 2024).

3.3 Level of use of CSAPs

Results in **Table 3** reveal the level of CSAPs used by arable crop farmers, where a mean of 15.2±4.1 was obtained. The majority (59.2%) of the respondents had low-level use, while 40.8% had high-level use of CSAPs.

By implication, there was low-level use of CSAPs in the study area, indicating that farmers had not yet fully utilized the package, and those that were used were related to farmers' conventional/traditional farm practices. This finding agrees with a similar study by Tabe-Ojong *et al*. (2023), who reported that Nigerian farmers have been using CSAPs partially, rather than fully or in a bundled form. They added that bundling matters more and is associated with higher productivity and food security gains. Arable crop farmers in the study area, therefore, are to be encouraged to utilise CSAPs in full, through enlightenment / education programmes via extension services to create awareness on CSAPs and how to access their required inputs easily. Experience in agricultural education services will

Table 3: Level of CSAPs used by arable crop farmers (n = 120)

Levels of CSAPs usage	Score range	Frequency	%
Low (below mean)	5 – 15	71	59.2
High (mean and above mean)	16 – 20	49	40.8

Mean = 15.2±4.1
Source: *Computation from Field Survey, 2024*

enhance farmers' knowledge, training, and access to information on climate change and farming practices, enabling them to adapt to and mitigate the associated problems (Wakweya, 2023).

3.4 Constraints to the use of CSAPs

The results in **Table 4** reveals mean scores of constraints faced by arable crop farmers in CSAPs use which comprised; sticking to traditional method of farming e.g. rain-fed method of farming (2.93), inadequate access to farm finance/high cost at the outset (2.90), low literacy level among farmers (2.89), lack of collateral security to secure formal loan (2.87), high cost of irrigation facilities (2.86), inadequate access to extension services on CSAPs (2.85), high cost of improved crop varieties *e.g*. draught, pest & disease resistant (2.51), inadequate access to farm labour (2.35), inadequate knowledge and awareness of CSAPs (2.30), obstacles of government policy and regulation on CSAPs (2.01), lack of awareness and access to NGOs programmes on climate change (1.98), religious, cultural and social resistance (1.56) and inadequate access to farmland (1.08).

This implies that arable crop farmers in the study area faced numerous challenges in their endeavor to use CSAPs; this could also be the reason for their low-level use of the technology and the

Table 4: Mean score of constraints to use of CSAPs by arable crop farmers

Constraints	VS	S	NS	TSS	MS
Inadequate access to extension services on CSAPs	111	009	000	342	2.85
Inadequate access to farm labour	043	076	001	282	2.35
Inadequate access to farm finance/high cost at the outset	109	010	001	348	2.90
Inadequate access to farmland	004	002	114	130	1.08
Inadequate knowledge and awareness of CSAPs.	037	082	001	276	2.30
Lack of collateral security to secure formal loan	110	004	006	334	2.87
High cost of improved crop varieties e.g. draught, pest & disease resistant	087	008	024	301	2.51
High cost of irrigation facilities	109	005	006	343	2.86
Religious, cultural and social resistance	030	007	083	187	1.56
Obstacles of government policy and regulation on CSAPs	013	095	012	241	2.01
Low literacy level among farmers	111	005	003	347	2.89
Sticking to traditional method of farming e.g. rain-fed	113	005	002	351	2.93
Lack of awareness and access to NGOs programmes on climate change	008	101	011	237	1.98

Key: VS = Very Serious, S = Serious, NS = Not Serious, TSS = Total Sum of score, MS = Mean score
Source: *Computation from Field Survey, 2024*

prevalent food scarcity in the area. These findings are in line with similar researches that found the following as constraints to use of CSAPs; low literacy level, poor access and high cost of irrigation facilities, lack of knowledge of CSA technologies, inadequate financial resources, inadequate extension service, lack of access to farm inputs, high cost of improved crop varieties, lack of proper policies and political commitment by government to climate change (Wakweya, 2023 and Yilai *et al.*, 2024).

3.5 Respondents' Food Security Index (FSI)

Table 5 presents the findings on respondents' food security index (FSI) which indicates 1.44, this implies that a very terrible, worrisome and concerning food insecurity situation existed among respondents in the study area where majority 65.0% were found to be food insecure, 2.58% were partially/slightly/moderately food secure and as low as 09.2% were highly food secure.

This finding is in line with Tabe-Ojong *et al.* (2023), who reported in similar research that smallholder farmers in SSA are food insecure due largely to challenges faced, such as inadequate access to production resources (land, labour, capital and information) and, most recently, the effects of climate change that have added up. Therefore, encouraging the use of CSAPs in full has the potential to improve the food security situation of the people (Wakweya, 2023; Omotosho and Omotayo, 2024).

Computation of Food Security Index (FSI)

Step 1: Assign Scores
Highly food secure = 3 points
Slightly/Moderately food secure = 2 points
Low Food secure = 1 point

Step 2: Calculate proportion for each category (Divide freq. by sample for each)
Highly food secure = 11 divided by 120 = 0.091
Slightly/Moderately food secure = 31 divided by 120 = 0.258
Low Food secure = 78 divided by 120 = 0.650

Step 3: Multiply each proportion by its assigned score
Highly food secure = 0.092 × 3 = 0.276
Slightly/Moderately food secure = 31 divided by 120 = 0.258 × 2 = 0.516
Low Food secure = 78 divided by 120 = 0.650 × 1 = 0.65
Step 4: Sum the results of step 3
= 0.276 + 0.516 + 0.65 = 1.442
Therefore FSI = 1.44

Table 5: Respondents' Food Security Status

Category	Frequency	Percentage	Food Security Index
Highly food secure	11	09.2	
Slightly/Moderately food secure	31	25.8	FSI = 1.44
Low food secure	78	65.0	
Total	120	100.0	

Source: *Computation from Field Survey, 2024*

3.6 Influence of CSAPs on food security

The ordered probit regression analysis, presented in **Table 6**, shows the influence of CSAPs on food security. Eight of the fifteen examined variables exert a statistically significant impact at the 1% level ($p < 0.01$).

Sex shows as a significant predictor with a negative coefficient (-0.5535), suggesting that female-headed households are associated with a reduced likelihood of achieving food security. This finding aligns with existing literature highlighting systemic disparities in access to crucial agricultural resources, such as land tenure, credit, and extension services, which often disproportionately affect women farmers and, consequently, their capacity to adopt Climate-Smart Agricultural Practices (CSAPs).

Similarly, the age of the household head reveals a statistically significant negative coefficient (-0.0372), indicating that advanced age is associated with diminished food security. This may be attributed to a combination of factors, including potential physical limitations that hinder labour-intensive agricultural activities and a documented aversion among older farmers to embracing innovative, risk-averse technologies like CSAPs. In a somewhat counterintuitive finding, education status also displays a statistically significant negative coefficient (-0.4317). While conventional wisdom posits a positive correlation between education and technology adoption, this result may indicate that higher educational attainment can create opportunities for individuals to transition out of direct agricultural production into

Table 6: Influence of CSAPs on food security

Variable	Coefficient	Std. Error	Z	p-value
Sex	-0.5535	0.0580	-9.55	0.000***
Age	-0.0372	0.0138	-2.69	0.007***
Household size	-0.0413	0.4653	-0.09	0.930NS
Education status	-0.4317	0.0318	-13.56	0.000***
Farming experience (yrs)	-0.0620	0.0148	-4.18	0.000***
Secondary occupation	0.1894	0.0572	3.31	0.001***
Farm size	0.2568	0.0377	6.82	0.000***
Extension visits	0.3715	0.0820	4.53	0.000***
Sources of agric. info	-0.0163	0.0660	-0.25	0.802NS
Type of agriculture	-0.0197	0.1163	-0.17	0.865NS
Annual income	-0.0798	0.0771	-1.03	0.303NS
Membership of association	-0.0849	0.0250	-3.39	0.001***
Total perception score	-0.0173	0.0856	-0.20	0.840NS
Total CSAPs use score	0.3448	0.0601	5.73	0.000***
Total constraints score	0.0270	0.0354	0.76	0.447NS

Source: *Computation from Field Survey, 2024*

Key *** means significant at 1%, and NS means Not Significant at the level of measurement.

alternative, potentially more lucrative occupations. Farming experience shows a negative and significant effect (-0.0620), which suggests that prolonged reliance on traditional farming methods may impede the adoption of novel CSAPs among more experienced practitioners.

Secondary occupation (0.1894) has a positive impact on food security, underscoring the critical role of diversified income streams in enabling households to overcome initial investment barriers associated with CSAPs, thereby enhancing their capacity for sustainable food production. Likewise, farm size (0.2568) and extension visits (0.3715) are both positively correlated with food security. Larger landholdings provide greater scope for experimenting with and scaling CSAPs. At the same time, consistent engagement with agricultural extension services serves as a vital conduit for disseminating knowledge, providing training, and facilitating the uptake of these beneficial practices. Membership in associations (-0.0849), although statistically significant, reveals an inverse relationship with food security. This unexpected outcome may warrant further investigation into potential inefficiencies within group benefit distribution or exclusionary practices that might inadvertently marginalize some members.

The total CSAPs use score (0.3448) is found to be a highly significant positive determinant of food security. This finding directly reinforces the premise that a more comprehensive and extensive adoption of Climate-Smart Agricultural Practices contributes to improved food security outcomes, enhancing resilience to climate-related shocks and fostering stable food production. This positive relationship underscores the potential of CSAPs when integrated effectively into farming systems.

4. Conclusion

The study concluded that the major constraints affecting rice production in the Dadin-kowa irrigation scheme were the high cost of farm inputs, incidence of pests and diseases, and farmers–herders conflicts. Other challenges identified by farmers included inadequate extension services, land fragmentation, inadequate storage facilities, land encroachment, and high labor costs, all of which negatively affected production efforts and farm income. These constraints discouraged farmers and limited their productivity and standard of living.

Based on the findings, the study recommended that the government and relevant agencies should provide adequate security to address farmers–herders clashes in the study area, thereby enabling farmers to maximize productivity. It also recommended exploring alternative methods of land acquisition beyond inheritance to increase land available for rice cultivation and expand production. In addition, improving farmers' technical efficiency through credit facilities was suggested as a means of sustaining rice production. Finally, the study emphasized the need for timely provision of farm inputs and supplies such as machinery, improved seeds, agrochemicals, and fertilizers at affordable prices to enhance productivity, income, and the overall standard of living of farmers.

5. Acknowledgement

The authors acknowledge the smallholder farmers who served as respondents. We also appreciate the contributions of the research assistants and reviewers.

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Current Innovation in Agriculture Science
Vol. 3, Issue 1, pp. 809-815
Research Article
ISSN (E): 3048-6009

Assessment of improved post-harvest management technology training amongst smallholder vegetable women farmers in Kwara State, Nigeria

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Received: 28 April 2025 | Accepted: 19 November 2025

DOI: https://doi.org/10.65791/cias.77

ABSTRACT

Household food and nutrition security relies heavily on rural food production and this substantially contributes to alleviating poverty. Consequently, sustainable production of food and adequate postharvest management leads to food security. In many of the countries, the diminishing capacity of agriculture in providing for household subsistence increased the workload shouldered by women as men withdrew their labour from agriculture and sought greener pasture in white collar jobs in cities and towns. Thus the focus on smallholder women farmers trained on grain value addition. A total of 90 smallholder women vegetable farmers were selected from three (3) villages of Ilorin East local government areas of Kwara State. Majority (96.1%) of smallholder women farmers are involved value addition for income generation, 98.3% belong to either women association, women farmers' association or some other associations, the smallholder women vegetable farmers agreed that the knowledge gained from postharvest management training could be shared with other women (WS=2.91). A total of 58.3% women smallholder farmers trained on postharvest management of grains had high knowledge. The women indicated that the constraints to adoption of postharvest technologies as lack of training on postharvest handling and storage (WS=3.17), unavailability of the technologies needed (WS= 3.01) and acceptance by other members of the household (WS= 3.27). Empowering and supporting women smallholder farmers is an essential tool to increase adoption of postharvest technologies and increase food supply. Thus, focusing training on smallholder women involved in vegetable value addition is recommended.

KEY WORDS: *Food and Nutrition Security*; *Postharvest Management*; *Smallholder Women Farmers*

1. Introduction

Food is a basic need of humans need and it is a major source of nutrients for human survival and existence. Food is highly important for human's well-being and for economic contribution and productivity (Agada & Igbokwe, 2016). Its demand has generally grown faster than its total supply, and its loss due to postharvest ineptness has contributed immensely to food insecurity.

Food and nutrition security has over the years remained Africa's most fundamental challenge to human welfare and economic growth. However, many people on the continent are unable to

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acquire and effectively utilize the food they need for a healthy life at all times. According to Peng & Berry, 2019, food and nutrition security is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. This definition speaks volume of the multidimensionality of food security. However, the major elements of food security are; its availability, its accessibility, its utilization and its protection of access (Agada & Igbokwe, 2016). Food and nutrition security is the bridge between agriculture and health, a major compass in the food system. One of the foremost challenging issues in the world today is how to provide sufficient food to the geometrically increasing world population.

There are several interventions ranging from improved yield, climate change mitigation and government support that has improved agricultural productivity, yet malnutrition remains the world`s most serious health problem and it is the single biggest contributor to child stunting and death (FAO, 2021).

The problem of postharvest loss has remained a nagging issue to attaining food and nutrition security in Nigeria. The level of high poverty and food insecurity in Nigeria is alarming, (Ike *et al*., 2017) with approximately 15% undernourished population, that is, 29.4 million undernourished people despite being one of the largest economies in Africa (FAO, IFAD, UNICEF & WFP 2021). Postharvest loss is the measurable quantity and quality loss of products at any point along the postharvest chain. (Kikulwe *et al*., 2018). It inadvertently leads to significant food losses and economic losses (Gross *et al*., 2000).

Women play a vital role in agriculture, but are faced with persistent economic constraints, their empowerment can be a major contributor to increased income of smallholder farmers, reduced hunger, empowered and independent women farmers, built local capacity, and strengthened resilience to economic and environmental shocks. Women disproportionately experience postharvest losses because of the time constraints and their lack of decision-making powers and lack of access to postharvest management knowledge, storage and handling technologies.

The gendering of farming activities and household food responsibilities in Nigeria has led to the complicated restriction of women to equal benefits from training opportunities, resources and empowerment. Family structures in most rural communities are patrilineal and restrains access to empowerment to male farmers mostly.

There is a great need to empower women in agriculture to foster food and nutrition security in Nigeria. This need informed this particular study which will allow women smallholder vegetable farmers become equipped with knowledge on postharvest management of vegetables.

The specific objectives of the study were to: access the level of knowledge from training; assess the perceived benefits of the respondents from training; and identify the factors influencing the attendance of training and the acceptance of empowerment materials. The specific research questions were: assess the' knowledge perception of postharvest management practices, examine the perceived benefit and to assessfactors influencing the acceptance of training and empowerment.

2. Material and Methods

The study was carried out in Kwara State, Nigeria. The State is in the North Central geo-political zone of Nigeria. It falls within the guinea savannah of the agro-ecological zones. She has a land area of about 36,825 Sqkm. Kwara State lies between latitude 9°25′35″N and longitude 3°30′38″E and it is bounded by Niger and Sokoto to the North; Oyo, Ondo and Edo to the South; Benue, Plateau and FCT to the East; and shares international boundary with the republic of Benin to the West. The 2018 population figure of Kwara State was estimated to be 3,390,188 people (http://www.citypopulation.de/php/nigeria).

This training was carried out in Kwara State of Nigeria. The State comprises of 16 Local Government Areas and there was an initial need assessment that informed the training on postharvest management of the women vegetable framers. The trainings were done in 3 selected villages of the Ilorin East Local Government Area. The villages were Amoyo, Sentu and Ile-apa. A scheduled interview was conducted after training to know the level of knowledge gained from each training. Data was subjected to statistical analysis; percentages and mean were used to analyse the level of knowledge from training and other training needs. The settings for this research were within the selected communities. The facilitators were outreach staff from Nigerian Stored Products Research Institute (NSPRI) with collaboration from Nigerian Women in Agriculture (NiWARD) Kwara State branch. The sponsorship came from African Women in Agriculture and Research (AWARD)

A sample size of 20% of the population of women who cultivate and or sell vegetable in the selected villages was randomly selected from each of the 3 villages for training on postharvest management of vegetable. A structured interview guide was administered after the training to elucidate information used for the analysis and result determination of this study

3. Results and Discussion

3.1 Knowledge rating of respondents on postharvest management

The result in **Table 1** revealed the knowledge perception of respondent. There was a pre-test done to ascertain the level of the respondents' knowledge on postharvest management of vegetable the result showed 10% of the respondent had knowledge in postharvest management of vegetable.

However, following the training, 50% of participants demonstrated a high level of knowledge, while only 8.9% showed fair

Table 1: Knowledge Rating of Respondents on postharvest management

Level of Knowledge	Frequency	Percentages	Mean Score	Rank
High Knowledge	45	50.0	2.0	1st
Moderate Knowledge	23	25.5	1.1	2nd
Low Knowledge	14	15.6	0.6	3rd
Fair knowledge	8	8.9	0.3	4th
Total	90	100.0		

Source: Field Survey, 2025

knowledge. This notable shift indicates that the training program was highly effective in bridging existing knowledge gaps. The high mean score (2.0) for the "High Knowledge" category underscores the positive impact of the training on participants' understanding and capacity to manage postharvest operations efficiently. Such improvement aligns with studies emphasizing capacity building as a key driver of postharvest innovation and loss reduction among smallholder farmers. This shows that the training was impactful and mostly important to the trainees.

3.2 Respondents' perceived benefits of training and empowerment

As shown in **Table 2**, participants strongly agreed that postharvest management significantly enhances profitability and reduces vegetable losses, reflected by the highest mean score (2.64). The second most acknowledged benefit was the potential of postharvest management to reduce household losses (mean = 2.54), followed by improvements in livelihood (mean = 2.28). Ersino *et al*., 2018 found that food security scores were better in households where women or both genders controlled farm produce, this indicates the importance of ensuring women's access of postharvest resources will better position them for improved food and nutrition security.

The relatively lower mean for "knowledge transfer" (2.02) indicates that while participants gained practical skills, there remains a need to strengthen peer-to-peer learning and community-level dissemination of knowledge. Overall, these findings affirmed that training and empowerment not only improve technical skills but also boost economic sustainability and household food security.

Food commodity (vegetable) will bring maximum profit due to postharvest management and vegetable loss reduction, the women vegetable farmers will be able to increase their profit by adopting the use of empowerment.

3.3 Factors influencing the acceptance of empowerment material

Table 3 demonstrates that respondents largely accepted the training and empowerment initiatives. High mean scores across variables indicate favorable attitudes: affordability and accessibility of technologies (3.21), familiarity of trainers and facilities (3.17), and the gender-friendly nature of practices (3.22). Importantly, the agreement that household acceptance

Table 2: Respondents' perceived benefits of training and empowerment

Benefits of empowerment and training	Mean	Standard Deviation	Rank
Food commodity (vegetable) will bring maximum profit due to Postharvest management and vegetable loss reduction	2.64	0.83	1st
Postharvest management will boost livelihood	2.28	0.84	3rd
Commodities can be processed into other products	2.10	0.79	4th
Postharvest management will cut down on household losses	2.54	0.96	2nd
The knowledge can be easily transferred to others.	2.02	0.88	5th

Source: Field Survey, 2025

Threshold of 2.0 of a 3 point Likert scale denote agreed for any mean score above 2.0

Table 3: Factors influencing the acceptance of empowerment material (vegetable baskets)

Attitude towards postharvest training and empowerment	Weighted Sum	Standard Deviation	Rank	Remark
Most of the technologies trained on are affordable and accessible	3.21	0.419	1st	Agreed
The facility and trainers are familiar	3.17	0.434	2nd	Agreed
Acceptance by other members of the household will encourage postharvest management practices	3.27	0.456	4th	Agreed
Postharvest management practices are gender friendly	3.22	0.426	3rd	Agreed
The training method used to teach postharvest management is simple and easy to understand	3.19	0.450	5th	Agreed

Source: Field Survey, 2025
Threshold of 3.0 of a 5 point Likert scale denote agreed for any mean score above 3.0

encourages postharvest adoption (mean = 3.27) suggests that social influence and household support play critical roles in sustaining behavioral change. The simplicity of training methods (3.19) further supports inclusivity and comprehension among rural women participants.

Therefore, acceptance by other members of the household will encourage postharvest management practices and the acceptance and use of postharvest technology.

3.4 Factors influencing the attendance of postharvest management training by smallholder women vegetable farmers

The respondents as shown on **Table 4** agreed to a list of factors influencing their attendance of training and empowerment programs. It shows the rank order analysis to determine factors that prompt respondent's attendance of postharvest training on vegetable and empowerment with vegetable baskets. Almost all the respondents, agreed on the items of statement, however the three most agreed upon will be highlighted as follows from the 1st to 3rd: item 3 "Decision making is influenced by membership of an organised group" with a mean of 3.21; item 2 "Influence of the male household heads" with a mean of 3.22; item 1 "Attendance by other members of the household" with a mean of 3.27.

4. Conclusion

Reducing postharvest losses can be achieved through consistent and deliberate effort using training and empowering of stakeholders particularly smallholder women farmers as the women agreed that food commodity (vegetable) will bring maximum profit due to postharvest management and vegetable loss reduction. The method used should be a holistic approach that will involve all members of the households as attendance by other members of the household proved to be a strong factor in encouraging women's participation in postharvest management practices among rural women in the study area. This might not literally mean all household members should attend training meant for women, but could mean informing and getting the consent of or raising the awareness about the training for all household members' notice. Reducing

Table 4: Mean Rank Order and Standard deviation of response on factors influencing the attendance of training.

N	Factors influencing attendance of training	WS	Standard Deviation	Rank	Remark
1	Liberty to make personal decisions	3.17	0.393	6th	Agreed
2	Decision making is influenced by membership of an organised group	3.21	0.419	3rd	Agreed
3	Influence of religious leaders	3.17	0.434	5th	Agreed
4	Attendance by other members of the household	3.27	0.456	1st	Agreed
5	Influence of the male household heads	3.22	0.426	2nd	Agreed
6	Results from previous training attended	3.19	0.450	4th	Agreed
7	Others	3.17	0.388	7th	Agreed

Source: Field Survey, 2025

postharvest losses and owning postharvest technologies has gained attention more among men than women. To ensure gender inclusiveness, women should be encouraged to own postharvest management technologies and participate in postharvest management training.

This study recommends that training women would be successfully conducted if the associations they belong to are used as avenue for invitation, and the male household heads are also contacted to prompt the women's participation among other strategies. The inclusion of women in postharvest management will help improve household food security,

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Current Innovation in Agriculture Science
Vol. 3, Issue 1, pp. 816-821
Research Article
ISSN (E): 3048-6009

Growth performance of broiler chickens fed various levels of African locust bean (*Parkia biglobosa*) based diets

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Received: 25 April 2025 | Accepted: 22 November 2025

DOI: https://doi.org/10.65791/cias.77

ABSTRACT

This experiment was conducted to evaluate the growth performance of broiler chickens fed various level of African locust bean (*P. biglobosa*) based diets. One hundred and twenty day old broiler chicks (marshal strain) were allotted to four dietary treatment in which African locust bean seed replace soybean as protein source at 0, 10, 20 and 30% levels coded as diets 1, 2, 3 and 4 respectively, The experiment was in a completely randomized design (CRD) with three replicates per treatment and ten birds per replicate. Feed and water were supplied ad libitum and the trial lasted for eight weeks. At the starter phase, daily feed intake (58.47-60.87 g), daily weight gain (16.19 - 18.39 g) and feed conversion ratio (3.22 - 4.02) were not significantly different. At finisher phase the daily feed intake (90.18-102.87 g) indicated significant difference ($P<0.01$) while the values of the daily weight gain (34.92 - 40.49 g) were significant in birds fed diet 4 and 3 respectively. However, feed conversion ratio did not show any significant treatment effect, the values ranged from (2.53 - 2.95). From these findings African locust bean meal can replaced soybean at 20% without any adverse effect on the performance of birds with concomitant reduction in cost.

KEY WORDS: *Africa locust bean seed*; *Soybean*; *Performance*; *Broiler chicken*; *Feed*

1. Introduction

Poultry production is gaining popularity in the developing countries due to its role in bridging the protein nutrition deficit, resulting to economic empowerment of the resource poor segment of society (Gebremedhn and Alemu, 2015). Such growth in the poultry industry is having a profound effect on the demand for feed and raw materials. However, it is also becoming clear that the requirements for the four traditional feed ingredients (maize, soybean meal, fish meal and meat meal) cannot be met (Adewale *et al.*, 2016). The gap between local supply and demand for these traditional ingredients are expected to be widening over the coming decades thus, providing a compelling reason for exploring the usefulness of locally available alternative feedstuffs in feed formulation (Adewale *et al.*, 2016). The utilization of locust bean in monogastric nutrition as replacement for a protein source *i.e* groundnut cake was reported to improved production performance, nitrogen retention and feed utilization, with varied results (Bridget *et al.*,

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2004; Alabi *et al*., 2005). Ayanwale and Ari (2002) and Dawodu (2009) found a positive attribute for fermented locust beans as against the unfermented locust bean which was said to inhibit broiler growth due to less protein quality and essential vitamins (Fetuga *et al*., 1974). However, Anti-nutritional factors (ANFs) such as tannins oxalate and hydrogen cyanide had been reported to limit the utilization of locust bean as feed ingredient (Apata, 2003). Fermentation has been reported to destroy some natural toxins which may occur in beans, thereby improving the nutritive-value, digestibility and enhance growth of chickens (Bridget *et al*., 2004).

This study was designed to evaluate the growth performance of broiler chickens fed various levels of African locust bean (*P. biglobosa)* meal.

2. Material and Methods

2.1 Experimental site

The experiment was conducted at the poultry unit of Abubakar Tafawa Balewa University Teaching and Research Farm, Bauchi. Bauchi State occupies a total land area of 49,119 km² representing about 5.3% of Nigeria's total land mass and is located between latitudes 9° 3' and 12° 3' North and longitudes 8° 50' and 11° East.

2.2 Materials for experiment

Maize, soybean, locust bean, groundnut cake, fish meal, wheat offal, bone meal, limestone, lysine, methionine, salt and vitamin premix were bought from Muda Lawal market in Bauchi town. One hundred and twenty (120) day old chicks were obtained from Zatech Hatchery.

2.3 Management of the birds

The broiler chickens were brooded on deep litter for a week fed commercial diet containing 23% crude protein and 2900 kcal kg^{-1} ME. Heat was provided during the brooding with two charcoal stoves and 200 watts electric bulbs as sources of light and heat. After the brooding, birds were randomly assigned to four dietary treatments. Each treatment was replicated three times, vaccine were administered as required, feed intake was determined by subtracting the left over from the supply of the previous day. The weights of the birds were measured in groups immediately after the brooding period and weekly thereafter.

2.4 Experimental design

The experimental design used was Completely Randomized Design**.**

2.5 Experimental diets

Four experimental diets for both starter (23% CP) and finisher (20% CP) phase were formulated. Locust bean meal were included at 0, 10, 20 and 30% level as replacement for soybean, designated as diets T_1, T_2, T_3 and T_4 respectively for both starter and finisher phase.

2.6 Data collection

Birds performance

Records of feed intake and body weight changes were taken daily and weekly respectively, feed conversion ratio was calculated using the values while mortality was recorded as they occurred.

2.7 Statistical analysis

The data obtained were subjected to analysis of variance (ANOVA) were significant difference occurred means, least significant difference (LSD) was used to separate them.

3. Results and Discussion

The ingredient composition of the experimental diets fed to broiler chickens during the starter (1–4 weeks) and finisher (5–8 weeks) phases is presented in **Tables 1** and **2**, respectively. Four dietary treatments were formulated by replacing soybean meal with processed locust bean meal at 0% (T_1), 10% (T_2), 20% (T_3), and 30% (T_4) levels.

Table 1: Percentage composition of experimental diets fed to broiler chickens at the starter phase (1-4weeks)

Parameters	Diets			
	T_1 (0%)	T_2 (10%)	T_3 (20%)	T_4 (30%)
Maize	40.25	40.25	40.25	40.25
Soybean meal	33.55	30.20	26.87	23.50
Locust bean meal	0.00	3.35	6.71	10.05
Groundnut cake	5.00	5.00	5.00	5.00
Fish meal	2.00	2.00	2.00	2.00
Wheat offal	15.00	15.00	15.00	15.00
Bone meal	2.00	2.00	2.00	2.00
Limestone	1.50	1.50	1.50	1.50
Salt	0.25	0.25	0.25	0.25
Lysine	0.10	0.10	0.10	0.10
Methionine	0.10	0.10	0.10	0.10
Premix	0.25	0.25	0.25	0.25
Total (%)	100.00	100.00	100.00	100.00
Calculated Composition (%)				
Crude protein (%)	23.00	23.81	23.77	23.69
Crude fibre (%)	4.09	4.06	4.04	4.01
ME (kcal kg^{-1})	2860	2834	2822	2812

Note: T_1 = 0% locust bean meal (control), T_2 = 10% locust bean meal, T_3 = 20% locust bean meal, and T_4 = 30% locust bean meal replacement of soybean meal.

Table 2: Percentage composition of experimental diets fed to broiler chickens

Parameters	Diets			
	T_1 (0%)	T_2 (10%)	T_3 (20%)	T_4 (30%)
Maize	51.56	51.56	51.56	51.56
Soybean meal	22.24	20.02	17.80	15.50
Locust bean meal	0.00	2.22	4.44	6.66
Groundnut cake	5.00	5.00	5.00	5.00
Fish meal	2.00	2.00	2.00	2.00
Wheat offal	15.00	15.00	15.00	15.00
Bone meal	2.00	2.00	2.00	2.00
Limestone	1.50	1.50	1.50	1.50
Salt	0.25	0.25	0.25	0.25
Lysine	0.10	0.10	0.10	0.10
Methionine	0.10	0.10	0.10	0.10
Premix	0.25	0.25	0.25	0.25
Total (%)	100.00	100.00	100.00	100.00
Calculated Composition (%)				
Crude protein (%)	20.00	20.81	20.77	20.69
Crude fibre (%)	5.01	5.05	5.07	5.09
ME (kcal kg^{-1})	3019	3020	3024	3032

Note: T_1 = 0% locust bean meal (control), T_2 = 10% locust bean meal, T_3 = 20% locust bean meal, and T_4 = 30% locust bean meal replacement of soybean meal.

At the starter phase, the inclusion of locust bean meal increased progressively from 0.00% in T_1 to 10.05% in T_4, while the soybean meal content

decreased correspondingly from 33.55% to 23.50%. Other dietary ingredients remained constant across all treatments. The calculated crude protein content ranged from 23.00% in T_1 to 23.81% in T_2, with slight reductions to 23.77% and 23.69% in T_3 and T_4, respectively. Crude fibre values showed a marginal decline from 4.09% in T_1 to 4.01% in T_4. Similarly, metabolizable energy (ME) decreased slightly from 2860 kcal kg^{-1} in the control diet to 2812 kcal kg^{-1} in the diet containing 30% locust bean meal.

During the finisher phase, a similar trend was observed. The inclusion level of locust bean meal increased from 0.00% in T_1 to 6.66% in T_4, while soybean meal decreased from 22.24% to 15.50%. The crude protein content varied slightly among treatments, ranging from 20.00% in T_1 to 20.81% in T_2 and declining marginally to 20.69% in T_4. Crude fibre content increased slightly from 5.01% in T_1 to 5.09% in T_4. Metabolizable energy values showed a gradual increase from 3019 kcal kg^{-1} in T_1 to 3032 kcal kg^{-1} in T_4.

The formulated diets at both starter and finisher phases maintained relatively similar nutrient compositions across treatments despite increasing levels of locust bean meal inclusion, indicating that the replacement strategy successfully produced nutritionally comparable diets for evaluating the effect of locust bean meal on broiler performance.

The performance of broiler chickens fed various levels of African locust bean *(P. biglobosa) based diets* for starter (1-4 weeks) were presented in **Table 3**. There was no significant (P>0.05) difference in the feed intake, weight gain, and feed conversion ratio between birds fed experimental diets implying that the inclusion levels of African locust bean *(P. biglobosa)* did not have any effect on these parameters. This is in line with the finding of Obun (2007) who reported no significant difference in feed intake among chickens fed graded level of fermented African locust bean (*P. biglobosa)* meal. Also the performance of broiler chickens fed various levels of African locust bean *(P. biglobosa) based diets* for finisher (5-8 weeks) were presented in **Table 4**. The feed intake were significantly affected by the dietary treatments (P<0.05) were birds on treatment 1, 2 and 3 were statistically similar and significantly higher than treatment 4 (30%). The daily weight gains were not significantly influenced by different dietary treatments. The observed increased feed intake of birds fed African locust bean meal as shown in Table 4 can be attributed to the less odour of locust bean meal due to low inclusion level which is 20%. At the level of inclusion 100%, the smell of the ALBM masked the smell of other ingredients making the

Table 3: Performance of broiler chickens fed various level of African locust bean at the starter phase (1-4 weeks)

Parameters	Dietary treatment					
	T_1 (0%)	T_2 (10%)	T_3 (20%)	T_4 (30%)	SEM	LOS
Daily feed intake (g)	59.84	60.00	60.87	58.47	13.70	NS
Daily weight gain (g)	16.79	16.85	16.19	18.47	0.75	NS
Feed conversion ratio	3.66	3.82	4.02	3.22	0.15	NS
Mortality (%)	0.00	0.00	0.00	0.00	–	–

LOS: Level of significance
NS: Non significance difference (P<0.05)

Table 4: Performance of broiler chickens fed various level of African locust bean at the finisher phase (5-8 weeks)

Parameters	T_1 (0%)	T_2 (10%)	T_3 (20%)	T_4 (30%)	SEM	LOS
Daily feed intake (g)	102.33[a]	102.37[a]	102.47[a]	90.18[b]	2.74	*
Daily weight gain (g)	36.05	40.46	38.97	34.92	3.62	NS
Feed conversion ratio	2.53	2.54	2.68	2.95	0.30	NS
Mortality (%)	3.33	3.33	6.60	3.33	–	–

SEM: Standard Error of Mean
LOS: Level of significance
NS: Non significance difference (P<0.05)

diets unattractive and possibly unpalatable to the birds, while at 50% ALBM inclusion, birds can still tolerate the aroma (Aderemi *et al*., 2017). This result is also similar to the findings of Odunsi (2003) who reported that feed intake by animal's increases if the aroma of their diet is acceptable. However, the better FCR may be due the low inclusion level of locust bean 20% which make the diet to be more palatable and acceptable.

4. Conclusion

It can be concluded that the African locust bean seed can replace soya bean at 20% level as sources of protein in broiler diets at both starter and finishing phase without any detrimental effect on the performance of broiler chickens hence the use of African locust bean seed could be well advocated and recommended to served as an alternative protein source for soya bean at up to 30% level. Thereby reducing completion and improving consumer access to animal protein.

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Current Innovation in Agriculture Science
Vol. 3, Issue 1, pp. 822-831
Research Article
ISSN (E): 3048-6009

Effects of open grazing on production activities of arable farmers in Niger State, Nigeria

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Received: 08 May 2025 | Accepted: 13 December 2025

DOI: https://doi.org/10.65791/cias.78

ABSTRACT

This study assessed the effects of open grazing on production activities of arable farmers in Niger State, Nigeria. Multistage sampling technique was used select 154 registered arable crop farmers for this study. The study showed that majority of the respondents (71.3%) were married, and their predominant age range were 31 – 40 years (66.9%) with a mean age of 34 years. In terms of educational attainment, (82.8%) of the respondents had formal education while only few has no formal education, with an average mean of 6 years of schooling. The result also showed that farmers are concerned about soil compaction and erosion caused by grazing animals, the need for additional fencing and other protective measures increases production costs and farmers perceive open grazing as a major threat to crop yields due to direct consumption and trampling of crops by livestock were major arable farmers' perception on open grazing activities in the study area. The findings further show that, open grazing can lead to conflicts between livestock and wildlife, potentially affecting biodiversity and crop pollination were major effects of open grazing on production activities of arable farmers in the study area. The results also show that, Aids to the victim of herders-farmers conflict to reduce the tendency of reprisal attacks ($\bar{X}$=3.46), Avoid dry season cultivation of crops ($\bar{X}$=3.40) and Help from local leaders to avoid impact of open grazing ($\bar{X}$=3.11) were major effective coping strategies to open grazing activities on arable farmers in the study area. It is therefore recommended that government should establish and enforce designated grazing zones away from crop fields to minimize soil compaction, erosion, and crop damage.

KEY WORDS: *Grazing*; *Production*; *Arable farmers*; *Activities*; *Perception*

1. Introduction

Nigeria's rural culture and economy are firmly anchored in the traditional practice of livestock grazing, especially open grazing. The Fulani pastoralists have a long history of leading a nomadic lifestyle, constantly moving their livestock across large areas in search of water and pasture. However, Livestock rearing provides a rich source of protein and income to individuals. Livestock rearing is a dominant practice of Fulani Herdsmen in Nigeria. Iloanya and Chukwuemeka (2020) noted that a typical Fulani herdsman keeps and sustains his herd through open grazing. Open grazing is the act of freely moving in search of pasture and water. It is an obsolete form of

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pasturing. According to Jooji (2020), open grazing is the age-old practice of roaming about with animals in open field, plains and nearby bushes in search of pasture or food for the animals. However, Jooji (2020) averred that it is mostly practiced in Nigeria by Fulani herders who move for days on foot with their herds from the north to the more rain-fed southern parts of the country pasturing their flock as they go. It is practice of moving livestock around bushes for pasture. According to Chukwuemeka, *et al.* (2019), open grazing is the practice whereby cattle are herded by taking them round in large numbers to feed in open spaces and uncultivated grasslands in amigratory or nomadic style. Madube *et al.* (2019), asserted that grazing abounds across the Nigeria due to variation in climate. The differences in weather conditions between North and other parts of Nigeria compel herdsmen to move their cattle to different regions of the country in search of pasture. While driving cattle across regions sometimes the destruction of crops occurs and becomes a source of crisis between farmers who claim customary right over land and herdsmen who are regarded as strangers (Akuul and Kizito, 2019).

Farmers' displacement is a serious setback to crop production in Niger State. The practice of open grazing has resulted to the struggle for control of resources contributes to incessant conflicts among herdsmen and farmers. Olaojo *et al.* (2020), maintained that the conflict between the Fulani herdsmen and the farmers usually arise when the former invade community farmland with their cattle and graze unrestricted both on cultivated and uncultivated land thereby destroying valuable food and cash crops which are the mainstay of the host communities. In addition, that they hinder traffic flows, endanger human and vehicular road users, and exacerbate city congestion, and most often, cause fatal road mishaps. More so, Igbokwe-Ibeto *et al.* (2021), stressed that local farmers hardly can cultivate at their full capacity due to fear of being attacked and killed by the rampaging Fulani herdsmen who engage in open grazing. This seems to have contributed to food shortages due to the abandonment of farmlands and destruction of crops among the arable crop farmers.

The need to provide arable crops and animals to meet the growing demand due to population increase necessitates the opening up of more land that is arable. Agricultural production in any country requires an enabling environment to reach its maximum potentials. Sustainable development in agriculture, among other things, demands a peaceful co-habitation of producer communities. It is only through cooperation that local communities could implement sustainable common pool of resource conservation and management strategies (Mohammed and Abdul, 2020).

2. Material and Methods

The study was conducted in Niger State, Nigeria. Niger State is in the North-central part of Nigeria and lies between Longitude 3° 40″ and 7°40″ East and Latitude 8°20″ and 11° 20″ North of the equator (National Bureau of statistics (NBS), 2018). However, the total population in the State are over 5,556,200 people. National Population Commission of Nigeria (NPCN, 2016) from 2016 population census. But, going by the annual population growth rate of 3.5 percent in Nigeria, the population of Niger State was projected to be 6,334,068 people (NPCN, 2016) in the year 2020. Niger State shares common boundaries to the North with Zamfara State, to the North-East with

Kaduna State, and to the South- East with the Federal Capital Territory (FCT) (NBS, 2018). The land area is about 76,363 square kilometres at a density of 72.76/square kilometres (NBS, 2018), with varying physical features like hills, lowlands, rivers and ample vegetation's; enormously in the Northern Guinea Savannah. There are two separate seasons in Niger State: the dry and rainy seasons, which allow the production of numerous agricultural products. The State experiences average annual rainfall of up to 1,100mm in the North, lasting up to about 120 days and 1,600mm in the South which last up to 150 days (NBS, 2018). The highest temperature of the State is about 340C between March and June (NBS, 2018). In this study Multistage, sampling technique was used to select 154 registered arable crop farmers from the study area. Data were collected using semi-structured questionnaire and analysis was conducted using descriptive statistics such as frequency, percentage count, and mean.

3. Results and Discussion

3.1 Socio-economic characteristics of the respondents

Age of the respondents: The result in **Table 1** shows that about 66.9% of the arable farmers were between the age brackets of 31-40 years. The mean age of the farmers is 34 years. This implies that the arable farmers are young and still in their active productive age, thereby constituting readily available labor force for crop production. Hence, arable farming practices may be carried out with some relative ease. This result is in line with the result of Ahmed *et al.* (2020) who reveals that majority (61.4%) of the farmers are between the ages of 31-50 years with an average of 33 years.

Sex of the respondents: The **Table 1** also revealed that majority (78.3%) of the farmers were males while male farmers accounted for only 21.7%. This implies that arable farming practices are mostly dominated by men in the study area as a result that arable crop farming practices is labor intensive. This result also disagrees with the findings of Nenzhelele *et al.* (2019) who reported that more than half (52.6%) of the farmers were female that carry out various farming activities in the production of cereals crop than their male counterpart.

Table 1: Socio-economic characteristics of respondents

Variable	Frequency	Percentage	Mean
Age			
< 30 years	36	22.9	
31-40 years	105	66.9	34
41-50 years	11	7.0	years
> 50 years	5	3.2	
Sex			
Male	123	78.3	
Female	34	21.7	
Marital status			
Widow	26	16.6	
Divorce	5	3.2	
Single	14	8.9	
Married	112	71.3	
Formal education			
Yes	130	82.8	
No	27	17.2	

Source: Field Survey, 2024.

Marital status of the respondents: However, majority (71.3%) of the respondents were married. This implies that most of the respondents are actively involved in arable crop production to cater for the household needs as a result that married respondents have family to cater for and the tendency for improving in farming activities to

provide food for the family is relatively high. This result substantiates with the findings of Oli *et al.*, (2020) who pointed out that, married persons were more involved in farming activities due to higher food demand in the household.

3.2 The arable farmers' perceptions on open grazing

The results in **Table 2** shows the arable farmers perception on open grazing activities in the study area. However, the result shows that farmers are concerned about soil compaction and erosion caused by grazing animals ($\bar{X}$=3.14), the need for additional fencing and other protective measures increases production costs ($\bar{X}$ =3.11), farmers perceive open grazing as a major threat to crop yields due to direct consumption and trampling of crops by livestock ($\bar{X}$=3.07) and repeated crop damage can threaten the livelihoods of farmers, leading to financial instability ($\bar{X}$=3.02) were rank top four major arable farmers perception on open grazing activities in the study area.

With respect to soil compaction and erosion caused by grazing animals which was rank first with a mean of ($\bar{X}$ =3.14) shows that, soil

Table 2: Arable farmers' perception on open grazing

Perception statements	SA (%)	A (%)	D (%)	SD (%)	WM	Rank
Farmers are concerned about soil compaction and erosion caused by grazing animals	65(41.4)	54(34.4)	33(21.0)	5(3.2)	3.14	1st
The need for additional fencing and other protective measures increases production costs	79(50.3)	38(24.2)	19(21.4)	21(31.4)	3.11	2nd
Farmers perceive open grazing as a major threat to crop yields due to direct consumption and trampling of crops by livestock	80(51.0)	39(24.8)	8(5.1)	30(19.1)	3.07	3rd
Repeated crop damage can threaten the livelihoods of farmers, leading to financial instability	86(54.6)	14(8.9)	32(20.4)	25(15.9)	3.02	4th
The risk of crop damage from grazing discourages farmers from investing in their fields	76(48.4)	19(12.1)	42(26.8)	20(12.7)	2.96	5th
Many farmers develop a distrust of herders, believing that herders do not respect property boundaries and farming activities	83(52.9)	14(8.9)	25(15.9)	35(22.3)	2.92	6th
Open grazing often leads to conflicts between farmers and herders	65(41.4)	37(23.6)	28(17.8)	27(17.2)	2.89	7th
Farmers who suffer crop losses due to open grazing often demand compensation or restitution from herders or the government	64(40.8)	18(11.5)	42(26.8)	33(21.0)	2.81	8th
Livestock pollute water sources used for irrigation	81(51.6)	27(17.2)	22(14.0)	27(17.2)	2.72	9th

Source: Field survey, 2024. SA=strongly agree, A=agree, D=disagree, SD=strongly disagree

compaction occurs when the weight and movement of grazing animals press down on the soil, reducing its porosity. This can lead to several negative outcomes, including poor water infiltration, reduced root growth, and diminished soil aeration. Erosion, on the other hand, can be exacerbated by the removal of vegetation cover by grazing animals, which leaves the soil more vulnerable to wind and water erosion. However, increase cost of production due to additional fencing and other protective measures which was rank second with a mean of ($\bar{X}$=3.11) indicates that, open grazing necessitates the implementation of measures to protect crops, such as the construction of fences and other barriers. These protective measures are essential to prevent livestock from accessing and damaging crops.

Furthermore, open grazing as a major threat to crop yields due to direct consumption and trampling of crops by livestock was rank third with a mean of ($\bar{X}$=3.07) this implies that farmers perceive open grazing as a significant threat to crop yields primarily due to the direct consumption and trampling of crops by livestock. When animals graze openly, they can eat young plants and trample over fields, causing physical damage to the crops. This agrees with Nenzhelele *et al.* (2018) who showed that the direct damage to crops by livestock trampling on young plant and compacting soil results in reduced yields and lower overall productivity.

More so, repeated crop damage can threaten the livelihoods of farmers, leading to financial instability with a mean of ($\bar{X}$=3.02) indicates that, the cumulative effect of repeated crop damage due to open grazing can be devastating for farmers. The continuous threat and actual incidents of crop destruction disrupt farming activities and reduce the predictability of harvests. Repeated crop damage threatens the livelihoods of farmers by creating financial instability. Farmers rely on consistent and predictable crop yields to manage their finances, repay loans, and support their families. When crop yields are compromised, it can lead to financial losses, debt accumulation, and in severe cases, threaten the overall viability of the farming operation.

3.3 The effects of open grazing on production activities of arable farmers

The results in **Table 3**; shows the effects of open grazing on production activities of arable farmers in the study area. However, the result shows that, Open grazing can lead to conflicts between livestock and wildlife, potentially affecting biodiversity and crop pollination ($\bar{X}$ =3.26), Livestock can introduce pests and diseases to crops, which can be difficult and costly to manage ($\bar{X}$=3.25), Livestock may compete with crops for water and nutrients, impacting crop growth and yield ($\bar{X}$ =3.17) and Grazing can reduce plant diversity, affecting the overall health of the ecosystem and its services to agriculture ($\bar{X}$=3.12) were rank top four major effects of open grazing on production activities of arable farmers in the study area.

Open grazing can lead to conflicts between livestock and wildlife, potentially affecting biodiversity and crop pollination was rank first among the major effect of open grazing on production activities with a mean of ($\bar{X}$ =3.26) which implies that, open grazing can lead to direct interactions between livestock and wildlife, often resulting in competition for resources and habitat disruption. This interaction can negatively affect biodiversity and the ecological balance of the area.

Table 3: The effects of open grazing activities

Variables	SA (%)	A (%)	D (%)	SD (%)	WM	Rank
Open grazing can lead to conflicts between livestock and wildlife, potentially affecting biodiversity and crop pollination	78(49.7)	55(35.0)	11(7.0)	13(8.3)	3.26	1st
Livestock can introduce pests and diseases to crops, which can be difficult and costly to manage	103(65.6)	12(7.6)	21(13.4)	21(13.4)	3.25	2nd
Livestock may compete with crops for water and nutrients, impacting crop growth and yield	70(44.6)	45(28.7)	42(26.5)	0(0)	3.17	3rd
Grazing can reduce plant diversity, affecting the overall health of the ecosystem and its services to agriculture	60(38.2)	60(38.2)	34(21.7)	3(1.9)	3.12	4th
Crop damage and reduced yields can lead to significant economic losses for farmers, impacting their livelihoods and food security	87(55.4)	14(8.9)	34(21.7)	22(14.0)	3.05	5th
Farmers may reduce fallow periods to prevent grazing, impacting soil recovery and future crop yields	80(51.0)	27(17.2)	21(13.4)	29(18.5)	3.04	6th
Overgrazing can lead to land degradation, reducing the long-term productivity of arable land	57(36.3)	61(38.9)	24(15.3)	15(9.6)	3.01	7th
Manure and urine from livestock can contaminate water sources used for irrigation, affecting crop health	73(46.5)	20(12.7)	41(26.1)	23(14.6)	2.91	8th
Livestock can spread weed seeds through their hooves and manure, leading to increased weed infestations in crop fields	70(44.6)	31(19.7)	20(12.7)	36(22.9)	2.86	9th

Source: Field survey, 2024. SA=strongly agree, A=agree, D=disagree, SD=strongly disagree

The presence of livestock in wildlife habitats can disturb native species, leading to decreased biodiversity. This reduction in biodiversity can impact crop pollination, as many pollinators are wildlife species whose habitats are disrupted by grazing. A decline in pollinator populations can adversely affect crop yields and overall agricultural productivity. Additionally, conflicts between livestock and wildlife can lead to increased predation on livestock, prompting retaliatory actions from farmers that further harm wildlife populations.

Livestock can introduce pests and diseases to crops, which can be difficult and costly to manage was rank second with a mean of ($\bar{X}$=3.25) this implies that, livestock can be carriers of various pests and diseases that can easily transfer to crops. These pests and diseases can spread rapidly, especially in open grazing systems where livestock move freely between different areas. The introduction of pests and diseases to crops can result in significant agricultural challenges. Managing these issues often requires increased use of pesticides and other control measures, which can be both difficult and costly. Bukari and Kuusaana, (2021) also showed that outbreaks of diseases can cause severe crop losses, directly affecting farmers' incomes and food security. More so, avoiding dry season cultivation of crops was rank second with a mean of ($\bar{X}$=3.40) which implies that, avoiding dry season cultivation is a strategy employed by farmers to reduce the risk of crop damage from grazing livestock. During the dry season, grazing resources such as pasture and water become scarce, prompting herders to move their livestock closer to cultivated areas in search of food. The finding of Adesoji and Justin, (2019) also showed that by refraining from planting crops during the dry season, farmers minimize the chances of their fields being grazed upon by livestock. This strategy reduces the likelihood of crop destruction and the resulting economic losses. Help from local leaders to avoid impact of open grazing was rank third with a mean of ($\bar{X}$=3.23) which shows that local leaders play a pivotal role in mediating conflicts and facilitating cooperation between herders and farmers. Their involvement is critical in implementing and enforcing regulations related to grazing activities.

Livestock may compete with crops for water and nutrients, impacting crop growth and yield was rank third with a mean of ($\bar{X}$=3.17) implying that livestock grazing in areas close to crop fields can lead to competition for vital resources such as water and soil nutrients. Both crops and livestock require these resources for growth and productivity. Competition for water and nutrients can adversely affect crop growth and yield. Crops may suffer from reduced access to these essential resources, leading to stunted growth, lower productivity, and poor-quality yields. This competition can be especially severe during periods of drought or in regions with limited water and nutrient availability. This agrees with Ahmed *et al.* (2020) who revealed that farmers may need to invest in additional irrigation and fertilization due to resource competition between herders-farmers conflict, further increasing production costs and potentially leading to resource depletion and environmental degradation.

However, grazing can reduce plant diversity, affecting the overall health of the ecosystem and its services to agriculture with a mean of ($\bar{X}$=3.12) shows that grazing activities can lead to a decrease in plant diversity within the ecosystem. Livestock often prefer certain plant species over others, leading to selective grazing and a reduction in the variety of plant species. Diverse plant communities provide various ecosystem services, such as soil stabilization, water filtration, and habitat for beneficial insects and other organisms. When plant diversity declines, these services are compromised, negatively impacting agricultural productivity and sustainability.

3.4 The effectiveness of coping strategies to open grazing activities

The results in **Table 4** shows the effectiveness of the coping strategies to open grazing activities in

the study area. However, the result shows that, Aids to the victim of herders-farmers conflict to reduce the tendency of reprisal attacks ($\bar{X}$=3.46), Avoid dry season cultivation of crops ($\bar{X}$=3.40), Help from local leaders to avoid impact of open grazing ($\bar{X}$=3.23) and Creation of routes for cattle rearing to prevent trespassing on farmlands ($\bar{X}$=3.11) were rank top four major effective coping strategies to open grazing activities on arable farmers in the study area.

Aids to the victim of herders-farmers conflict to reduce the tendency of reprisal attacks rank first with a mean of ($\bar{X}$=3.46) which shows that, providing aid to victims of herders-farmers conflicts is essential for addressing immediate needs and reducing the likelihood of retaliatory violence. Conflicts between herders and farmers often result in property damage, loss of livelihoods, and injuries or fatalities. Offering support to victims can help rebuild trust and foster peaceful coexistence between herders and farmers. Aid can come in various forms, such as financial compensation, legal assistance, and rehabilitation programs.

By addressing the needs of affected individuals and communities, the risk of reprisal attacks

Table 4: The coping strategies to the problem of open grazing

Effectiveness of the coping strategies	SA (%)	A (%)	D (%)	SD (%)	WM	Rank
Aids to the victim of herders-farmers conflict to reduce the tendency of reprisal attacks	103(65.6)	12(7.6)	21(13.4)	21(13.4)	3.46	1st
Avoid dry season cultivation of crops	107(68.2)	18(11.5)	20(12.7)	12(7.6)	3.40	2nd
Help from local leaders to avoid impact of open grazing	92(58.6)	22(14.0)	31(19.7)	12(7.6)	3.23	3rd
Creation of routes for cattle rearing to prevent trespassing on farmlands	52(33.1)	13(8.3)	48(30.6)	44(28.0)	3.11	4th
Forming of farmers group organizations	73(46.5)	20(12.7)	41(26.1)	23(14.6)	3.10	5th
Orientation of herders and farmers on the need to embrace peace in the practice of grazing and farming	40(25.5)	37(23.6)	65(41.4)	15(9.6)	3.07	6th
Early planting and harvesting	79(50.3)	32(20.4)	21(13.4)	25(15.9)	3.05	7th
Enacting open grazing prohibition law	63(40.1)	21(13.4)	35(22.3)	38(24.2)	2.93	8th
Used of local security agency	45(28.7)	42(26.8)	67(42.7)	3(1.9)	2.82	9th
Establishment of modern ranch for cattle rearing	55(35.0)	28(17.8)	25(15.9)	49(31.2)	2.56	10th

Source: Field survey, 2024. SA=strongly agree, A=agree, D=disagree, SD=strongly disagree

diminishes, promoting stability and cooperation. With the support of local leaders, communities can develop and enforce agreements that delineate grazing areas and farming zones. This helps prevent livestock from straying into crop fields and causing damage. Local leaders can also mediate disputes, provide a platform for dialogue, and promote awareness about sustainable grazing practices. Their influence and authority are instrumental in fostering a sense of community and shared responsibility, leading to more effective management of open grazing activities and enhanced social cohesion.

Furthermore, creation of routes for cattle rearing to prevent trespassing on farmlands with a mean of ($\bar{X}$=3.11) shows that establishing designated routes for cattle rearing is a proactive measure to prevent livestock from trespassing onto farmlands. These routes, also known as cattle corridors or grazing pathways, provide a structured way for herders to move their livestock without encroaching on cultivated areas. The creation of cattle routes helps to clearly separate grazing areas from farmland, reducing the likelihood of conflicts and crop damage. This strategy requires careful planning and collaboration between herders, farmers, and local authorities. It involves mapping out routes, securing the necessary land, and potentially constructing infrastructure such as water points and resting areas for livestock. This agrees with the findings of Adeoye, (2020) who showed that creating livestock pathway reduces conflicts between farmers and herders over resources.

4. Conclusion

The result concludes that there is unfavorable arable farmers' perception on open grazing activities in the study area which shows that farmers are concerned about soil compaction and erosion caused by grazing animals and the need for additional fencing and other protective measures increases production costs as the most farmers' perception on open grazing activities. The result also concludes that, Aids to the victim of herders-farmers conflict to reduce the tendency of reprisal attacks and avoid dry season cultivation of crops were the most effective coping strategies to open grazing activities in the study area. Therefore, it was recommended that arable farmers should be offered financial assistance or subsidies to farmers for the installation of fences and other protective measures. Additionally, provide technical guidance on cost-effective methods to safeguard crops from livestock, reducing the burden of increased production costs and protecting farmers' livelihoods from repeated crop damage.

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Current Innovation in Agriculture Science
Vol. 3, Issue 1, pp. 832-837
Research Article
ISSN (E): 3048-6009

Unlocking tomato potential: Colchicine and seasonal effects on UC-82B variety's growth and yield

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Received: 16 May 2025 | Accepted: 21 December 2025

DOI: https://doi.org/10.65791/cias.79

ABSTRACT

The response of tomato variety (UC-82B) to colchicine and seasonal variations for improved growth and yield related traits was investigated with the aim of inducing variability that could be exploited in the improvement of some quality traits in Tomato. The seed of the tomato variety (UC-82B) was treated with three different concentrations of colchicine (1.0 mM, 1.5 mM, 2.0 mM and 0.0 mM as control). The result indicated that, the interaction makes all the three varieties of tomato to respond more to the mutagenic treatments during the rainy season than the dry season. The interaction showed that, seedlings height, height at maturity and pericarp thickness of the controls have the highest response during the dry season. However, all the mutants treated with 1.0 mM concentration showed highest response in all the selected traits during rainy season except fruit diameter. Similarly, all the 1.5 mM treated mutants showed highest response during rainy season except in leaf area where highest response was found in dry season. Similar result was found in 2.0 mM treated mutants.

KEY WORDS: *Colchicine*; *UC82*; *Rainy season*; *Dry season*; *Mutation.*

1. Introduction

Tomato is one of the most highly praised vegetables consumed widely and it is a major source of vitamins and minerals. It is one of the most popular salad vegetables and is taken with great relish. Tomatoes and tomato products are rich in health related food components as they are good source of carotenoids (lycopene and -carotene), ascorbic acid (vitamin C), vitamin A, vitamin E, folate, flavonoids, minerals, proteins and dietary fibre (Beecher, 2001 ; Davis *et al.*, 2003). Regular consumption of tomatoes has been correlated with a reduce risk of various types of cancer and heart disease. These positive effects are believed to be attributable to the anti-oxidant particularly the carotenoid, flavonoids, ascorbic acid and phenolic compounds Giovanelli *et al.*, 2006.

In Nigeria, especially at the Southern or Western region, tomato production is highly seasonal and mostly weather dependent, which as lead to surfeit during the favorable season and scarcity during

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the unfavorable season. This scenario have caused unfriendly consumer price of this commodities during the off season. The demands for high quality, moderate sized, red colored tomato with high firm fruit, pleasing appearance and good taste is increasing, while grower prefer high yielding, higher weight, indeterminate growth habit and resistance to pest and diseases. The solution to these is to find suitable varieties for growing that will meet the consumer's wants under a controlled environment. Growth, yield and fruit quality performance of tomatoes varieties under controlled environment conditions.

Colchicine is a chemical mutagen and has been one of the most powerful mutagens in crop plants. The mutagenicity is mediated through the production of an organic metabolite of azide compound. This metabolite enters into the nucleus, interacts to DNA and creates point mutation in the genome. Kozgar *et al.*, 2011; Mostafa, (2011). It has also proved its worth as chemical mutagens to induce genetic variability. Thus, this chemical mutagen has become important tool to enhance agronomic traits of crop plants (Khan, 2006).

Presently imported varieties and hybrid tomatoes are introduced into the market; green house vegetable growers use this variety without full knowledge of the performance of these varieties under controlled environment. The main aim of this study was to investigate Response of tomato variety (UC-82B) to colchicine and seasonal variations for improved growth and yield related traits was investigated with the aim of inducing variability that could be exploited in the improvement of some quality traits in Tomato. Findings will help growers overcome the problem associated with varieties at the same time achieving increase in yield with high quality, typical to this agriculture system.

2. Material and Methods

2.1 Study site

The research was conducted in the Green House of the Botanical Garden of the Department of Biological Sciences, Ahmadu Bello University Zaria. (Lat 11° 12' N, Long 7° 37' E, Alt 550-700 m above sea level).

2.2 Sources of the seeds

Seed of the cultivated tomato (UC-82B) was collected from the Institute for Agricultural Research (I.A.R), Ahmadu Bello University Zaria, Nigeria.

2.3 Treatment and experimental design

The treatments used in the research are mutation using various concentrations of colchicine, The seeds of the tomato variety was treated with four different concentrations of Sodium Azide (1.0 mM, 1.5 mM, 2.0 mM and 0.0 mM as control) respectively. The tomato variety used was UC-82B. It flourishes and grows successfully during the dry season. The treated plants were grown in 45 polythene bags arranged in a Completely Randomized Design (CRD) with three repetitions in each season as described in McVoy (2005) protocol.

2.4 Data analysis

All the data collected were analyzed using Analysis of Variance, and the means were separated using Duncan's Multiple Range Test, (DMRT).

3. Results and Discussion

The result of the interaction of concentration with variety and season is presented in the **Table 1**. The result indicated that, the interaction makes all the three varieties of tomato to respond more to the mutagenic treatments during the rainy season than the dry season. The interaction showed that, seedlings height, height at maturity and pericarp thickness of the controls have the highest response during the dry season. However, all the mutants treated with 1.0 mM concentration showed highest response in all the selected traits during rainy season except fruit diameter. Similarly, all the 1.5mM treated mutants showed highest response during rainy season except in leaf area where highest response was found in dry season. Similar result was found in 2.0 mM treated mutants.

The distinct differences observed in most of the quantitative and qualitative traits among the colchicine induced mutants of tomato evaluated showed significant improvements in the selected traits. Although there were few traits with no significant differences in responses to the applied treatments; the ability of the mutants to germinate faster after one and two weeks of planting in respect to the controls showed that the mutagenic treatments induced increase enzymatic activities, which could be responsible for the early germination. This finding is in agreement with the findings of Mensah *et al*. (2007) who reported decreased in germination with increase in the dose of chemical mutagens. In the present investigation, germination, plant heights and leaf number and area decreased with increasing concentration of colchicine. This finding conformed to the earlier report by Ahloowali and Maluszynski (2001) that, the viable mutants observed are mainly dependable measure of genetic effect in mutagen. The increased in the number of leaves, fruit number and plant heights due to colchicine treatments is also in conformity with the work of Adamu and Aliyu (2007) who reported increased in growth and yield parameters of tomato due to colchicine treatments. Reductions in germination percentages and diameter of the fruit due to the effects of mutagens on various crop plants have earlier been documented by Mensah and Akomeah (1997); Mensah *et al*. (2007).

The increased in the leaf area and seedling height among the mutants signifies the ability of the mutagen (colchicine) to initiate more foliar buds. This finding agrees with the work of Maluszynski *et al*. (2001) who independently reported an increase in leaf number and leaf area among *Zea mays* mutants.

More so, the improvement in the growth and yield components of tomato due to colchicine treatments stressed the effect of mutation on the growth and yield of plants. This is in conformity to the work of Adamu *et al*. (2002) when groundnut was treated with gamma rays and Sheeba *et al*. (2005) when gamma rays and EMS were used to treat *Sesamum indicum* L. where seed germination, seedling, survival, plant height and pollen fertility were reduced significantly with an increase in dosage levels of both mutagens. However, in contrast, Sasi *et al*. (2005) showed that all plant mutant types registered lower yields compared to their parents in the study of the effects of diethyl sulphate and EMS on Okra (*Abelmoschus esculentum* L.) var. MDU-1).

The increased in fruit quality, such as pericarp thickness due to induced mutagenesis by colchicine signifies the vital role played by the

Table 1: Effects for interaction of concentration, variety and seasons on some selected tomato traits

Concentration (mM)	Variety	Season	Germination % (2 WAP)	Seedlings Height (cm)	Survival Rate (%)	Height at Maturity (cm)	Number of Leaves	Leaf Area (cm^2)	Number of Fruits	Pericarp Thickness (mm)	Fruit Diameter (cm)	Root DW (g)
0.0	UC	Dry	40.51[a]	22.83[a]	44.29[a]	37.73[a]	15.11[a]	9.83[a]	2.77[a]	0.40[a]	0.39[a]	1.66[a]
	UC	Rainy	40.66[a]	19.44[a]	23.70[a]	30.81[a]	12.44[a]	11.50[a]	1.77[a]	0.30[a]	0.42[a]	2.60[a]
1.0	UC	Dry	83.11[a]	33.07[b]	83.11[a]	55.50[a]	20.33[a]	31.83[a]	9.33[a]	0.28[b]	0.15[a]	3.04[a]
	UC	Rainy	73.70[b]	34.97[a]	62.66[b]	50.35[b]	17.55[b]	30.66[b]	4.77[b]	0.50[a]	0.14[b]	2.90[b]
1.5	UC	Dry	75.77[a]	29.07[b]	73.66[a]	47.31[a]	18.77[a]	25.94[a]	6.22[a]	0.25[b]	0.28[b]	2.77[a]
	UC	Rainy	64.37[b]	29.78[a]	49.92[b]	41.54[b]	16.33[b]	23.33[b]	3.22[b]	0.28[a]	0.30[a]	2.58[b]
2.0	UC	Dry	64.48[a]	27.54[a]	58.88[a]	43.46[a]	17.77[a]	17.72[a]	4.55[a]	0.21[b]	0.36[b]	2.47[a]
	UC	Rainy	53.40[b]	25.66[b]	38.81[b]	38.32[b]	14.33[b]	14.83[b]	2.44[b]	0.32[a]	0.45[a]	2.26[b]

N.B: *[1] Means within the columns with the same letter(s) are not significantly different (P≤0.05)

mutagen in improving the quality traits of tomato. The increased in dry weights of the tomato varieties due to sodium azide treatments is in contrast to the findings of Ikhajiagbe *et al*. (2012). Significant improvements were found among the mutant tomatoes in both the dry and wet seasons.

4. Conclusion

It was concluded that, there is significant difference in the effect of colchicine on the growth and yield components of the tomato variety under study. It was found that 1.0 mM concentration of colchicine has the highest effect. Significant difference was found in the response of the variety UC responding more significantly to colchicine treatment. While variety Roma responds more to grafting treatment.

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Current Innovation in Agriculture Science
Vol. 3, Issue 1, pp. 838-846
Research Article
ISSN (E): 3048-6009

From tuber to energy: Comparing the metabolic profiles and dietary versatility of Tannia (*Xanthosoma sagittifolium*) and Irish potato (*Solanum tuberosum*)

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Received: 11 April 2025 | Accepted: 21 December 2025

DOI: https://doi.org/10.65791/cias.80

ABSTRACT

This study provides a comparative analysis of the metabolic profiles and dietary applications of two significant starchy tubers: Tannia (*Xanthosoma sagittifolium*) and the Irish Potato (*Solanum tuberosum*). While the Irish potato remains a global staple, Tannia - a tropical aroid - offers a distinct nutritional and physiological blueprint that warrants closer examination in the context of food security and metabolic health. By synthesizing these data points, the study highlights Tannia's underutilized potential as a robust, "energy-dense" alternative to the Irish potato, particularly in regions facing climate instability. The findings suggest that diversifying tuber consumption can optimize metabolic outcomes and enhance dietary resilience.

KEY WORDS: *Tannia*; *Irish Potato*; *Metabolic Profiling*; *Glycemic Index*; *Starch Bioavailability*

1. Introduction

The global food landscape is currently dominated by a narrow selection of staple crops, with the Irish potato (*Solanum tuberosum*) ranking as the primary carbohydrate source for a significant portion of the world's population. As the third most important food crop globally, the Irish potato is valued for its high caloric yield and versatility. However, as global health trends shift toward managing metabolic syndromes and Type 2 diabetes, the "quality" of dietary energy has become as important as the quantity. The rapid digestibility of potato starch often leads to significant glycemic spikes, prompting a need to explore alternative tubers with more favorable metabolic profiles. Tannia (*Xanthosoma sagittifolium*), a tropical aroid often categorized as "New Cocoyam," represents a promising yet underutilized resource in this context. While it has been a dietary staple in parts of Africa, Asia, and the Caribbean for centuries, its biochemical potential remains largely untapped on a global scale. Unlike the Irish potato, which thrives in temperate climates, Tannia is highly resilient in tropical environments and acidic soils, offering a strategic solution for food security in the face of climate instability.

Tannia and Irish potato functions as versatile tubers, yet their physical properties dictate different outcomes in the kitchen. Tannia cormels typically possess a higher dry matter content (often exceeding 30%) compared to the 20–24%

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range found in potatoes suitable for processing (Akinlua *et al*., 2016; Boakye *et al*., 2017). When boiled, Tannia maintains a structural integrity that allows it to be used in heavy stews without disintegrating as quickly as many potato varieties. While the Irish potato dominates the global frozen food and fast-food industries, Tannia is increasingly viewed as a "food security crop" with untapped export potential. Its better storability compared to other tropical tubers like cassava makes it an ideal candidate for value-added processing into shelf-stable flours and ready-to-eat snacks, mirroring the industrial trajectory of the potato (Boakye *et al*., 2017). The Ekpang Nkukwo dish highlights the versatility of the entire Tannia plant. Unlike the Irish potato, which has toxic leaves, the leaves of the Tannia are edible and central to this recipe **(**Ukom *et al*., 2020; Tchiégang and Fanni, 2002). Beyond traditional consumption, Tannia has significant potential for industrial exploitation. Its starch properties make it suitable for gluten-free products such as noodles and biscuits catering to the growing market for celiac-safe foods (Winara *et al*., 2022), biodegradable plastics **(**Toto Rusianto *et al*., 2019) and pharmaceuticals **(**Ajala & Silva, 2020).

The versatility of these tubers allows them to be converted into various similar food forms, most notably "French fries" or chips, as well as traditional boiled and pounded forms. The production of French fries from cocoyam is an emerging area of value addition intended to reduce post-harvest losses. The production of French fries and chips is the most common area of direct culinary competition between these two tubers. Research comparing cocoyam strips to Irish potato fries shows that Tannia (particularly the pink variety) is a viable alternative. When blanched at 90°C for 5 minutes and fried at 160°C, cocoyam fries exhibit a crispier outer crust and a denser interior than potato fries (Boakye *et al*., 2017; Akinlua *et al*., 2016). Because of its higher starch density and lower moisture content, Tannia often absorbs less oil during deep-frying than the Irish potato. This results in a product that is perceived as less "greasy" by some consumer panels. While Irish potatoes naturally achieve golden-brown color in fries, the *Colocasia* variety of cocoyam produces a similar light golden brown, whereas Tannia (pink variety) tends to result in a darker golden brown. When processed into frozen strips for fries, both tubers show stability over a 12-week period at −18°C. Sensory evaluations indicate that while the aroma of potato fries is often more familiar to global consumers, the taste and mouth feel of cocoyam fries are frequently rated as highly acceptable, sometimes exceeding potato in specific sensory categories like "sweetness" or "richness (Akinlua *et al*., 2016; Boakye *et al*., 2017). Furthermore, the flavor of the Irish potato is characterized by a mild, earthy, and slightly nutty profile, largely influenced by the presence of methoxy pyrazines (Lewu, and Adebola, 2010). In contrast, Tannia possesses a more pronounced, "earthy-nutty" intensity, often described as richer or more "acrid" if not processed correctly due to the presence of calcium oxalate crystals. In addition, the "sweetness" levels differ. While Irish potatoes can become sweet if stored at low temperatures (due to cold-induced sweetening), Tannia generally maintains a consistent, low-level sweetness that complements savory spices better than the Irish potato, which can sometimes become cloyingly sweet or "watery" in certain recipes (Sefa-Dedeh and Agyir-Sackey, 2002). Moreover, studies on flavor volatiles in tannia have identified a variety of alcohols, aldehydes, and ketones that contribute to its unique "tropical" scent, which is often

described as more "aromatic" or "pungent" than the relatively muted scent of a boiled Irish potato (Chemura *et al*., 2022; Lewu and Adebola, 2010)

In the face of global climate change, cocoyam has emerged as a critical "orphan crop" for food security due to its adaptability (Taylor *et al.*, 2022). Research indicates that Tannia can maintain net CO_2 assimilation even under reduced light conditions, making it an ideal component for multi-strata cropping systems that protect the soil from direct solar radiation and moisture evaporation. One of the primary ways Tannia mitigates climate impacts is through its inherent physiological robustness. Unlike many cereal crops that fail under erratic sunlight and temperature fluctuations, cocoyam exhibits significant shade tolerance. (Valenzuela, 1991). The tree canopy buffers the cocoyam from extreme temperature fluctuations and reduces evapo-transpiration, which is vital as precipitation patterns become more erratic (Taylor *et al*., 2022). Additionally, the crop's ability to produce yield in "marginal lands" where other crops might fail ensures that rural households have a continuous supply of carbohydrates.

The transition from "Tuber to Energy" is governed by the starch architecture within the plant. Preliminary studies suggest that Tannia possesses a distinct advantage over the Irish potato: a higher proportion of Slowly Digestible Starch (SDS) and Resistant Starch (RS) (Englyst and Hudson, 1996). These fractions are crucial because they slow the release of glucose into the bloodstream, providing sustained energy rather than a temporary spike. Furthermore, Tannia is reported to have a superior micronutrient profile, containing higher concentrations of essential minerals such as calcium and magnesium, which are vital for metabolic regulation (Ukom *et al.*, 2022).

Despite these advantages, Tannia's dietary versatility is often hindered by the presence of calcium oxalate crystals, which cause acridity if not properly processed. This research aims to provide a comprehensive comparison between Tannia and the Irish potato, evaluating their metabolic profiles, nutritional densities, and culinary applications. By analyzing how these tubers behave during digestion and food processing, this study seeks to validate Tannia as a functional, energy-dense alternative capable of supporting long-term metabolic health.

2. Material and Methods

2.1 Sample preparation and flour extraction

Fresh samples of Tannia (*Xanthosoma sagittifolium*) and Irish Potato (*Solanum tuberosum*) were sourced, washed, and peeled. To ensure metabolic consistency, tubers were sliced into 2 mm segments and dried in a convective oven at 45°C until a constant weight was achieved. The dried chips were then milled into a fine powder (passing through a 250 µm sieve) to create the substrate for biochemical assays.

2.2 Analysis of starch microstructure and fractions

The starch was isolated using a wet-milling process.

Morphology: Starch granule size and shape were observed using Scanning Electron Microscopy (SEM) at magnifications of 500x and 1000x to determine surface area-to-volume ratios.

Fractionation: Amylose content was determined using the Iodine Binding Method. The ratio of amylose to amylopectin was calculated to predict the degree of starch retrogradation (firming) after cooking.

2.3 *In vitro* starch digestibility (Englyst Method)

To simulate human digestion, 200 mg of each flour sample was incubated with a porcine pancreatic alpha-amylase and amylo glucosidase mixture at 37°C.

RDS and SDS: Aliquots were taken at 20 minutes (Rapidly Digestible Starch) and 120 minutes (Slowly Digestible Starch).

Free Glucose: Glucose release was measured via the Glucose Oxidase Peroxidase (GOPOD) assay.

2.4 Determination of mineral and antinutrient content

Mineral Profiling: Samples were acid-digested and analyzed via Atomic Absorption Spectroscopy (AAS) for Calcium (Ca), Magnesium (Mg), and Potassium (K).

Oxalate Quantitation: Total and soluble oxalates in Tannia - which contribute to its "itchy" acridity - were determined using HPLC to evaluate how different cooking methods (boiling vs. roasting) reduce these metabolic inhibitors.

2.5 Thermal stability (DSC Analysis)

The transition temperatures (To, Tp, Tc) and enthalpy of gelatinization (Delta H) were measured using Differential Scanning Calorimetry (DSC). A sample-to-water ratio of 1:3 was heated from 30°C to 120°C at a rate of 10°C/min to define the tubers' functional limits in industrial food processing.

3. Results and Discussion

Tannia (*Xanthosoma sagittifolium*) and Irish Potato (*Solanum tuberosum*) comparison centers on starch rheology, granule morphology, and postprandial metabolic kinetics. Comparing Tannia and the Irish Potato reveals fascinating differences in how their structural biology dictates their behavior in the kitchen and the bloodstream. While both are staple carbohydrates, their starch profiles are worlds apart. Their classic comparison are as summarized in the table below (**Table 1**).

Table 1: The nutritional challenge between Tannia and Irish Potato

Nutrient (per 100g, raw)	Tannia	Irish Potato
Calories	~128–144 kcal	~74 kcal
Carbohydrates	~29g	~15g
Dietary Fiber	~1.8g	~2.4g
Protein	~1.8g	~1.9g
Starch Type	Small-grain (Easy digest)	Large-grain

The most striking difference is in their energy density. Tannia is denser and contains more complex carbohydrates. It therefore provides a longer-lasting feeling of fullness (satiety) than a standard white potato and nearly double the calories per gram while potatoes higher water content means fewer calories per bite (**Table 1**).

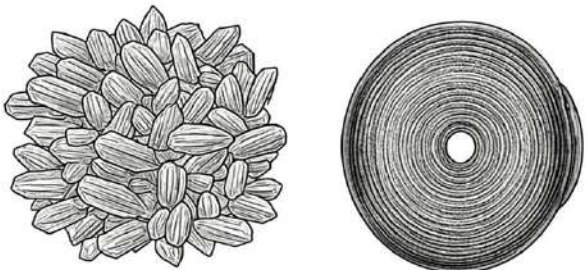
The metabolic profile of Tannia is defined by its high Slowly Digestible Starch (SDS) and Amylose content (Englyst & Hudson, 1996) (**Table 2**). For an athlete that needs a more sustaining, slow-burn energy source, Tannia is a perfect choice.

Physiologically, Tannia provides a "trickle" of glucose into the bloodstream rather than the "flood" associated with Irish potatoes. This makes Tannia a superior dietary choice for managing Type 2 diabetes and metabolic syndrome (Oridupa *et al*., 2017; Facchin *et al*., 2024).

Table 2: Comparative biochemical data: Tannia vs. Irish Potato

Metric	Tannia (*X. sagittifolium*)	Irish potato (*S. tuberosum*)
Amylose Content (%)	26.5 – 29.0	18.0 – 22.6
Rapidly Digestible Starch (RDS, %)	33.0 – 38.0	52.0 – 58.0
Slowly Digestible Starch (SDS, %)	16.0 – 20.0	6.0 – 11.0

Tannia starch (0.5 to 5.0 µm) has high surface-area-to-volume ratio thus, amylolytic enzymes (like salivary and pancreatic alpha-amylase) can hydrolyze the starch much more efficiently compared to Irish potato that contains much larger, oval-to-spherical granules, ranging from 10 to 110 µm (Sefa-Dedeh & Sackey, 2002) (**Fig. 1**). **Fig. 1**, illustrates the key morphological differences between the two starch types. Unlike the Irish potato, which contains larger starch granules that gelatinize at lower temperatures (60-68°C), Tannia's granules are smaller and more resilient (76-81°C) (Xu *et al.*, 2021). **Table 2** presents a "representative" data based on typical values for these tubers, illustrating why Tannia is often categorized as a source of "slow-release" energy compared to the Irish potato. The higher SDS and lower RDS in Tannia provides the scientific basis for claiming it offers a more sustained energy release, which directly counters the insulin spike typically associated with the high RDS content in Irish potatoes.



Tannia Starch Granules (Small, Angular) | Irish Potato Starch Granules (Large, Oval)

Fig. 1: Starch granule morphology: Tannia (small, angular) vs Irish potato (large, oval).

The significantly higher gelatinization temperature of Tannia (**Table 3**) confirms why it holds its shape better in soups, stews and industrial canning compared to the Irish potato, which tends to soften and break down more easily (Xu *et al*., 2021). Results further show that Tannia contains nearly four times the calcium of the Irish potato (**Table 4**). The mineral gap, particularly in calcium, positions Tannia as a functional food rather than just a calorie source. While the Irish potato is a respected source of potassium, Tannia's high magnesium and calcium levels suggest it plays a more significant role in musculoskeletal health (Oridupa *et al.*, 2017; Facchin *et al*., 2024). However, the presence of calcium oxalates in raw Tannia (the "itch" factor) means that metabolic benefits are only fully realized through proper processing - such as boiling, roasting, frying or fermentation - which leaches these antinutrients while preserving mineral integrity.

From a culinary standpoint, the high gelatinization temperature of Tannia translates to structural integrity (**Table 3**). While Irish potatoes often disintegrate into a mash when overcooked, Tannia maintains a firm texture, making it more versatile

for industrial canning, frozen par-boiling, and long-simmering stews. Furthermore, Tannia's ability to be processed into a high-fiber, low-GI flour offers a gluten-free alternative that outperforms potato starch in terms of thickening power and nutritional density (Facchin *et al*., 2024).

Table 3: Gelatinization temperature parameters

Parameter	Tannia Starch	Irish Potato Starch
Onset Temperature (To)	74-76 °C	53-60 °C
Peak Temperature (Tp)	81 °C	59-66 °C
Conclusion Temperature (Tc)	84-86 °C	72-74 °C
Temperature Range (Tc-To)	9-11 °C	10-16 °C

Despite Tannia's rapid enzymatic hydrolysis due to small granule size, it often results in a lower overall glycemic response than the Irish potato. This is attributed to its higher fiber density and the presence of mucilage (a soluble fiber), which slows down the gastric emptying rate and the absorption of glucose in the small intestine (Facchin *et al*., 2024). When these tubers cool after gelatinization, the starch molecules re-align into a crystalline structure. Tannia has a higher rate of retrogradation, meaning it forms Type 3 Resistant Starch (RS3) more efficiently than the Irish potato. This makes cold Tannia a potent functional food for blood glucose management (Xu *et al*., 2021; Ukom *et al*., 2022). Furthermore, the hydro colloidal mucilage in Tannia increases the "bolus viscosity" in the digestive tract creating a physical barrier that interferes with the migration of digestive enzymes to the starch granules. This is the primary reason why Tannia maintains a lower Glycemic Index despite its tiny, "easy-to-digest" starch granules (Xu *et al.*, 2021). In the large intestine, the resistant starch in tannia is fermented by specialized bacteria like *Bifidobacterium* and *Ruminococcus bromii*. The fermentation process produces short-chain fatty acids (SCFAs), including butyrate, acetate, and propionate (Facchin *et al.*, 2024; Ukom *et al*., 2022). Butyrate is particularly important because it serves as the primary energy source for colonocytes and has been associated with anti-inflammatory and gut-protective properties. Propionate, another fermentation product, has been shown to inhibit HMG-CoA reductase, the enzyme responsible for cholesterol synthesis in the liver. This mechanism suggests that Tannia consumption may contribute to improved lipid metabolism and reduced risk of hyperlipidemia. In addition, because of Tannia's slower fermentation rate in the digestive tract, it contributes to improved glucose tolerance not just for the current meal, but for the subsequent meal - a phenomenon less pronounced with the faster-fermenting Irish potato.

Table 4: Mineral comparison of Tannia and Irish potato

Mineral	Tannia (mg/100 g)	Irish Potato (mg/100 g)
Calcium	32–43	7–11
Magnesium	23–32	16–20
Potassium	348–452	398–423
Iron	0.5–1.0	0.2–0.4

Nutritionally, Tannia is the superior "functional fuel," while the Irish potato is the superior "rapid recovery" substrate. For weight loss, the Irish potato is technically "better" because of its lower caloric density while for sustained performance (*e.g*., manual labor, long-distance hiking, or athletics), Tannia is the victor. Its higher starch concentration and mucilage content provide a "slow-release" energy profile that prevents the mid-afternoon "sugar crash" often associated with

high-GI foods like mashed white potatoes (Lewu *et al.*, 2010; Falade and Okafor, 2019; Ubalua, 2016). Tannia is naturally higher in amylopectin and small-grain starch, which tends to retrograde more effectively than the large-grain starch of the Irish potato (Ukom *et al.*, 2022). Because Irish potato has a higher Glycemic Index (GI), frequent consumption of mashed or fried Irish potatoes can lead to Hyperinsulinemia (Akilen *et al.*, 2016; Sagili *et al.*, 2022). This signals the liver to convert excess glucose into fatty acids (Lipogenesis), raising blood triglyceride levels.

4. Conclusion

In conclusion, while the Irish Potato is a global staple for its versatility and Vitamin C content, Tannia is the "Elite Bio-Fuel." Scientifically, Tannia offers the most sophisticated interaction with the human endocrine and digestive systems - acting more like a functional medicine than a simple carbohydrate. Furthermore, Tannia's ability to be processed into a high-fiber, low-GI flour offers a gluten-free alternative that outperforms potato starch in terms of thickening power and nutritional density. Moreover, the transition from ingestion to energy is more efficient in Tannia due to its resistant starch fractions. This supports a shift in dietary guidelines: promoting Tannia not just as a "famine crop" or tropical curiosity, but as a functional staple for the modern, health-conscious consumer. The comparative analysis confirms that while the Irish potato remains a high-yield, rapidly accessible energy source, Tannia offers a superior metabolic profile. Its higher concentration of Slowly Digestible Starch (SDS), resistant starch, and essential minerals like calcium and magnesium positions it as a "functional staple." The study concludes that Tannia provides a more stable energy release curve, making it a critical tool for combating diet-related metabolic disorders. However, a primary barrier to Tannia's global dietary versatility is its calcium oxalate content. To move Tannia from a regional crop to a global staple, food processing policies should prioritize:

- Promoting boiling, roasting, fermentation, or drying techniques that reduce oxalates by up to 90%.
- Developing Tannia-based composite flours for the gluten-free market, capitalizing on its high gelatinization temperature and thickening power.

As climate instability affects traditional potato-growing regions, Tannia's resilience in tropical and subtropical acidic soils offers a strategic advantage. Thus, integrating Tannia into crop rotation cycles can:

- Reduce over-reliance on a single starch (monoculture).
- Support small-scale tropical farmers by elevating Tannia from a "subsistence crop" to a high-value export.

The transition from Tuber to Energy is not merely a caloric exchange but a metabolic process that can be optimized through biodiversity. By embracing the unique starch architecture of Tannia, global food systems can transition toward a model that prioritizes long-term metabolic health over short-term glucose spikes. Finally, the interpretation of the Englyst Method results shows that the Irish potato is a "fast-fuel" source. It's high Rapidly Digestible Starch (RDS) content means that glucose is liberated almost immediately upon ingestion. With the increase in metabolic diseases rise, there is an urgent need for "slow-release" carbohydrate alternatives. Tannia,

a climate-resilient tropical tuber, offers a unique biochemical solution. In contrast, results for Tannia reveal a higher SDS percentage. This is not just a statistical difference - it's a metabolic one. The smaller, angular starch granules of Tannia provide a greater surface-to-volume ratio. The study therefore confirms that Tannia is more than a potato substitute; it is a metabolic upgrade that offers sustained energy and superior nutritional resilience for the 21st century diet.

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