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COMPARATIVE ANALYSIS OF THE NUTRITIONAL POTENTIALS OF SELECTED TUBER PEEL MEALS AS FEED SUPPLEMENTS FOR RUMINANT ANIMALS

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ABSTRACT
The research explores the nutritional potentials of selected tuber peel meals namely Cassava, (*Manihot esculenta)*, Sweet Potato, (*Ipomoea batatas*); and Irish Potato, (*Solanum tuberosum L*,) as sustainable feed supplements for ruminant animals. With the world drifting toward sustainable agriculture to meet the United Nations' 2030 Sustainable Development Goals, the inclusion of agro-industrial by-products such as tuber peel meal is one assured way to advance ruminant productivity with reduced environmental waste. The tuber peels used in this study were collected, processed, and analyzed for their proximate and mineral compositions. The results showed that cassava peel meal (CPM) is energy-dense, with a high crude fiber content; sweet potato peel meal (SPPM) is rich in ether extract; and Irish potato peel meal (IPPM) has the highest crude protein and nitrogen-free extract values. The findings further stated that the selected tuber peels are high in nutrients, fiber, carbohydrates, and minerals and hence nutritionally adequate for supplementing ruminant feeds. These findings project tuber peel meals as cheap and nutritionally adequate supplements in ruminants' diets, especially in dry seasons. The study recommends government support for research funding, machinery, processing, and preservation technologies, to improve tuber peel use in animal feed, thereby reducing production costs, promoting ruminant production, and environmental conservation in the tropics.

Keywords: Feeds, Peels, Ruminants, Sustainable, Tubers.

INTRODUCTION
The increasing global demand for food coupled with the urgency to address environmental challenges, has highlighted the critical need for sustainable agricultural practices which is also aimed at achieving the United Nations' 2030 Sustainable Development Goals (SDGs) (Calicioglu *et al.,* 2019, Khanal, 2024). The global target is to eliminate hunger and poverty by promoting sustainable livestock production; while ensuring a healthy environment. The sustainability of ruminant animal production is hinged on efficient and nutritionally balanced feeding practices that ensure optimal productivity. Tuber peels are abundant in the tropics; with an annual cassava production of 550 million metric tons, yielding 350 MMT waste (Sivamani *et al*.,2018). Nigeria alone discards over 10 tons of cassava peels from 59. 5 million metric tons produced annually (Oghenejoboh *et al*.,2021); and between 25 – 30% of cassava waste is considered feed for livestock while 70 – 75% is wasted, and discarded into nearby bushes and rivers causing a nuisance and pollution to the environment (Coker *et al.,* 2015. One promising solution to enhancing ruminant production is the use of agricultural by-products, particularly tuber peels namely cassava (*Manihot esculenta*), Sweet potato (*Ipomoea batatas*), and Irish potato (*Solanum tuberosum* L) peels, as supplemental feed resources for ruminants. These by-products are nutrient-rich and represent a cost-effective and sustainable alternative to conventional feed ingredients. Studies have shown that cassava peels are energy-dense due to their high starch content, with crude protein levels ranging between 4% and 7%, (Aro *et al*., 2010). Similarly, sweet potato peels are rich in fermentable carbohydrates and moderate crude protein levels, in the range of 5.63% -7.89%, (Coker *et al.,* 2015). Irish potato peel is considered a nutrient-rich feed resource higher in value than some concentrate feeds (Akinsulie *et al*., 2021).

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Despite the significant potential of Cassava, Sweet potato, and Irish potato peels as nutritionally adequate livestock feed supplements, there is still limited information regarding their nutrient value, processing, and preservation. While a small proportion is often fed to ruminant animals in smallholder farms, the greater proportion is usually regarded and discarded as waste, causing environmental nuisance and pollution. Incorporating tuber peels into ruminant diets offers multiple benefits, including reduced feed costs and alignment with circular economy ethics by transforming agricultural waste into a valuable resource, alleviating animal feed scarcity, particularly during dry seasons when grasses are depleted in nutrients. Research has demonstrated that feeding properly processed tuber peels can sustain ruminant productivity without adverse effects on animal health or performance, (Jumare *et al*., 2024). By reducing dependence on conventional feed resources, enhancing resource use efficiency, and minimizing waste; smallholder farmers stand to gain maximally from tuber peel use. This preliminary study examines and compares the nutritional and mineral composition of the different tuber peel meals designated as CPM, SPPM, and IPPM to estimate their potential as ruminant animal feed supplements, especially in extended dry seasons in the tropics.

Plate 1: Women peeling cassava with a view of massive cassava peels discarded as waste.

Credit: D. Dufour (2024), CIRAD: *https://www.cirad.fr/en/cirad-news/news/2024/choosing-new-root-tuber-and-plantain-varieties.*

MATERIALS AND METHODS

Experimental Site

The study was carried out at the Federal University Oye-Ekiti, Ikole campus located between Longitude 5°29′0″E and Latitude 7°48′0″N mainly on the upland zone rising to about 250 meters above the sea level with an average annual rainfall of about 1778mm. The minimum and maximum temperatures during the experimental period were 26.54^{0}C and 34.02^{0}C, respectively.

Sample Collection

Freshly harvested tubers of tropical Cassava peels (*Manihot esculenta*), Sweet Potato Peels (*Ipomoea batatas*) and Irish Potato (*Solanum tuberosum*) tubers were collected from different food processors around the Ikole and Oye environs within Ekiti-State. The tuber peels which were hand-peeled and are about 0.6 – 1.00mm thickness were cleaned under running water to remove sand and dirt. The tuber peel samples were then sorted, thoroughly mixed and rinsed again with distilled water and then airdried on a polythene sheet for seven days, till samples were fully dried, and peels weighing approximately 1kg per sample were collected from each peel type. The cassava, sweet potato, and Irish potato peel samples were then labeled as: CP, SPP, IPP respectively.

Sample Preparation

5 grams of each peel were placed in a pre-weighed crucible. The samples were dried in a hot-air oven at 105°C for 3 to 4 hours until they reached a stable weight. After cooling in a desiccator, the samples were reweighed. The dehydrated samples were ground, cooled, and sieved through a 2 cm

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sieve to make a fine powder. Each peel meal was mixed well to ensure homogeneity and stored in airtight plastic bowls labeled as CPM, SPPM, and IPPM for future chemical analyses.

Sample Analysis

The chemical analysis of samples was conducted in triplicates at the Diagnostic and Nutrition Laboratory, Department of Animal Production and Health, Federal University Oye-Ekiti, Nigeria. The parameters evaluated were moisture, Dry matter (DM), Crude Protein (CP), Crude Fibre (CF), Ether extract (EE), Ash, and Nitrogen Free Extract (NFE) using AOAC standard methods (2010). The gross energy of the feed was calculated with a bomb calorimeter, and mineral analyses of calcium, phosphorus, potassium, sodium, and magnesium were performed using an Atomic Absorption Spectrophotometer (AAS – Model MFAA32ON).

Statistical Analysis:

The data collected were statistically analyzed to calculate the mean and standard error(mean±SE). The differences observed between the control and treated groups were tested for significance by the one-way analysis of variance (ANOVA) The standard deviation and coefficient of variation were also calculated, and where significant differences were found, the Duncan's Multiple Range Test (Duncan, 1955) was used to separate the treatment means. Differences were considered significant at $P<0.05$ level using SPSS version 16 Computer Program (Ridgman, 1990). ANOVA was the preferred choice as it may compare the mean of three or more groups.

RESULTS AND DISCUSSIONS

Cassava Peels (*Manihot esculenta*)

Manihot esculenta, or cassava, is a woody shrub in the Euphorbiaceae family, producing over 250 million tonnes of fresh roots annually. It is the third-largest carbohydrate source in tropical diets, supporting over 500 million people (Howeler *et al.*, 2013). Cassava has sweet and bitter varieties and are cultivated as an annual crop in tropical and subtropical regions for its starchy tuberous root (Bill Gates, 2012). The results of the proximate composition and the minerals recorded in this study are presented in Tables 1 and 2.

The cassava peel, a by-product of root peeling, accounts for 20% of fresh root weight and can be used in fresh, hay, or ensiled animal feeds (FAO, 2001). Cassava peels can serve as roughage and energy feed for ruminants. Cassava peels, abundant and high in energy, are extensively studied tuber by-products, accounting for 5 to 15% of the root (Aro *et al*., 2010). In the tropics, it has been emphasized as a high-energy source for animal feed (Negesse *et al.,* 2009). According to Howeler *et al.*, 2013, cassava peels contain 65–75% carbohydrates, particularly fermentable starch, but are low in protein (2–5%) which aligns with the findings of (CP: 5.28% and NFE: 62.57) from this study. The crude fibre was highest in CPM at 13.14%, which was higher than values observed in the other peel meals; this agrees with Aro *et al.,* (2010) who opined that cassava peel is high in fibre. Cassava peel contains a considerable amount of minerals like K, Mg, P, Na, and Ca as observed in this study, similar reports were also given (Khalil, 2022).

The use of these tropical root crop peels in ruminant diets has been explored, with promising results. Cassava peels have been used as a feed source for ruminants, including cattle, sheep, and goats, for they are inexpensive, readily accessible, and provide a significant source of energy. (Agustin, *et al*., 2020). Cassava peels have been successfully incorporated into silages as an energy source in dairy cows' feeds (Lounglawan *et al.,* 2011). Khalil, (2022) observed improved growth performance and digestibility in sheep fed fermented CPM, emphasizing its potential as an energy source when combined with protein-rich forages. Santos, et al., (2015) recommended that cassava peels be completely substituted for corn in the diets of sheep, as there were no adverse changes in nutrient intake, digestibility, or ruminal parameters when fed.

Despite the nutritional advantages of cassava peels, for a balanced diet, they should be supplemented with protein and micronutrients (Heuzé *et al*., 2016). They however contain cyanogenic glucosides, which can release hydrogen cyanide (HCN), posing a potential toxicity risk. Effective processing methods, such as fermentation, drying, and soaking, have demonstrated a significant

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reduction in HCN levels, as well as in bulkiness and rapid spoilage (Lounglawan *et al*., 2011), and also preserve their nutritive quality.

Sweet Potato Peel (*Ipomoea batatas*)

Sweet potato, a dicot in the Convolvulaceae family, is known for its sweet, starchy tuberous roots (Sarkar, 2022). Numerous cultivars exist in the tropics, with peel colors ranging from cream and white to purple (Ayeleso, 2018). Sweet potato peels are rich in fiber, antioxidants, vitamins, and minerals, benefiting ruminants and enhancing the health and productivity of small ruminants (Akoetey *et al.*, 2017).

The results of the proximate composition and the minerals recorded in this study are presented in Tables 1 and 2. Feeding trials have also reported positive outcomes with sweet potato peel-based diets. Sweet potato peels are useful as a source of energy, as they contain large amounts of readily digestible carbohydrates (Heuzé, 2020) as observed from this study. The crude fibre value observed in this study (5.42%) was higher than the value range of (3.41%, and 3.68%), reported by (Agubosi, 2021) and 1% by (Ibrahim, 2018) but lower than values of (8–10%) reported by (Akoetey *et al*., 2017) making them easily digestible and suitable for small ruminants with high energy demands. The sweet potatoes contain high levels of fiber, vitamins with most of the fiber content mainly comes from the peel (Marconato *et al*., 2020). (Akoetey *et al*., (2017) opined that protein in the tuber is unevenly spread, with more in the outer layer near the peel depending on the methods of peeling. The crude protein value observed for the SPPM in this study (6.65%) was within the range of what was published for differently processed sweet potato peels (7.89%, 5.63%) by Agubosi, (2021). Values lower than what was reported by Agubosi, (2021) was observed for calcium (2.2g/kg DM) and magnesium (1.17(g/kg DM) in this study.

Sweet potato peels are high in energy, fibre, and cause improved feed intake in ruminants. Feeding trials by Aruna *et al*. (2020) demonstrated improved growth rates and milk production in sheep-fed sweet potato peel-based diets. He further opined that sweet potato peels are protein-rich as also observed in this study; and that they lack significant anti-nutritional factors, making them good for ruminant diets. Okoruwa and Bamgboye (2015) reported sweet potato peels as a valuable animal feed resource which when fed with other supplements improved and enhanced growth indices in goats. Potato peel is a notable food waste that can serve as an alternative animal feed, as it provides natural sources of energy and fiber along with moderate protein content. (Ncobela, *et al.,* 2017).

Irish Potato Peel (*Solanum tuberosum* L)

Solanum tuberosum L, the Irish potato, is a key global staple food and a perennial tuber in the Solanaceae family (Maiti and Singh, 2022). Potato waste is estimated at 12 million tonnes globally, and this peel waste contains significant starch, cellulose, hemicelluloses, and fermentable sugars (Mridula and Mahendra, 2018). The results of the proximate composition and the minerals recorded in this study are presented in Tables 1 and 2

According to (Mridula and Mahendra, 2018), IPPM contains 1.7% protein and 2.5% crude fibre which were lower than values of 8.21 CP and 3.93% CF observed in this study. Kpanja *et al.,* 2024 reported an ash content of 7.11 which was higher than the 5.55 observed in this study while the NFE reported (74.02) was also higher than the value of (71.03%) in Irish potato peels evaluated in this study.

Irish potato peels are rich in minerals, Akinsulie *et al*., (2021) reported 0.12% Mg, 0.10% Ca, 0.05% Na, 0.27% K, and 0.25% P, for the Irish potato peels evaluated, while values observed from this study are 1.53% Mg, 0.81% Ca, 0.34% Na, showing higher values. Cozma *et al*. (2024) reported 7.00 mg/100 g Na, 414 mg/100 g K, 6.76 mg/100 g Ca, and 20.40 mg/100 g Mg values for the Irish potato peels assessed; higher values were observed in this study. Previous reports indicated that feeding Red Sokoto bucks varying levels of Irish potato peels leads to increased weight gain and reduced costs (Yashim, 2017).

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Table 1: Proximate Composition of Selected Tuber Peel Meals

PARAMETERS (% DM)	CPM	SPPM	IPPM	SEM
Dry Matter (% as fed)	88.16	85.84	89.23	2
Crude Protein	5.28^{c}	6.65^{b}	8.21^{a}	0.3
Crude Fibre	13.14^{a}	5.42^{b}	3.93^{b}	0.6
Ether Extract	1.46^{b}	3.49^{a}	0.57^{c}	0.1
Ash	5.71^{a}	4.41^{b}	5.5^{a}	0.3
Nitrogen Free Extract	62.57^{ab}	65.88^{a}	71.03^{a}	2.2
Gross Energy (MJ/Kg Dm)	18.95^{a}	16.64^{ab}	17.7^{a}	0.6

CPM: Cassava Peel Meal, SPPM: Sweet Potatoes Peel Meal, IPPM: Irish Potato Peel Meal
a, b, c, d, e Means along the same row with different superscripts are significantly different (P<0.05).
SEM = Standard error of the mean.

Table 2: Mineral Composition of Selected Tuber Peel Meals

MINERALS (g/kg DM)	CPM	SPPM	IPPM	SEM
CALCIUM	4.31^{a}	2.2^{b}	0.81^{c}	0.22
POTASSIUM	7.14^{c}	10.5^{b}	26.4^{a}	0.64
PHOSPHORUS	0.78^{c}	1.71^{b}	2.8^{a}	0.13
MAGNESIUM	1.14	1.17	1.53	0.17
SODIUM	1.42^{b}	5.88^{a}	0.34^{c}	0.83

CPM: Cassava Peel Meal, SPPM: Sweet Potatoes Peel Meal, IPPM: Irish Potato Peel Meal
a, b, c, d, e Means along the same row with different superscripts are significantly different (P<0.05).
SEM = Standard error of the mean.

CONCLUSIONS AND RECOMMENDATIONS

The findings of this study underscore the nutritional variability among the three types of tuber peel meals. CPM exhibits the highest crude fiber content, while IPPM is noted for its superior crude protein and nitrogen-free extract values. Additionally, SPPM is characterized by a comparatively high ether extract content. The gross energy analysis indicates that CPM is the most energy-dense option among the three. These compositional variations emphasize the importance of adequate evaluation and balancing in formulating ruminant diets. The distinct nutrient profiles of the tuber peel meals suggest that, despite their differences, all can contribute to dietary fiber and energy when processed correctly. Discrepancies with previous studies may arise from variations in soil type, cultivars, growth locales, processing, and preservation methods employed. The examined tuber peels can be processed and preserved as peel meals, thereby mitigating environmental pollution and addressing the rising demand for cost-effective and nutritionally adequate feed supplements for ruminants, particularly during dry seasons. Further studies to compare the effect of feeding the different tuber peels to ruminants could be carried out.

The government could fund research on value addition to tuber peels and provide an enabling investment environment. Modern processing technologies and equipment should be provided to smallholder farmers as subsidies or cooperative loans to encourage effective processing. Tuber peels could be used for biofuel production, aiding energy supply to the tropics. Extension agents should educate farmers on the nutritional importance of tuber peels and processing methods to increase shelf life. Additionally, tuber peels could be processed into pellets and feed meals to enhance accessibility for ruminants' feeding.

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LEVEL OF ADOPTION OF IMPROVED POST-HARVEST TECHNOLOGIES FOR RICE PROCESSING AMONG WOMEN RICE PROCESSORS IN NIGER STATE, NIGERIA

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ABSTRACT
The study examined the level of adoption of improved post-harvest technologies for rice processing among women rice processors in Niger State, Nigeria. Multi-stage purposive and random sampling procedures were adopted in selecting 424 women rice processors for the study. Data were collected through questionnaire and focus group discussion and analysed using frequency, percentage, mean, ranking and standard deviation. The mean ages and household sizes of the adopters and non-adopters were 36 and 41 years, and 6 to 7 persons per household, respectively. The results also revealed that majority (86% and 98%) had gone through different educational courses. Most (97% and 93%) and majority (86%) had mean scores of 2.925, 2.901, and 2.778 for using false bottom for rice steaming, packaging materials and rice mill technologies while 34% and 20% had primary school certificates, with a mean 9 and 7 years of rice processing experience and 5 and 3 years of membership in cooperative societies, respectively. A significant proportion of 64% and 50% received credits of ₦200000-299000 and ₦100000-199000, with mean values of ₦200605 and ₦92357.14. Additionally, mean scores of 3.156, 2.778, 2.925, and 2.901 were recorded for various technologies, indicating a high level of adoption. The results further revealed that experience in rice processing and household size were significant ($P<0.01$) in influencing the level of adoption of IPhTRP. Also, contact with extension agents and access to market were significant ($P<0.05$) in influencing the level of adoption of IPhTRP. However, several key issues: inadequate funding, perceived ineffectiveness of the technology, and low demand for processed rice, all of which hinder adoption. The Study concluded that experience in rice processing, household size, extension contact and access to the market were the significant factors influencing the level of adoption of IPhTRP. It also resulted in advanced skills, the drivers of rice processing quality, increased income, changes in spending habits, and reduced physical exertion of the women rice processors. The study recommends that both government and non-governmental organisations train women rice processors, ensure fair paddy prices, establish a stable market for processed rice, and provide ongoing support through extension agents.

Keywords: Adoption, Post-Harvest, Technologies, Rice, Processing, Women

INTRODUCTION
Agriculture plays a crucial role in Nigeria's economy, similar to other developing countries. According to Qu *et al.* (2021), developing countries suffer more food losses than food waste. The reduction in income due to food losses is a great threat to farm livelihoods in these countries that are already on the verge of food insecurity. Nigeria has an estimated population of over 237.8 million people (Worldometer, 2025) to feed, so the need for food security, sustainability and research on agricultural activities become vital. According to the Food and Agriculture Organization of the United Nations (FAO), food production will have to increase by 70% to feed the world's projected 9.1 billion population by 2050 (FAO, as cited in Qu *et al.,* 2021).

Rice production and processing account for over 40% of the gross domestic product (GDP) (National Bureau of Statistics [NBS], 2019). Rice is a vital food crop for Nigeria's economy. However, domestic production does not suffice to meet the growing demand, leading to substantial imports of over 2,000,000 metric tonnes each year (Organisation for Economic Co-operation and Development (OECD) and FAO, 2021). According to Uduma *et al.* (2016), the increasing demand for rice in Nigeria can be attributed in part to the growing population, rising income, rapid urbanization and

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changes in family occupational structures. In Niger State, women play a vital role in the rice value chain, particularly in post-harvest processing (Danbaba *et al.,* 2019). According to Aminu and Ogunlade (2018), women rice processors are faced with challenges in accessing improved rice processing technology. Also, this has impacted their livelihoods, drudgery and time-consuming nature, traditional rice processing technologies do not offer significant improvement or efficiency in processing capacity, leading to reduced rice quality such as broken grains, impurities, and low grain integrity, exposure to dust, fumes, and stones. Additionally, this affects consumer acceptability and the women processors' income. Due to these problems, the efforts of the women rice processors were supported with a set of IPhT4RP such as rice parboilers, destoning sieves, stitching machines, weighing scales, drying slabs, rice mills, and packaging materials to enhance high-quality stone-free rice to serve both domestic and foreign markets (Danbaba *et al.,* 2013).

It was 'expected' that each group of women rice processors would use the equipment and continue to apply the technologies learned to produce better-quality rice to supply the domestic and foreign markets' demands. Aside from the equipment, special presidential committees on quality rice processing were set in motion to facilitate the training of women rice processors on the use of IPhTRP in their various communities to enhance the quality of rice processed locally (Federal Ministry of Agriculture and Rural Development (FMARD), 2016). Despite all these interventions, there was no significant change as expected in the quality of rice processed locally among these women rice processor groups in Niger State. There is scanty empirical evidence of the IPhT4RP impact on their livelihood. Also, the preference for imported rice did not stop (FMARD, 2016). Furthermore, no sufficient document on the level of adoption of the IPhTRP disseminated to show the sustainability and reduction in the losses and increased income (Qu *et al.,* 2021). Reducing food losses in developing countries is more urgent. Therefore, against this background, the study assesses the level of adoption of IPhTRP among the women in Niger State, Nigeria. The specific objectives of the study are to:

(i) describe the socio-economic characteristics of the women rice processors in the study area;
(ii) ascertain the institutional and technological factors that affect the level of adoption of IPhTRP;
(iii) evaluate the level of adoption of the IPhTRP by the women; and
(iv) constraints faced by the women rice processors in the use of IPhTRP.

METHODOLOGY

Study Area

This study was conducted in the Niger State of Nigeria, which lies appropriately on longitudes 5.5° 98' and 3° E and latitudes 9.9° 30' and 9° N in the North central geopolitical zone of Nigeria. Niger State occupies about 76,363 square kilometres (29,484 sq mi) of land mass, with a population of 6,783,300, as documented (National Bureau of Statistics (NBS), 2024).

Sampling of Data Collection

The population of the study included women rice processors across the three agroecological zones (1, 2, and 3) in Niger State. A multistage random sampling procedure was used in collecting primary data from 424 women rice processors from rice processing cooperative societies.

Method of Data Collection

The survey instrument used for data collection was a structured questionnaire administered as an interview schedule to elicit information from the women. It was augmented using key informant interviews scheduled for some NCRI staff to elicit more detailed information and views of the experts.

Method of Data Analysis

The data for the study were analysed using descriptive statistics and inferential statistics, such as frequency, table, chart, percentage, mean score, graphical illustration, multiple regression and thermatic analysis to achieve specific objectives. The perception analysis on the level of adoption of IPhT4RP was used to draw inferences of the women rice processors' view and were then categorized as follows: 1.00-1.49 = Non-adopters; 1.50-2.49 = Least adopters; 2.50-3.49 = Moderate adopters;

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3.50-4.49 = High adopters and 4.50-5.00 = Very High adopters. And, were measured through a 5-point Likert-type scale as applicable to this study and the mean was tabulated and presented.

RESULTS AND DISCUSSION

Socio-economic Profile of the Women (Adopters and Non-adopters)

The results presented in Table 1 showed that more than half (52.07%) and about a quarter (33%) of the adopters and non-adopters were within the ages of 30–39 years. The mean ages for adopters and non-adopters of IPhTRP were 36 and 41 years, respectively. This indicated that the women rice processors were generally in their active prime years in the study areas. When women rice processors are young, they are more likely to be efficient in labour-tasking jobs such as rice processing, packaging, storage, and marketing. This finding is in agreement with Tsado *et al.* (2014), who reported that women involved in rice farming had received training on improved rice processing technologies.

The results revealed that about 34% and 20% of adopters and non-adopters had a primary school, while 18% and only 4% of adopters and non-adopters attained secondary education, respectively. Only 1% of the non-adopters had tertiary education, while 5% of the adopters had tertiary education. This finding indicated that adopters and non-adopters were literate and had different levels of education. This suggests younger women with formal education are more likely to adopt new technologies due to their openness to innovation and improved access to information, indicating that adopters have received some level of formal education (secondary or higher) than non-adopters, which means they are more likely to access information about new technologies and understand their benefits. This finding is in line with a study by Tsado *et al.* (2014), and Halliru *et al.* (2021), which reported that the majority of women had received some form of education.

Table 1: Socio-economic Characteristics of Adopters and Non-adopters of IPhT4RP

Variable	**Adopters**		**Non-adopters**	
	Freq.	**Per cent**	**Freq.**	**Per cent**
Age category				
20-29yrs	34	16	12	6
30-39yrs	110	52	71	33
40-49yrs	60	28	97	46
50-59yrs	4	2	25	12
60≥	3	1	7	3
Total	**212**	**100**	**212**	**100**
Mean	**36**		**41**	
Std. dev	**6.400**		**8.344**	
Educational status				
Adult education	34	16	98	46
Primary school	42	20	72	34
Qur'anic	86	41	31	15
Secondary	38	18	9	4
Tertiary	11	5	2	1
Total	**212**	**100**	**212**	**100**
Years of experience				
1-5yrs	56	27	85	40
6-10yrs	96	45	109	51
11-15yrs	37	18	11	5
16≥ yrs	23	11	7	3
Total	**212**	**100**	**212**	**100**
Mean	**9**		**6**	
Std. dev	**5.950**		**2.509**	

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Institutional Influence on the Women Rice Processors (Adopters and Non-adopters)

The results in Table 2, show that the majority (91%) of adopters were members of cooperative societies, while only 9% of non-adopters do not belong to any of these societies. Of the 192 and 10 adopters and non-adopters who were members of cooperative societies, a proportion of 48% and a large portion of 70% of the adopters and non-adopters had 5-8 years and 1-4 years of membership in cooperative societies, respectively, with a mean of 5 and 3 years. This implied that cooperative membership can provide access to pooled resources, bulk discounts on inputs and equipment, collective bargaining power, knowledge sharing, training, and technical assistance for new technologies like rice processing. This finding is in variance with Chukwu *et al.* (2016), who reported that the majority (70.42%) did not belong to any cooperative society, whereas a few (29.58%) were members of a cooperative society.

Furthermore, the results in Table 2, indicated that (81%) and (10%) of adopters and non-adopters of IPhTRP had access to extension agents, respectively. Of the 171 and 21 adopters and non-adopters who had access to extension agents, a large portion (89% and 95%) of the adopters and non-adopters) were visited 1-3 times by extension agents, with a mean of 2 years, respectively. This suggests that regular interaction with extension services can significantly influence adoption decisions, providing crucial information and guidance that non-adopters may miss. This finding is in disagreement with the findings of Chukwu *et al.* (2016), who observed that 49.58 per cent of the respondents could not have frequent access to extension services, whereas a few (10 per cent) had frequent access to extension services.

Table 2: Distribution of Adopters and Non-adopters of IPhT4RP based on Institutional Characteristics

Variable	**Adopters**		**Non-adopters**	
	Freq.	**Per cent**	**Freq.**	**Per cent**
Cooperative society				
Yes	192	91	10	5
No	20	9	202	95
Total	**212**	**100**	**212**	**100**
Years of Membership				
1-4 years	79	41	7	70
5-8 years	93	48	3	30
11 years and above	20	10		
Total	**192**	**100**	**10**	**100**
Mean	**5**		**3**	
Std. dev.	**1.749**		**1.449**	
Extension contacts				
Yes	171	81	21	10
No	41	19	191	90
Total	**212**	**100**	**212**	**100**
Number of contacts				
1-3 times	152	89	20	95
4-6 times	19	11	1	5
Total	**171**	**100**	**21**	**100**
Mean	**2**		**2**	
Std. dev.	**0.857**		**0.814**	

Level of Adoption of the Improved Post-harvest Technologies for Rice Processing

Results on adoption in Table 3, showed there were disparities in the adoption of IPhT4RP between the women rice processors within and outside the study communities, based on the perception index range, with an average total mean score (x =4.9) found generally for level of

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adoption. The mean score (x =1.1) was obtained for the destoner, (x = 0.9) for the concrete dry slab, (x =0.8) for the False bottom, (x =0.5) for the stitching machine, (x =0.5) for weighing scale, (x =0.4) for package machine, (x = 0.3) for tarpaulin, while (x = 0.4) for rice milling machine were found always used respectively. The reported statement shows that, generally, both women rice processors have experienced some level of adoption of the IPhT4RP as indicated, based on the index score range (x =4.9) and were profound high adopters in the study areas. Also, it implied that the level of adoption of the IPhT4RP was based on the relative advantages of technologies introduced to the women rice processors in the study areas. This is contrary to the study of Ojo *et al.* (2018), who reported a relatively low level of adoption of rice processing technologies among rice processors in Ekiti State, Nigeria. The implication is that the adoption of IPhT4RP could translate to an increase in the quantity and purity of locally processed rice, which invariably will bring about more adoption of the technologies respectively; in the study areas.

Table 3: Distribution of Women based on Technology Adoption in Rice Processing (pooled data) =424

Improve post-harvest technologies for rice	**Weighted scores**			
	Always	**Never**	**Sometimes**	**Mean score**
False bottom	158	116	64	0.8
Destoner	100	69	47	0.5
Stitching machine	258	185	41	1.1
Weighing scale	100	88	42	0.5
Packaging materials	100	56	34	0.4
Concrete drying slab	200	143	27	0.9
Tarpaulin	100	18	17	0.3
Rice milling machine	100	29	26	0.4
Average total mean score				**4.9**

Factors Affecting Adoption Level of Improved Post-Harvest Technologies for Rice Processing among Women Rice Processors

The results of the Multiple regression presented in Table 4, showed that household size, experience in rice processing, extension contacts, access to markets, and technology accessibility are statistically significant (P<0.01) and (P<0.05), respectively. The result showed that the years of experience in rice processing were directly related to the level of adoption and was significant (P<0.05). The implication is that an experienced woman rice processor is more likely to be interested in the adoption of IPhTRP than someone with fewer years of experience. The results also revealed that household size was positive and significant (P<0.01) on the adoption of IPhTRP. This implied that effective household sizes could serve as a substitute for hiring labour to utilise the IPhTRP. The findings agree with the study by Sodjinou *et al.* (2015), who reported positive and significant effects of household size on the adoption of improved technology. This also corroborates the results of Awoyemi and Aderinoye-Abdulwahab (2019), who found that large family sizes are a feature of most rural settings in developing countries and signify the possibility of family labour use. The result also showed that extension contact was positive and significant (P<0.05) in influencing the level of adoption of the IPhTRP. This implied that extension contact is a crucial factor that promotes adoption. A similar outcome was also found by Adeogun *et al.* (2008), and Adeniji (2002), which enhanced the level of adoption among women in the study area. Results show the coefficient of access to markets (-2.643) was negatively related to the adoption of improved postharvest technologies for rice processing and was significant at (P<0.05). This implies that access to markets has a direct effect to influence the adoption of IPhT4RP.

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Table 4: Factors Influencing the level of Adoption of Improved Post-harvest Rice Processing Technologies

Variables	Coefficient	Std. Err	T-value	P>|t|
Age	0.28579	0.76187	0.38	0.708
Educational level	0.11011	0.87732	0.13	0.900
Marital status	-0.92997	0.78761	-1.18	0.239
Experience in rice processing	-2.06837**	0.85695	-2.41	0.016
Household size	2.58474***	0.86990	2.97	0.003
Extension contacts	1.98739**	0.96987	2.05	0.041
Access to credit	0.07774	0.84154	0.09	0.926
Membership of association	0.42833	1.14741	0.37	0.709
Access to markets	-2.64370**	1.32231	-2.00	0.047
Technology affordability	0.23789	1.37837	0.17	0.063
Technology accessibility	2.65839	1.34125	1.98	0.048
Technology durability	-0.45040	1.37155	-0.33	0.743
Technology usability	0.19324	1.01064	0.19	0.849
_cons	13.65433	0.80007	17.07	0.000
Prob > F	0.0005			
R-squared	0.7190			
Adj R-squared	0.6911			

***Note:** *, **, *** represent significant at 10%, 5% and 1% levels of significance*

Constraints to IPhT4RP Adoption Faced by the Women in the Study Area

In conclusion, the barriers identified in this study underscore significant impediments to the successful adoption of Improved Post-Harvest Technology for Rice Processing (IPhTRP) by women rice processors. The overwhelming accord among the women emphasized issues such as inadequate funding, perceived ineffectiveness of the technology, and low demand for processed rice, which collectively contribute to a challenging scenario for adoption. Additionally, inadequate training and technical support further exacerbates these difficulties, leaving many of the studied women unprepared to implement and benefit from the advancements offered by the IPhTRP. The findings further clarify a critical need for targeted interventions that address not only financial support but also the improvement of the technology itself to enhance its applicability and effectiveness. Moreover, increasing the demand for processed rice through strategic market initiatives could create more favourable conditions for adoption. It implies that the acknowledgement of poorer quality paddy in remote areas as a significant barrier also calls for initiatives that ensure better access to quality inputs. In due course, addressing these multifaceted challenges is vital in empowering women rice processors, thereby enhancing their economic independence and improving their overall quality of life. The implication is that, sustainable solutions that integrate training, financial support, and market access to unlock the potential of women in this sector will foster a more equitable agricultural system.

Table 5: Constraints to the Adoption of IPTRP

Perceived constraints	Percentage	Rank
Insufficient funds for business	97.14	1st
Inadequacy of the IPhTRP	81.43	2nd
Low demand for rice-processed	62.86	3rd
Inadequate training/ technical support	57.14	4th
Inadequate subsidies on the IPhT4RP in remote areas	54.29	5th
Inadequate and low-quality of paddy	54.29	5th
Low level of education	52.86	7th
High cost of rice processing machines	34.29	8th
Inadequate extension contacts and advisory services	31.43	9th
Cultural/ norms barriers	0.00	10th

CONCLUSION AND RECOMMENDATIONS

The study' concluded experience in rice processing, household size, extension contact and access to market were the significant factors influencing the adoption of improved post-harvest technologies for rice processing among female rice processors in the study area. Also, the skills of the women rice processors were enhanced, rice processing quality improve, and workload reduce using the IPhTRP. However, some challenges persist including inadequate funding, ineffective implementation of the IPhT4RP, and low demand for processed rice.

Strategically, to overcome these impediments recommendations were made.

i. Both non-government and government organizations prioritize training and capacity building for women rice processors.
ii. Non-government and government organizations should facilitate access to fair prices for paddy and create a stable market for processed rice.
iii. Extension agents should also provide regular follow-ups and technical support to address any challenges that may arise after adoption of technologies.

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THE PERCEPTION OF SUPPLY CHAIN ACTORS ON FACTORS THAT DETERMINE FRESH TOMATO SUPPLY IN BAUCHI STATE, NIGERIA

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ABSTRACT
The study was carried out to examine the determinants of fresh tomato supply in Bauchi State, Nigeria. A multistage sampling technique was used to select 301 producers, 105 wholesalers, 252 retailers and 150 consumer making a total of 808 Supply Chain Actors (SCA) for the study. Data were collected using structured questionnaire and analysed using descriptive statistics. The result reveals that 76.7%, 78.2%, 76.5% and 78.6% of the producers, wholesalers, retailers and consumers to be between the age category of 21-50 years old. Further, the result shows a mean age of 40 years old for the SCA in all the zones. The result reveals that consumers in all the zones agree that all the stated factors were determinants of fresh tomato supply (mean = 3.07 to 4.95). However, they disagree on packaging, and organic products as a determinants of fresh tomato supply. Price of tomato, seasonality and sorted tomato mean = 2.58, 1.23 and 2.93 respectively, were not considered as determinants by the wholesalers. All factors stated were regarded as determinants of supply by the retailers. While consumers disagree with packaging (mean = 1.67) and organic (mean = 1.67) as determinants of supply. It is concluded that all the SCA in Bauchi State agree and disagree on some factors as the determinants of fresh tomato supply. Therefore, the study recommends that Supply chain actors particularly producers and marketers of fresh tomato should look into the factors considered by the consumers as obstacles to the supply of tomato and improve on them so as to increase its consumption and in return increase their profit. Also, using the appropriate technologies, producers should be able to produce tomato with desired qualities that will attract consumers.

Keywords: Actors, Chain, Determinants, Tomato, Supply, Perception

INTRODUCTION
Agriculture in Nigeria is the main source of food and raw material for the nation's economy and it also provides job opportunities to many of its citizens both directly and indirectly. The sector also has exports earning potentials that could assist in the expansion of foreign exchange earnings of the country.

Tomato originated from South America (Aja, 2012). It is introduced into West Africa by Portuguese traders and freed slaves from West Indies (Tindal, 1988). Tomato is a short duration crop and it gives high yield, especially when high yielding varieties under improved production technology is adopted (MINFAL, 2013). According to FAO (2011), tomato production has increased throughout the world. About 125.5 MTs were produced in 2012. China, the largest producer, accounted for one quarter of the global output followed by United States and India. Nigeria ranked second largest in Africa and thirteenth largest in the world producing 1.8 million tonnes of fresh fruits of tomato annually, with national demand of about 2.3 million MTs annually and a demand gap of about 500,000 Metric tonnes. An annual total area of one million hectares is reportedly used for tomato cultivation with an annual average of 25-30 tonnes per hectares (Charity, 2015).

Tomato is a major food component used mostly by Nigerians and also the most widely used vegetable in the World (Usman and Bakari, 2013 and Sanaullah *et al*., 2015). Also, tomato has been ranked as the highest vegetable product in terms of consumption (Shettima *et al.,* 2016). It contains high moisture content in their fresh forms, they are rich in vitamins A, B, C, D, E and K it is also rich in Potassium, a mineral most of us do not get enough of (John *et al.*, 2010; and Debjit *et al.*, 2012). It

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helps in the fight against cancerous cell formation as well as other health complications. It reduces the risk of cancers of the mouth, stomach oesophagus, prostate, pancreatic, breast cancer, cervical, colon and rectal (Osemwegie, *et al.*, 2010).

As a result of the growing population, the per capita consumption of tomato on world average has increased from 7.5kg to 20.5kg/annum/capita. The availability of tomato and prices differ from season to season. The production and marketing of tomato serve as source of employment and food to producing and marketing families as well as to its consumers. Hence, its importance includes its nutritional and economical value (Oladapo *et al*., 2011). Tomato Vegetables are therefore of great value to human development (Kalidas *et al.,* 2014). Fruits and vegetables constitute about 25% of the major food crops cultivated in the country (Shuaibu and Mohammed, 2015).

However, the amount of a commodity purchase or offered for sale in a given market and in a given time is determined by some factors (Panda, 2013). Tianyi (2013) reported these factors as follows:- price of the good, price of factors of production, number of sellers technology, future expectations as factors affecting supply while on the other hand listed factors affecting demand as price of the good, price of substitute, population among others. Reem (2016) said supply and demand is perhaps one of the most fundamental concepts of economics. These two concepts operate on individual laws. Demand refers to the quantity of a good that is desired by buyers and supply is defined as the total quantity of a product or service that the market place can offer. These concepts, demand and supply are governed by just one condition and that is holding all other factors (such as those listed above) constant, and allow price to be the only determinant of the quantity demanded and or supplied and vice versa (Reem, 2016). Fresh tomato in Nigeria is very scarce and expensive particularly during its off season (May to September). Today, it has become a cash crop even in the production areas like the northern part of the country. Hence, consumers resort to other forms of tomato like the processed types such as canned, sachet, and dry tomato. Pumpkin are also use in place of fresh tomato in some parts of Northern of Nigeria.

METHODOLOGY

Study Area

Bauchi state as the study area, is one of the thirty six states of Nigeria and was created in 1976.The state is boarded by Taraba and Plateau state to the south, Gombe and Yobe to the East, Kano and Jigawa to the North and Kaduna in the west (BSG, 2011) Bauchi State is divided into three agricultural zones namely: Northern, Central and Western zones. The state is made up of twenty local government areas which are Bauchi, Kirfi, Alkaleri, Toro, Dass, Tafawa-Balewa, and Bogoro in the Western Zone; Zaki, Itas-Gadau, Gamawa, Jama'are, Katagum, Dambam, Giade, Shira and Misau in the Northern zone, and Darazo, Warji, Ningi and Ganjuwa are in the central zone. Bauchi state is located in the Northern Guinea Savannah Ecological zone of Nigeria. It lies between latitude 9° 3' and 12° 3' North of the equator and longitudes 8° 50' and 11°East of the Greenwich Meridian. Bauchi state occupies a total land area of 49,119km^2 representing about 15% of the Nigerian's total land mass (BSADP, 2015). The state has an estimated population of 4,889,811.2 (NBS, 2016). Majority of the inhabitants are Geremawa, Hausa Fulani, Sayawa, Jarawa and others. Most (80%) of the farmers of Bauchi State are predominantly subsistence farmers. The farmers in the state practice both dry and rainy seasons farming. They produce vegetables such as tomato, pepper, okra, lettuce, cabbage, amaranth among others. Other major crops produced include rice, maize, millet, cowpea, acha, groundnut, sesame and guinea corn. They also keep livestock such as goats, sheep, cattle, and poultry too.

The temperature range is 9.11°C minimum and 40.55°C maximum (BSADP, 2015). Bauchi State is characterized by a dust atmosphere referred to as harmattan with visibility being low as 100m. Secondly, is the southwest Maritime air mass. This wind system is responsible for the rainy season experienced in the state. The mean annual rain fall ranges from 700mm in extreme north (Zaki) and 1300mm in the southern part (Toro) of the state The state is characterized by two distinct seasons (the

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rainy and dry seasons). The rainy season begins from May and ends October and the dry season starts November and ends in April.

Sampling Techniques and Sample Size

The target population for the study was the fresh tomato small scale producers, marketers and consumers. Both purposive and simple random sampling techniques were used. First, a purposive sampling technique was used to select three local government areas from each zone and two villages from each of the selected LGAs. This gave the total number of nine LGAs and eighteen villages. The purposive selection of both the LGAs and villages was based on the intensity of tomato production in the areas. These LGAs and their villages in bracket were as follows: Northern zone; Jama'are (Dogon-Jeji and Gongo); Zaki (Sakwa and Ariri); Misau (Zindi and Misau); Central zone: Warji (Badeyaso and Wando); Ningi (Kafin Zaki and Tsangaya), Ganjuwa (Filin-Shagari and Marbini); and in the Western zone; Toro (Tilde and Ganye); Kirfi (Badara and Baba) and Dass (Dabandak and Wandi).

Two markets were selected from each zone. These markets were Jama'are and Misau in the northern zone; Cheledi and Toro in the Western zone while Ningi and Soro were from Central zone. In addition, Muda-Lawal market was also chosen being a collection centre for fresh tomato in Bauchi State. A list of both small scale tomato farmers (1,524) and Retailers (1,278) were obtained and used as the sample frame. This was achieved with the help of some key informants such as government officials from various B.S.A.D.P Headquarters in Bauchi State and from leaders of tomato farmers and marketers association.

A simple random sampling technique was used to ensure that each member of the target population is given equal chance of being selected. Thus, 20% of both farmers and retailers from the selected areas were chosen. This gave the total number of 301 farmers and 252 retailers from the sampling frame of 1,524 and 1,278, respectively. All 105 the identified wholesalers in the three zones were observed for the study. This was because their population was considered not very large. Five retailers from each selected markets were identified based on volume of trade. From each retailer four consumers were selected and interviewed at the point of purchase of fresh tomatoes. The numbers of yes and no made up the sample frame. Muda-Lawal market served as the collection centre for fresh tomato commodity and also has large number of different categories of fresh tomato consumers; hence, six consumers were selected from the five retailers and interviewed at the point of purchase of fresh tomato using accidental sampling procedure. This gave the total number of 150 consumers. In all, 808 respondents were randomly selected and interviewed for the study. This is shown in Table 1 and 2.

Table 1: Sample Size Selection Plan for Producers

Zone	LGA	Village	Sampling frame	Sample size (20%)
	Jama'are	Dogon-jeji	220	44
		Gongo	77	15
	Misau	Zindi	81	16
		Misau	60	12
Northern Zone	Zaki	Sakwa	125	25
		Ariri	65	13
	Ningi	Kafin zaki	112	22
		Tsangaya	63	12
	Ganjuwa	Filing shagari	31	6
Central Zone		Marbini	35	7
	Warji	Badayaso	53	10
		Bakin Kogin-Duburna	49	9
	Dass	Dabandak	100	20
		Wandi	115	23
	Kirfi	Badara	81	16
		Baba	72	14
WesternZone	Toro	Tilde	80	16
		Ganye	105	21
Total			**1,524**	**301**

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Table 2: Sample Size Selection Plan for Marketers and Consumers

Zone	Market	Sampling Frame			Sample Size (20%)		
		W/saler	Retailer	Consumer	W/saler	Retailer	Consumer
	Jama'are	47	174	95	47	34	20
Northern Zone	Misau		191	103		38	20
	Cheledi		153	75		30	20
Western Zone	Toro	32	214	115	32	42	20
	Muda-Lawal		293	185		58	30
Central Zone	Ningi		132	80		26	20
	Soro	26	121	64	26	24	20
		105	**1,278**	**717**	**105**	**252**	**150**

W/Saler = Wholesaler

Methods of Data Collection

Primary data from a field survey were collected using a well structured questionnaire. The Information obtained included socio-economic characteristics and factors that affect fresh tomato supply.

Methods of Data Analysis

Descriptive statistics such as mean, average and graph were used. likert-type scale was used to obtain responses from respondents. This measures the degree of agreement and or severity of response by the respondents. The respondents were asked to give their opinions as to the level of agreement to a number of listed factors using a 5-point likert-scale of strongly agree (SA), Agree (A), undecided (UD), disagree (DA), and Strongly disagree (SD) coded as: 5,4,3,2 and 1 respectively. The mean of the various factors were computed by multiplying the frequency of each response with its appropriate nominal value and dividing the sum by the number of respondents to the items. Thus:

$$\overline{X_s} = \sum FX/S_s$$

Where:

$\overline{X_s}$ = Mean score
$\sum$ = Sign of summation (Almu and Olukosi, 2010)
F = Frequency of response
X = Normal code of rating scale (5,4,3,2 or 1 or 3,2, and 1)
S_s = Sample size

The means was compared with the bench mark calculated as:

Bm = $\sum X/n$

Where:

Bm = Bench mark
$\sum$ = Summation
X = Normal Code
n = Number of codes

Thus,

$\frac{5+4+3+2+1}{5} = 3.00$ and $\frac{3+2+1}{3} = 2.00$

Based on Bagheri (2010) perception analysis, the means for all indicators were then categorised as follows:

1.00 - 1.49 = Strongly Disagree (SD)
1.50 - 2.49 = Disagree (D)
2.50 - 3.49 = Undecided (UD)
3.50 - 4.49 = Agree (A)
4.50 - 5.00 = Strongly Agree (SA)

Thus, any perception mean of $\geq$ 3.00 is a true factor (cause and constraints), otherwise it is not.

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RESULTS AND DISCUSSION

Socio-economic Variables of Fresh Tomato Supply Chain Actors by Zones in Bauchi State

Figure 1, 2 and 3 presents the result on means of socio-economic characteristics of the supply chain actors by zones. The results show the average age for all the supply chain actors to range from 38.22 to 46.96, across zones indicating, that all actors between and among zones are within their active farming and marketing age. The average family size ranges between 8.00 to 16.00 across the three zones among producers, wholesalers, retailers consumers. This indicates a high household size, which provides cheap labour. The result contradict that of Abdurrahman *et al*. (2016), who reported that large family sizes does not necessarily manifest into higher use of family labour as some of the young able bodied members of the family may prefer other Jobs than farming. The mean years of formal education falls between 3.82 and 14.45, indicating that supply actors attained formal education in the study area. The mean years of experience ranges between 15.42 to 11.73 years, implying that supply chain actors are experienced. The mean income falls between ₦134968.87 to 1,074,000.85. the result also reveals mean size of between 1.15 to 1.25 hectares. There is no significant difference among and between zones for all the actors in the individual zones.

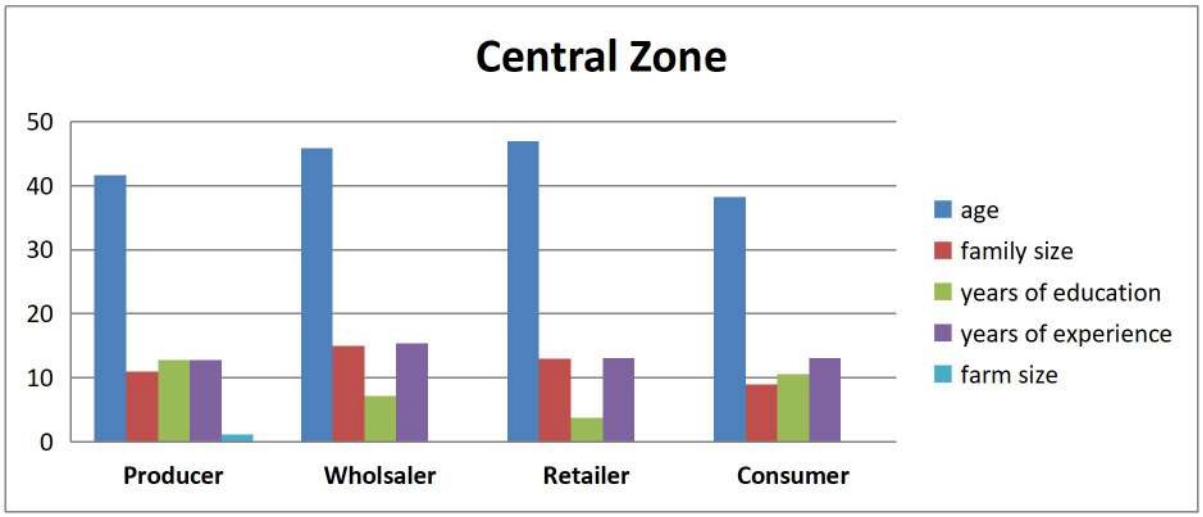

Figure 1: *Average Distribution of Fresh Tomato Supply Chain Actors in Central Zone*

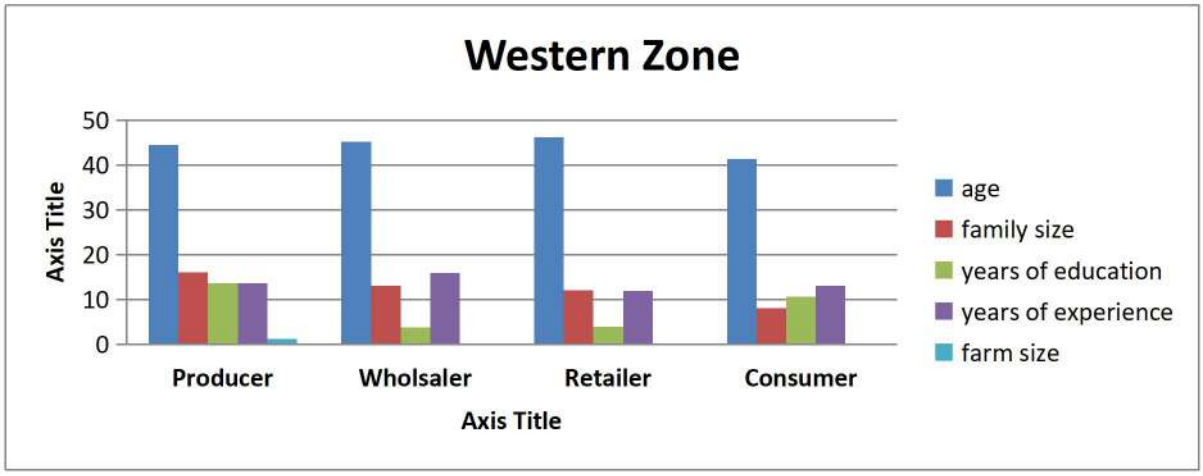

Figure 2*: Average Distribution of Fresh Tomato Supply Chain Actors in Western Zone*

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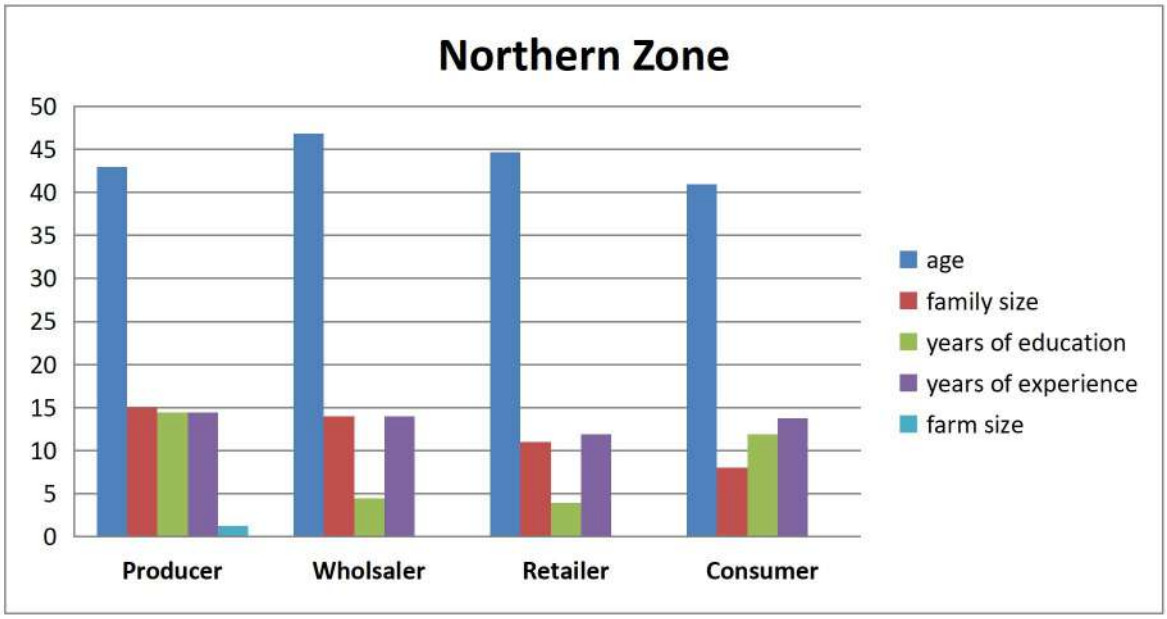

***Figure 3**: Average Distribution of Fresh Tomato Supply Chain Actors in Northern Zone*

Perception of the Supply Chain Actors on Determinants of Fresh Tomato Supply by Zones

Table 3 presents the mean perception of supply chain actors on factors that affect the supply of fresh tomato between zones in Bauchi state. The perception of producers on whether the listed factors affect the supply of fresh tomato or not between Central, Western and Northern zone were agreed on almost every factor except for the factor festivity which is believed by Northern producers as determinant of fresh tomato supply. Northern zone producers regards festivity (mean = 4.01) as determinant of fresh tomato supply as compared to Central zone and Western zone producers who do not believe that festivity is a determinant of supply. This means that festivity does not affect tomato supply in both Central and Western zones.

Wholesalers too were compared between the three zones and the result indicated that all other factors were agreed to be factors that affect the supply of fresh tomato except for location (3.30). Location was disagreed upon by Central and Western wholesalers but was agreed upon by northern zone wholesalers as a factor that determines fresh tomato supply. This could be because Northern tomato sellers sell at farm gate because they are far from Muda-Lawal market which is the major vegetable market located in the State capital of the State.

Also, consumers were compared between zones and were found to agree on the same factors except for the factor sorted tomato (3.70) which Northern zones consumers believed that it affect the supply of fresh tomato. The implication is that consumers of fresh tomato in Northern zone agree that grading of tomato affect their decision on the prices they pay for fresh tomato.

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Table 3: Perception of Supply Chain Actors on Determinants of Fresh Tomato Supply by Zones in Bauchi State

	Producers			Wholesalers			Retailers			Consumers		
Factors	**CZ Mean**	**WZ Mean**	**NZ Mean**	**CZ Mean**	**WZ Mean**	**NZ Mean**	**CZ Mean**	**WZ Mean**	**NZ Mean**	**CZ Mean**	**WZ Mean**	**NZ Mean**
Price of tomato	2.73	2.79	2.59	3.92	3.88	3.91	3.00	4.19	4.33	4.65	4.64	4.95
Tomato Variety	4.76	4.79	4.93	4.00	4.06	3.47	3.50	3.34	3.13	3.75	3.56	3.82
Festivity	2.92	2.41	4.01	3.77	4.00	3.60	4.04	4.04	3.74	4.28	4.37	4.28
Consumers income	3.68	3.63	3.18	3.38	3.06	3.09	4.50	4.15	4.42	4.58	4.67	4.85
Tomato quality	4.67	4.57	4.00	3.81	4.00	3.89	4.50	4.18	4.40	4.78	4.64	4.90
Packaged tomato	3.64	3.57	4.00	1.96	2.09	2.53	4.50	4.15	4.42	2.55	1.37	1.53
Organic product	3.27	3.16	4.01	2.77	2.34	2.64	2.42	1.77	2.11	1.63	1.64	1.95
Seller's attitude	3.71	3.53	5.00	2.00	2.16	2.30	4.04	4.05	3.74	4.08	4.16	3.93
Clean tomato	4.21	4.33	4.95	3.73	3.66	3.94	4.24	4.25	4.36	4.5	4.37	4.48
Distance	3.56	3.44	4.00	3.12	3.28	3.11	3.62	3.55	3.06	3.98	3.07	3.25
Clean selling area	3.80	3.65	4.97	4.00	3.97	3.70	3.94	3.92	3.99	4.20	4.19	4.03
Product shelf-life	4.58	4.85	3.98	3.65	3.69	3.36	4.00	3.90	3.36	3.75	3.72	4.7
Seasonality	1.06	1.00	1.00	3.81	3.91	3.81	4.04	3.66	3.06	3.80	4.24	4.33
Sorted tomato	1.89	2.06	2.36	4.04	3.81	3.72	3.82	3.88	3.47	2.48	2.76	3.70
Location	4.03	4.25	4.00	2.77	2.91	3.30	3.90	3.58	3.40	3.65	4.17	4.15

CZ = Central zone WZ = Western zone NZ = Northern zone
Source: Field Survey, 2017

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Perception of Producers and Wholesalers on Determinants of Fresh Tomato Supply retailers

Table 4 presents the mean perception of producers and wholesalers on factors that affect the supply of fresh tomato supply in Bauchi state as perceived by the marketing chain actors. Producers of tomato gave their opinions as to their level of agreement to a number of listed factors. Prices of tomato (mean=2.62), seasonality (mean=1.01) and sorted tomato (mean=2.15) were not factors that affect tomato supply. This implies that it is generally agreed among producers of tomato in Bauchi State that the listed factors do not affect the supply of tomato. However, this is not in conformity with the supply theory which states that prices of goods determine the level of supply .On whether the remaining factors listed were determinants of tomato supply or not producers agreed that these factors (Table 4) affect the supply of tomato in the state, as any factor with the mean of 3.00 is considered as a factor that affects the supply of fresh tomato in Bauchi State as at when the study was conducted.

Also, the result in Table 4 shows the extent to which Wholesalers of fresh tomatoes in Bauchi state agreed or disagreed to the listed factors that affect fresh tomato supply in the State, except for packaged tomato (mean=2.26), organic products (mean=2.58), sellers attitude (mean=1.23) and location (mean=2.93) which were considered as not determinants of tomato supply, all other factors were agreed upon by the Wholesalers as factors that affect tomato supply in the state. This connotes that the factors agreed upon are determinants of tomato supply at wholesale level in Bauchi state. This findings is in agreement with Fabien and Timothy (2006), that price, variety, and quality are important determinants of trade between buyers and sellers of organic produce in the U.S.

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Table 4: Producers and Wholesalers Perception on Determinants of Fresh Tomato Supply in Bauchi State

Factor	Producers							Wholesaler						
	SA	A	UD	DA	SD	Total%	Mean	SA	A	UD	DA	SD	Total%	Mean
Price of Tomato	0.0	0.0	76.86	23.02	0.12	100	2.62	2.44	94.63	1.46	0.98	0.48	100	3.90
Tomato Variety	88.46	11.33	0.0	0.14	0.7	100	4.81	2.52	81.61	15.11	0.50	0.25	100	3.78
Festivity	8.34	59.65	15.95	13.14	2.92	100	3.19	2.53	91.14	1.52	4.05	0.76	100	3.76
Consumers income	0.48	55.44	42.44	1.54	0.10	100	3.45	0.0	56.79	25.38	17.52	0.30	100	3.15
Tomato Quality	45.77	53.39	0.23	0.46	0.15	100	4.36	2.44	94.63	1.46	0.98	0.49	100	3.90
Packaged Tomato	4.41	83.32	8.21	3.88	0.18	100	3.76	2.11	8.44	21.52	66.67	1.26	100	2.26
Organic Product	0.94	81.50	6.48	11.08	0.0	100	3.54	7.38	5.90	46.49	39.85	0.37	100	2.58
Sellers attitude	55.25	28.62	14.31	1.75	0.07	100	4.18	3.88	6.20	34.88	52.71	2.33	100	1.23
Clean tomato	65.18	34.08	0.44	0.15	0.15	100	4.56	5.01	79.20	15.04	0.50	0.25	100	3.80
Distance	1.88	83.54	7.61	6.77	0.19	100	3.53	1.52	55.76	25.45	16.97	0.30	100	3.13
Clean selling Area	54.55	33.38	10.59	1.41	0.16	100	4.23	4.96	82.38	11.91	0.49	0.25	100	3.84
Product Shelf-life	50.30	49.55	0.0	0.15	0.0	100	4.43	1.35	80.86	6.47	11.32	0.0	100	3.53
Seasonality	10.0	1.31	0.0	0.66	98.03	100	1.01	2.42	95.88	0.73	0.48	0.48	100	3.93
Sorted Tomato	3.08	1.85	43.75	40.99	10.32	100	2.15	1.24	87.56	10.45	0.49	0.25	100	3.86
Location	19.04	78.12	2.43	0.32	0.08	100	4.10	1.62	32.47	51.62	13.64	0.65	100	2.93

Bench mark = 3.00
SA= Strongly Agreed, A = Agreed, UD= Undecided,
DA = Disagreed, SD= Strongly Disagreed,
Source: Field survey, 2017

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Perception of Retailers and Consumers on Determinants of Fresh Tomato Supply

Table 5 presents the mean perception of retailers and consumers on the factors that affect the supply of fresh tomato among retailers and consumers in Bauchi State. Retailers of fresh tomato also gave their opinion as to the level of agreement to a number of factors that determine the supply of fresh tomato in Bauchi state. Only the factor, organic product (mean=2.33) was disagreed upon, suggesting that organic product is not a factor that affects fresh tomato supply among retailers in Bauchi state; indicating that retailers of fresh tomato in Bauchi State do not differentiate their product into organic and non –organic products . This explains too, why consumers did not regard this factor as a determinant of fresh tomato supply. However, all other listed factors were considered as determinants of fresh tomato supply by the retailers.

Consumers' opinion as to how the listed factors affect the supply of tomato was also revealed in Table 5. Consumers in Bauchi state collectively disagreed that packaged tomato (mean=1.67) and organic product (mean=1.69) are not factors to tomato supply in Bauchi state. However, they agreed on all other listed factors to be factors affecting the supply of fresh tomato in Bauchi state. Price of tomato which was not considered as a factor that affect tomato supply by producers, was collectively agreed upon by both traders and consumers as a factor that affects tomato supply in Bauchi state. This clearly shows that wholesalers, retailers and consumers of fresh tomato in Bauchi state believe that price of tomato affect its supply. This contradicts producer's result but is in conformity with the supply theory that price of a good is a determinants of its supply. Panda (2013) and Tianyi (2013) reported price of the product, seller's innovation and quality as determinants of supply. This is not surprising because, to some extent farmers are not actually directly involved in the trading of their produce, but traders and Consumers are directly involved in the buying and selling of tomato. Quality of a product is not a bonus for the customer, it is expected. High cost, low productivity, and loss of market share are directly related to poor quality of product (Henry *et al.*, 2012).Quality of tomato and other factors were agreed upon by all (producers, wholesalers, retailers and consumers) supply actors as determinants of fresh tomato supply in Bauchi state. Quality of product is an important factor for the acceptance of any product (Henry *et al.*, 2012). In support of this, Fabien and Timothy (2006) reports that quality plays equal if not greater role than price in determining product supply.

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Table 5: Retailers and Consumers' Perception on Determinants of Fresh Tomato Supply in Bauchi State

Factor	Retailers							Consumer						
	SA	A	UD	DA	SD	Total%	Mean	SA	A	UD	DA	SD	Total%	Mean
Price of Tomato	26.02	73.42	0.28	0.19	0.09	100	4.19	76.87	23.13	0.0	0.0	0.0	100	4.73
Tomato Variety	1.19	71.82	10.70	16.17	0.12	100	3.34	14.49	73.19	3.80	7.61	0.91	100	3.68
Festivity	10.54	84.34	3.61	1.20	0.30	100	3.95	63.27	30.25	1.85	4.63	0.0	100	4.32
Consumers income	54.47	42.11	1.39	1.29	0.74	100	4.30	73.86	26.14	0.0	0.0	0.0	100	4.69
Tomato Quality	40.94	58.14	0.27	0.55	0.09	100	4.31	80.92	19.08	0.0	0.0	0.0	100	4.61
Packaged Tomato	54.48	42.11	1.38	1.29	0.74	100	4.30	0.0	19.20	0.0	51.20	29.60	100	1.67
Organic Product	4.26	9.54	30.15	52.81	3.24	100	2.33	0.0	0.0	0.0	81.85	18.15	100	1.69
Sellers attitude	11.03	83.85	3.60	1.20	0.30	100	4.00	31.30	66.13	0.0	2.57	0.0	100	4.15
Clean tomato	37.11	61.97	0.56	0.18	0.18	100	4.28	48.87	51.13	0.0	0.0	0.0	100	4.15
Distance	2.91	63.25	26.16	7.21	0.47	100	3.41	8.96	51.79	29.88	8.36	1.00	100	4.46
Clean selling Area	5.04	91.44	2.42	0.80	0.30	100	3.94	17.68	82.32	0.0	0.0	0.0	100	3.35
Product Shelf-life	2.64	85.23	8.54	3.37	0.21	100	3.76	73.46	13.36	0.0	12.35	0.83	100	4.15
Seasonality	10.92	70.74	10.48	7.42	0.44	100	3.63	62.70	28.30	0.0	9.00	0.0	100	4.00
Sorted Tomato	2.65	87.61	5.08	4.23	0.42	100	3.75	0.0	80.00	0.0	11.82	8.18	100	4.15
Location	0.55	76.91	16.90	5.52	0.11	100	3.39	23.18	72.85	-	3.97	-	100	

Bench mark = 3.00
SA= Strongly Agreed, A = Agreed, UD= Undecided,
DA = Disagreed, SD= Strongly Disagreed,
Source: Field survey, 2017

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CONCLUSION AND RECOMMENDATION

All the supply chain actors in Bauchi State agree and disagree on some factors as determinants of fresh tomato supply.

Based on the findings of the study the following recommendation was made:

Supply chain actors particularly producers and marketers of fresh tomato should look into the factors considered by the consumers as obstacles to the supply of tomato and improve on them so as to increase its consumption and in return increase their profit.

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STRATEGIES USED BY SUPPLY CHAIN ACTORS TO STAY IN FRESH TOMATO BUSINESS IN BAUCHI STATE, NIGERIA

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ABSTRACT
The study was conducted to examine the strategies applied by the supply chain actors to stay in fresh tomato business in Bauchi State, Nigeria. A multistage sampling technique was used to select 301 producers, 105 wholesalers and 252 retailers making a total of 659 Supply Chain Actors (SCA) for the study. The data were analysed using descriptive statistics only. The result shows that 35.67% of the producers used regular customers as a strategy to reduce transportation cost. About 44.68% and 58.78% of wholesalers retailers use collective transportation as means of reducing cost of transportation respectively. The result also indicates that 69.10%, 94.29%, 80.56% and 77.50% of producers, wholesalers, retailers and consumers belong to a cooperative society respectively. Further, a significant proportion (31.75%) of the producers used multiple production as strategy to stay in business. About 25.18% and 25.78% of wholesalers and retailers used collective transportation respectively. Again the result shows that producers (48.94%), wholesalers (35.64%), retailers (38.90%) and consumers (39.6%) sell and purchase their fresh tomato in farm gate, urban market from street hawkers. From the result it can be observed that producers (83.9%), wholesalers (91.4%) and retailers (58.3%) handled between 1 to 900 of fresh tomato per month. The result shows that 35.9% of the producers, 47.6% of wholesalers and 93.7% of the retailers sold their tomato at ₦601-₦700, ₦701-₦800, ₦800 and above per baskets respectively. the result also indicates that 17.61% of the tomato was sold by commission agents, 15.73% were sold by rural assemblers and 33.33% were sold to outside Bauchi state wholesalers. It can be concluded that SCA use one form of strategy to reduce cost of transportation and or to stay in business. The study recommend that SCA can contribute through cooperatives and buy bigger vehicles to ease transportation cost.

Keywords: Strategies, Fresh, Tomato, Business, , Chain, Actors

INTRODUCTION
Supply chain actors are members of a distribution channel. Distribution channel, otherwise known as marketing channel is a set of interdependent organizations that help make a product or service available for use or consumption by the consumer or business user. It consists of firms that have partnered for their common goal (Philip and Gary, 2007). Olukosi *et al*. (2004) defined marketing channel as a path of a product as it moves from producers to the final consumer. Agricultural producers do not work alone in creating values for consumers, instead they give some of their selling activities to channel workers (Nonyelu, 2013) such selling activities take place as the product moves from one point to another. These create a path known as marketing channel through which the commodity follows to the final consumer. Channel workers, otherwise known as middlemen help reduce the amount of work that is to be done by both farmers and consumers. For instance, farmers produce the products while middlemen create greater efficiency in making the product available to buyers. This justifies why Philip and Gary (2013) pointed out that a farmer is offered more than he/she can achieve on his/her own. More so, middlemen transform the assortment of product made by the producers into assortment that is wanted by the consumers. This shows that middlemen are given some control as to where and to whom they sell their product to.

FAO (2011) reported that efficiency in chain flow means the availability of efficient communication, transportation, processing and storage facilities, common grade and standard, credit

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availability to finance short run inventory and processing operation. On the other hand, lack of such facilities and activities results into marketing inefficiency. The study of marketing channel helps in the understanding of the various costs incurred through the value chain at different levels of transaction. Marketing costs, according to Olukosi *et al.* (2007) are the actual expenses incurred in the performance of the marketing functions as the commodities move from the farm to the ultimate user. It is the sum total of all costs incurred by middlemen in assembling, processing, transporting, storing and distribution of a product.

Tomato is important in the diet of almost all the people in Nigeria. Its importance include: nutritional, medicinal and economic value (Oladapo *et al*., 2011). However, it has been observed that the distribution of tomato products in Nigeria is surrounded by a number of constraints including poor transportation system, lack of information on both production and marketing (Olukosi *et al.*, 2010) Also, Yusuf *et al*. (2015) reported distance from producing areas to consumption areas as one of the problems affecting the distribution of fresh tomato. In Nigeria, for instance, the major tomato producing areas are in the northern part of the country while its high demand is in the southern part of the country. A good packaging material, good transport system and large cold storage facility could help in the smooth delivery of the tomato products. All these pose serious challenges to the tomato supply chain. In Nigeria, the estimated total loss in tomato is about 60%. Inadequate distribution of tomato does not only make it scarce to obtain but also reduces its consumption and pushes its prices to go up, usually beyond the reach of the lower income earners. Also, with the increasing population and rising standard of living of Nigerians, its demand is expected to rise. In other words, there is a ready market for tomato out there. Therefore, the need for tomato to be produced and distributed all the year round is important. However, its production is seasonal and consequently resulting to shortage in supply at certain period of the year. For instance, in the urban slums, the large number of consumers causes demand for tomato to rise during the off season. Inadequate supply of tomato in both rural and urban areas is crucial during raining season when marketing activities are reduced as a result of poor condition of feeder roads and unfavourable condition for tomato production in the raining season. Despite federal Government's efforts in form of programmes/projects for poverty alleviation, Nigeria still experiences serious food shortages (Afolabi, 2012). Causes of too much food for a stated time and too little for prolonged periods are common. This could be why food items such as rice and tomato have to be imported into the country. Erhabor and Ahmadu (2013) described Nigeria to be among the largest importers in the world. Between 2009 and 2010, a total of 105,000 metric tonnes of tomato paste valued at over ₦15 Billion was imported to bridge the deficit gap between supply and demand (Erhabor and Ahamadu, 2013). In view of the above mentioned problems, it then becomes necessary to examine the distribution channel for fresh tomato in Bauchi State. The broad objective of the study is to examine the strategies used by SCA to stay in fresh tomato business in Bauchi State. The specific objectives were to:

i. describe the strategies used to stay in fresh tomato business;
ii. identify the buyers and sellers of fresh tomato produced in Bauchi State;
iii. examine the quantity of fresh tomato handled by the SCA.
iv. identify both buying and selling points of fresh tomato in Bauchi State

METHODOLOGY

The Study Area

Bauchi State is the Study area. It is one of the thirty six States of Nigeria and was created in 1976. The State is boarded by Taraba and Plateau States to the South, Gombe and Yobe to the East, Kano and Jigawa to the North and Kaduna in the west (BSG, 2011) Bauchi State is divided into 3 agricultural zones namely: Northern, Central and Western zones. The State is made up of 20 Local Government Areas (LGAs) which are Bauchi, Kirfi, Alkaleri, Toro, Dass, Tafawa-Balewa, and Bogoro in the Western Zone; Zaki, Itas-Gadau, Gamawa, Jama'are, Katagum, Dambam, Giade, Shira and Misau in the Northern zone, and Darazo, Warji, Ningi and Ganjuwa are in the central zone. Bauchi State is located in the Northern Guinea Savannah Ecological zone of Nigeria. It lies between latitude 9° 3' and 12° 3' North of the equator and longitudes 8° 50' and 11° East of the Greenwich

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Meridian. Bauchi State occupies a total land area of 49,119.000km^2 representing about 15% of the Nigerian's total land mass (BSADP, 2015). The State has an estimated population of 4,889,811.2 (NBS, 2016). Majority of the inhabitants are Geremawa, Hausa, Fulani, Sayawa, Jarawa and others. Most (80%) of the farmers of Bauchi State are predominantly subsistence farmers. The farmers in the state practice both dry and rainy seasons farming. They produce vegetables such as tomato, pepper, okra, lettuce, cabbage, amaranth among others. Other major crops produced include rice, maize, millet, cowpea, acha, groundnut, sesame and guinea corn. They also keep livestock such as goats, sheep, cattle, and poultry.

The temperature range is 9.11℃ minimum and 40.55℃ maximum (BSADP, 2015). Bauchi State is characterized by a dusty atmosphere referred to as harmattan with visibility being as low as 100m. This wind system is responsible for the rainy season experienced in the State. The mean annual rain fall ranges from 700mm in extreme north (Zaki) and 1300mm in the southern part (Toro) of the State. The State is characterized by two distinct seasons (the rainy and dry seasons). The rainy season begins from May and ends October and the dry season starts November and ends in April.

Sampling Techniques and Sample Size

The target population for the study was the fresh tomato small scale producers, marketers and consumers. A preliminary survey was conducted in order to identify the major tomato producing areas in each zone, during which some questionnaires meant for the collection of the data for the study were pre-tested and observations were made. Both purposive and random sampling techniques were used. First, a purposive sampling technique was used to select three local government areas from each zone and two villages from each of the selected LGAs. This gave the total number of 9 LGAs and 18 villages. The purposive selection of both the LGAs and villages was based on the intensity of tomato production in the areas, and the need for a spread of the research work was also put into consideration. These LGAs and their villages in bracket were as follows: Northern zone; Jama'are (Dogon-Jeji and Gongo); Zaki (Sakwa and Ariri); Misau (Zindi and Misau); Central zone: Warji (Badeyaso and Wando); Ningi (Kafin Zaki and Tsangaya), Ganjuwa (Filin-Shagari and Marbini); and in the Western zone; Toro (Tilde and Ganye); Kirfi (Badaraand Baba) and Dass (Dabandak and Wandi).

Two markets were selected from each zone. These markets were Jama'are and Misau in the northern zone; Cheledi and Toro in the Western zone while Ningi and Soro were from Central zone. In addition, Muda-Lawal market was also chosen being a collection centre for fresh tomato in Bauchi State. A list of both small scale tomato farmers (1,524) wholesaler (105) and retailers (1,278) were obtained and used as the sampling frame. This was achieved with the help of some key informants such as government officials from various B.S.A.D.P zones in Bauchi State and from leaders of tomato farmers and marketers association. Thus, 20% of both farmers and retailers from the selected areas were chosen, this gave the total number of 301 farmers and 252 retailers from the sampling frame of 1,524 and 1,278, respectively. All 105 of identified wholesalers in the three zones were selected for the study. This was because their population was considered not very large. Five retailers from each selected markets were identified based on volume of trade. From each retailer four consumers were selected and interviewed at the point of purchase of fresh tomato. The number of cooperating and non-cooperating consumers made up the sampling frame. Muda-Lawal market served as the collection centre for fresh tomato commodity and also has large number of different categories of fresh tomato consumers; hence, six consumers were selected from the five retailers and interviewed at the point of purchase of fresh tomato using accidental sampling procedure. This gave the total number of 150 consumers. In all, 808 respondents were randomly selected and interviewed for the study.

Methods of Data Collection

Primary data were collected from a field survey. Information pertaining membership of cooperative societies, strategies to stay in tomato business, point of purchase/ selling quantity harvested and/or marketed were obtained and use for the study. The data were collected with the help of some trained enumerators guided by the researcher. The trained enumerators were obtained from the various ADP headquarters of each selected LGAs. The data were collected over the period of 12 months (multiple visits).

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Method of Data Analysis

Data were analysed using descriptive statistics such as frequency distribution, and percentages only.

RESULTS AND DISCUSSION

Membership of Cooperatives and Strategies to Stay in Farm Business

Membership of cooperatives

Table 1 compared the supply actors with regards to belonging to any social group or not. The result shows that 69.10% of producers, 94.29% of wholesalers and 80.56% of retailers were members of a cooperative society. The implication is that supply chain actors in Bauchi state were aware of the benefits of joining a cooperative society. These benefits include access to farming and marketing information. James *et el*. (2017) and Manu *et al*. (2017) reported 92.5% and 66.7% respectively to belong to cooperative society in vegetable marketing and production in Gombe and Kano States. Olajide and Oyebode (2014) suggested the need for belonging to an organization by the farmers. This is because collective efforts might serve as a catalyst in motivating members towards a positive decision making.

Strategy to reduce transportation cost

Table 1 reveals the result on strategies used by tomato supply chain actors to reduce transportation cost. The result shows that 35.67% of producers use regular customers, 27.32% utilized the opportunity of empty vehicles heading to destination of sale of tomato, 23.00% used collective transportation with other farmers and 14.00% used carts as a strategy to reduce cost of transportation. About 44.68% of the Wholesalers used collective transportation, 38.9% used old customers and 20.48% used empty vehicles heading to their destination. Also the result of retailers on strategies to reduce cost of transportation shows that 58.78% used collective transportation, 26.30% used old customers, 13.00% used empty vehicles heading to their destination and 3.00% used carts. Saurav and Neeraj (2015) reported used of collective transportation and empty vehicles heading to intended destination as strategies to reducing cost of transportation for vegetable and fruit supply chain in India.

Strategies to stay in tomato business

Also, strategies utilized by supply chain actors to stay in fresh tomato business are presented in Table1. The result reveals that 31.75%, 29.21% and 16.14% of the producers used multiple productions, drying of tomato, used disease free seeds and *Asusu* respectively to stay in tomato farming. The result also shows that 25.18%, 19.66% and 4.80% of the Wholesalers used multiple trades, buy small and sell, reduce product price, *Asusu* and dry tomato were the strategies used to stay in the business. Retailers used multiple trade (25.78%), reduce product price (25.87%) buy small and sell (22.17%) used *Asusu* (19.66%) and dry tomato (4.80%) to stay in the fresh tomato marketing.

Point of buying and selling of tomato

Again Table 1 revels that 48.94% of Producers sell their product at the farm gate, 33.98% at rural markets, and 17.07% at urban market. The result also shows that 35.64% of Wholesalers buy at farm gate, 32.64% from rural markets and 28.72% at urban markets. Similarly Retailers buy at farm gates (30.42%). Majority (40.27%) of consumers buy tomato at urban markets, 39.60% from street hawkers and 13.42% rural markets. Consumers' preference to buy from street hawkers could be associated with them wanting to reduce cost of transportation energy and time management reasons.

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Table 1: Membership of Cooperation and Strategies to Stay in Farm Business in Bauchi state.

Variables	Producers		Wholesaler		Retailers		Consumer		Total	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Membership of cooperation										
Yes	208	69.10	99	94.29	203	80.56	0.0	0.0	510	77.50
No	93	30.90	6	5.71	49	17.44	0.0	0.0	148	22.49
Strategies to Reduce transport cost										
Use of collection transport	190	23.00	105	44.68	252	58.78	0.0	0.0	547	22.33
Use carts	116	14.00	0	0.00	118	3.00	0.0	0.0	234	9.55
Empty vehicles heading to Destination	224	27.32	48	20.48	69	13.00	0.0	0.0	341	13.92
Use of old customers	295	35.67	820	38.9	212	26.30	0.0	0.0	1327	54.18
Strategies to stay in Business										
Multiple production/ trade	301	31.75	105	25.18	252	25.78	0.0	0.0	658	28.72
Buy small and Sell	0	0.0	105	25.18	216	22.17	0.0	0.0	321	14.01
Use of disease free seeds	218	22.99	0	0.0	0	0.0	0.0	0.0	218	9.51
Reduce product price	0	0.0	105	25.18	252	25.78	0.0	0.0	357	15.58
Dry tomato	277	29.21	20	4.80	67	6.89	0.0	0.0	364	15.88
Asusu	154	16.14	32	19.66	187	19.70	0.0	0.0	373	16.28
Point of buying/selling										
Farm gate	301	48.94	103	35.64	167	30.42	10	6.71	581	36.26
Urban markets	105	17.07	83	28.72	168	30.65	59	39.60	415	25.90
Rural market	209	33.98	103	32.64	213	38.90	20	13.42	545	34.01
Street hawking	0	0.0	0	0.0	0	0.0	61	39.60	61	3.80

Source: Field survey 2017

Quantity Produced, Marketed and the Prices of Tomato by Producers and Marketers in Bauchi State

Quantity handled in baskets

It can be deduced from the result (Table 2) that 10.8%, 91.4% and 100% of producers, wholesalers and retailers, respectively, handled between 1-300 baskets of tomato. About 43.3% of the producers handled between 501 and above 900 baskets. This implies that 100% of retailers of fresh tomato buy below 301 baskets of tomatoes. Price of tomato per basket was also revealed. The result reveals that 28.9%, 47.6 and 0.8% of producers, wholesalers and retailers sold a basket of tomato at less than ₦500- ₦600, 15.9%, 9.5% and 1.6% of producers, wholesalers and retailers sold their tomato at ₦601-₦700. About 35.9% of the Producers, 21.0% of the wholesalers and 10.0% of the retailers sold theirs at ₦701- ₦800, 19.3% of producers, 21.9% of wholesalers and 93.7% of the retailers sold theirs at ₦800 and above per baskets. The implication is that retailer's sale at higher price compared to producers and wholesalers. Comparing producers and wholesalers, the result indicates that about (35.9%) of the producers sold at higher prices than the wholesalers.

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Table 2: Distribution of Supply Chain Actors by Quantity (kg) Handled and Price in Bauchi State

Variables	Producers		Wholesaler		Retailers		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq	%
Quantity handled (basket)								
1-300	32	10.8	96	91.4	252	100	380	58.37
301-500	129	43.9	9	8.6	0	0	138	21.04
501-700	84	28.6	0	0	0	0	84	12.90
701-900	26	83.9	0	0	0	0	26	3.99
Above 900	23	7.8	0	0	0	0	23	3.53
Price /₦/Basket								
Less Than ₦500 -₦600	87	28.9	50	47.6	2	0.8	139	21.12
₦601-₦700	48	15.9	10	9.5	4	1.6	62	9.42
₦701-₦800	108	35.9	22	21.0	10	4.0	140	21.27
Above ₦800	58	19.3	23	21.9	236	93.7	317	68.17

Basket = 49.41kg
Source: Field survey 2017

Buyers and sellers of fresh tomato

The result reveals in Table 3 that 22.81% of the tomato produced is sold to wholesalers, 10.41% to retailers and 0.11% to consumers. This implies that most buyers of fresh tomato from the Producers were bulk buyers. Furthermore, the result also indicates that 17.61% of the tomato was sold by commission agents, 15.73% were sold by rural assemblers and 33.33% were sold to outside Bauchi state wholesalers. The implication is that very negligible percentage of consumer goes to buy from producers. This could be because farmers prefer those that buy in bulk than in beats. It also indicates that major buyers of tomato from producers were retailers and wholesalers. Haruna *et al*. (2012) also reputed that retailers and wholesaler are market intermediaries for fresh tomato market in Bauchi metropolis The finding confirms the report of Nonyelu (2013) who stated that agricultural produces do not work alone in the creation of values for consumers but instead give some of their activities to channel workers. This also justifies Philips and Gary (2013) who stated that farmers are offered more than what they can achieve on their own. Also the chi-square result shows positive and significant relationship between source of seed, cost of raising seedlings, revenue from raising seedling, labour type, buyers of tomato and the net income obtained by the producers.

Table 3: Distribution of Fresh Tomato Producers by Their Buyers and Sellers in Bauchi State

Variables	Freq.	%
Buyers of tomato		
Wholesalers	206	22.81
Retailers	94	10.41
Consumers s	1	0.11
Assemblers (Farmers)	142	**15.73**
Total	443	
Sellers of tomato		
Commission agents	159	17.61
Outside dealers	301	33.33

Basket = 49.41kg
Source: Field survey 2017

CONCLUSION AND RECOMMENDATION

The study concluded that Supply chain actors used multiple productions, drying of tomato, used disease free seeds and *Asusu* as strategies to stay in tomato farming. in addition, SCA use one form of strategy to reduce cost of transportation and or to stay in business.

Based on the findings of the study the following recommendations are made:

i. Both producers and marketers of fresh tomato, under the umbrella of cooperative societies, larger vehicles. This will also help in reducing the cost of transportation. When the cost of transport is reduced, marketers will be able to sell to consumers at affordable prices and also the product will reach consumers in the right condition.
ii. Government should provide good roads that will link fresh tomato producing areas with markets to help Producers dispose of their products.
iii. Also, there is need for adequate market with stable prices for tomato in addition to processing to ensure availability of tomato year round. This can be achieved through the exchange of market information among states, green houses, storage and processing facilities.

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SURVEY OF THE SOIL PHYSICAL CHARACTERISTICS OF ABUBAKAR TAFAWA BALEWA UNIVERSITY FARM AS IT'S RELATE TO MOISTURE AVAILABILITY FOR AGRICULTURAL PRODUCTIVITY

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ABSTRACT
A detailed survey of the university farm was conducted, using rigid-grid sampling method to obtain one hundred and forty-four (144) soil samples from 4.7 hectares of land. Surface soil samples of 0-15 and 15-30 cm were collected at grid intersection points. The collected soil samples were air-dried and passed through a 2mm sieve, and analyzed using standard laboratory procedures for physical parameters. Undisturbed soil samples were collected in situ using stainless steel core rings for determination of soil moisture release using pressure membrane apparatus, while double ring infiltrometer was used to determine infiltration rates. Simple linear correlation and regression analysis were conducted to establish relationship between the various data obtained. The findings of the research reveal that out of the analyzed samples, 34 samples were identified as clay, 28, 1, 3 and 6 as sandy loam, sand, silty clay and gravelly sand respectively. At 0.33, 0.5 and 1 bar sandy loam was negatively correlated with clay, while at 5, 10 and 15 bars clay was negatively correlated with sandy loam respectively. The simple linear correlation between bulk density and total porosity indicated a negative correlation at both levels. In conclusion, the linear curve fitting for both Horton and modified Kostrakov's infiltration equations yielded a positive coefficient of determination(R) of 0.992 and 0.982 respectively. Therefore, it is recommended that sandy loam with preponderance of small, medium and large soil particles is capable of retaining soil moisture at different tension levels and should be preferably used for farming activities in the University farm.

Keywords: Survey, Soil, Moisture, Properties, Infiltrometer, Models

INTRODUCTION
Soil physical properties are the basic and fundamental unit of soil. They serve as the foundation and essential components that characterize the nature and behavior of soil. These properties of soil are important in agricultural contexts because they affect water retention, availability of nutrients, aeration, and the growth of roots (Andreas *et al.,* 2020). A comprehensive understanding of these properties facilitates the implementation of improved management strategies aimed at promoting soil health and enhancing agricultural yields. Furthermore, the physical characteristics of soil significantly contribute to the enhancement of its chemical and biological properties (Ehiem *et al.,* 2016). It is a misconception and a myth that agricultural productivity can be sustained by addition of fertilizer and/or water per se. Expensive inputs can be easily wasted if soil physical properties are suboptimal or below the critical level. Under adverse soil physical conditions, applied Fertilizer, amendments, and pesticides can be leached out, washed away, volatilized, miss the target, and pollute the environment (Abubakar 2015). Therefore, high soil physical quality plays an important role in enhancing soil chemical and biological qualities. As modern agriculture is shifting toward sustainable practices, soil physical properties are more important now than ever before in sustaining agricultural productivity due to the shrinking global per capital of arable land area. It was 0.50 ha in 1950, 0.20 ha in 2000, and may be only 0.14 ha in 2050 and 0.10 ha in 2100. Therefore, preserving and restoring world soil resources is crucial to meeting demands of the present population without jeopardizing needs of future generations. Soil moisture significantly influences weather and climate, plant growth and productivity, hydrology, and soil ecology (i.e., carbon/nitrogen dynamics, and trace gas emissions). As such, the need for compilation of extensive and intensive soil moisture information has been recognized for several decades. Research efforts to develop new techniques for

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monitoring soil moisture also continue, often with focus on large-scale monitoring. One prominent area of research is remote sensing. Remote sensing techniques offer promise; however, may provide information only for the top few centimeters of the soil (Ehiem *et al.,* 2016). Therefore, application of remotely sensed soil moisture data may be limited for determining conditions at typical plant rooting depths or for other ecological and hydrological applications, without significant complementary information from proximal (field) measurement (Ehiem *et al.,* 2016). Proximal sensing tools are in direct contact or very close with the soils, therefore the proximity is high compared to remote sensing. The study was therefore carried out to conduct a survey on the soil physical properties of university farm and assess the influence of these properties on moisture retention and release.

METHODOLOGY

Description of the Study Area

The study area is the Departmental Research Farm for Crop Production of the Abubakar Tafawa Balewa University (A.T.B.U), which is located at the permanent site of Abubakar Tafawa Balewa University, Gubi Campus, Ganjuwa, Bauchi State, Nigeria. The area is located 25 kilometers away from Bauchi metropolis. It has a total land area of 48km^2 and lies within Savanna zone at Latitude 10^{o}45'N and longitude 9^{o}82'E with an annual average rain fall of 250 mm occurring mainly during the month of June to September.

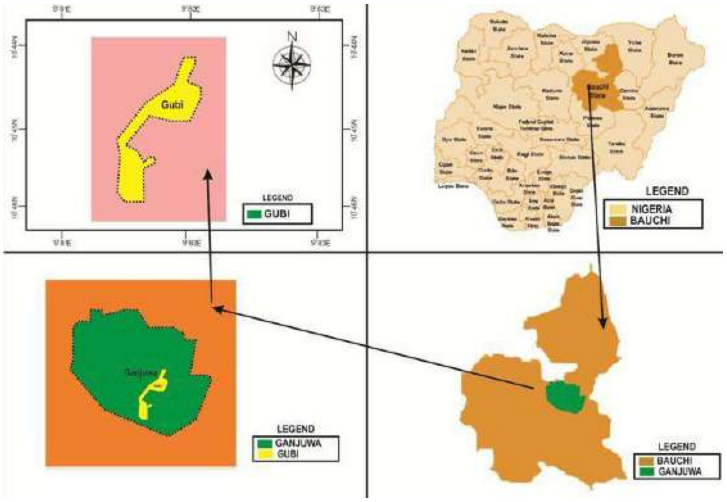

Figure 1: *Map of the Study Area.*

Methods of Data Collection

A detailed survey typed was used at a scale of 1:12000. This is according to Brady and Weil that area of land ranging from 0.5 – 5.2 hectares should be categorized under detailed survey for agricultural purpose. The survey method used is rigid grid. This is because the method is useful for large scale highly intensive detailed and detailed survey. The sample point along the traverses can be located and mapped with accuracy.

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Figure 2: *Rigid Grid Survey of the Area using ArcGIS 10.0*

Sampling Techniques

Samples were collected (from grid intersection points) at 72 collection points for 0-15cm as well as 72 collection point for 15-30cm respectively, given a grossed total of144 samples.

Particle Size Determination

The first stage involved composite sampling where 6 samples from each data collection point were transformed into 1 sample. The soils were air dried, gently crushed with a wooden roller to break up the clods/peds. After that, the soils were sieved with a 2 mm sieve for analysis. The samples were stored in properly labeled soil bags (polythene bag) from which portions were taken for all physical properties analysis. Particle size distribution (to ascertain texture) was carried out using Bouyoucous hydrometer method as outlined by Gee and Or (2002).

Soil Preparation for Hydrologic Conductivity

Undisturbed soil samples were prepared and confined within stainless steel rings according to the procedures described by Fong *et al*. (2018).

Field Test for Infiltrometer

Infiltration rate was determined in the study area using double ring inflitrometer as outlined by Wells and Moure (1986).

Statistical Analysis

Modified Kostiakov Model

$$I = i_c t + \alpha t^{\beta} \quad \text{.....(1)}$$

Where, α(α>0) and β (0<β< 1) are constants, i_c= final infiltration rate (cm/hr), i= infiltration rate (cm/hr), t= time and I= infiltration rate.

Horton Model

$$i = i_c + (i_o - i_c)\, e^{-kt} \quad \text{.....(2)}$$

Where, i= infiltration rate at time, t, (cm/hr), io= initial infiltration rate (cm/hr) at t = 0, ic= final infiltration rate (cm/hr), k = infiltration decay coefficient in dimension of time, t, (t-1).

Simple Linear Correlation Formula

$$r = \frac{\sum xy}{\sqrt{(\sum x^2)\,(\sum y)^2}}$$

Simple Linear regression formula

$y = \alpha + Bx$

B= slope

α= y - intercept

y = y - coordinate

x= x - coordinate

Coefficient of uniformity

$$Cu = \frac{D60}{D10}$$

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Coefficient of curvature

$$Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

T-test Formula

$$t = \frac{x_1 - x_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

where x_1 = mean value Horton's Model
x_2 = mean value of Kostiakov's Model
s_1 = standard devaition of Horton's Model
s_2 = standard devaition of Kostiakov's Model
n_1 = numbers of observation of Horton's Model
n_2 = numbers of observation of Kostiakov's Model

RESULTS AND DISCUSSION

Particle Size Analysis

Table 1 presents a grouping of the various soil samples into different textural classes from the detailed analysis of particle size distribution of the soil sample obtained from the University farm. The distribution comprises various proportions of gravel, sand, silt, and clay, which were critical for categorizing the soil into distinct textural classes (*Figure* 3). This classification underscores the heterogeneity of the soil within the study area, allowing for an apparent understanding of its composition. Brady *et al*. (2015) assert that soil texture was a fundamental and enduring property of any soil type, as it remains relatively stable over time and does not easily undergo alterations. This intrinsic characteristic of soil texture was pivotal for making informed management decisions regarding the agricultural practices employed in the University farm.

Furthermore, Skaggs *et al*. (2011) underscored the significance of soil texture as a primary physical property, thereby advocating for its critical role in formulating effective water management strategies. The understanding of soil texture lays the groundwork for optimizing irrigation practices, enhancing crop yields, and ensuring sustainable land use, thus reinforcing the necessity for detailed soil classification in agricultural research and practice.

Table 1: Textural Classes of Soils of the Study Area

Group	**Transverse and intersection (point of data collection)**									**No. of point of collection involved**	**Textural classes**
Site A	T_1P_5	T_1P_6	T_1P_7	T_1P_8	T_1P_9	T_2P_6	T_2P_7	T_2P_8	T_2P_9	28	Sandy loam
	T_3P_7	T_3P_8	T_3P_9	T_4P_6	T_4P_7	T_4P_8	T_4P_9	T_5P_6	T_5P_7		
	T_5P_8	T_6P_6	T_6P_7	T_7P_5	T_7P_6	T_8P_5	T_8P_6	T_4P_8	T_3P_4		
	T_5P_9										
Site B	T_1P_1	T_1P_2	T_1P_3	T_1P_4	T_2P_1	T_2P_2	T_2P_3	T_2P_4	T_2P_5	34	Clay
	T_3P_2	T_3P_3	T_3P_4	T_4P_3	T_5P_1	T_5P_2	T_5P_3	T_5P_4	T_6P_2		
	T_6P_3	T_7P_1	T_7P_2	T_7P_3	T_8P_1	T_8P_2	T_8P_3	T_8P_4	T_9P_1		
	T_9P_2	T_9P_3	T_9P_4	$T_{10}P_1$	$T_{10}P_2$	$T_{10}P_3$	$T_{11}P_1$				
Others	T_3P_5	T_3P_6	T_4P_4	T_4P_5	T_5P_5	T_6P_5				6	Gravely sand
	T_4P_2	T_6P_4	$T_{11}P_2$							3	Silty clay
	T_6P_6									1	Sand
Total										72	

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Figure 3: *Textural Classes of Soils in the University Farm*

The gradation curve depicted in Figure 4 provides a comprehensive analysis of the particle size distribution for sandy loam at Site A, indicating its classification as a well-graded soil. The coefficient of uniformity (Cu) for this particular sample is determined to be approximately 6.13, while the coefficient of curvature (Cc) falls within the range of $1 < Cc < 3$. Supporting this assertion, Skaggs *et al*. (2011) highlighted that well-graded soils provide plants with an optimal moisture supply when compared to poorly graded soils, as illustrated in Figure 3. In contrast, Site B presents a distinctly different scenario; it was classified as poorly graded, with a predominance of clay particles. Such soils typically exhibit limited drainage capacity and can pose significant challenges for agricultural practices due to their tendency to retain excess moisture and become compacted (Figure 3).

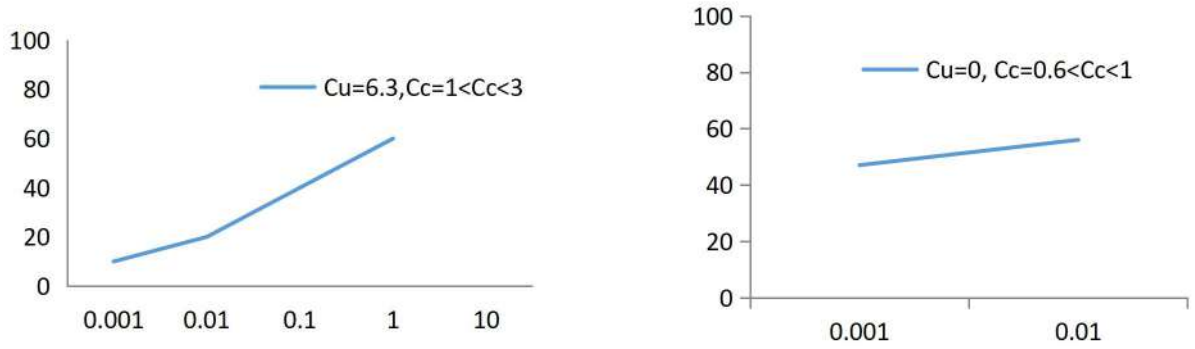

Figure 4: *Gradation Curve for Clay and Sandy Loam Soil of the University Farm*

Infiltration Rates and Infiltration Models

Table 2 and 3 provides a comprehensive information of both the measured and calculated infiltration rates across the eleven transverses evaluated in the study. The process of linear curve fitting was employed to derive the rate constants for both Horton's infiltration equation and the modified Kostiakov's infiltration model. The statistical analysis yielded notably high coefficients of determination (R^2) of 0.992 and 0.982, respectively, indicating a very strong correlation between the observed data and the predictions made by these models. This level of fit suggested that both models reliably represent the infiltration dynamics of the soils under study. Furthermore, the research conducted by Abubakar, 2015 and Abdulkadir *et al.,* (2013) has demonstrated impressive performance of the Horton model, utilizing both linear and nonlinear least squares regression techniques to derive accurate infiltration predictions.

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Table 2: Relationship between Measured and Calculated Infiltration Ratios

Measurement point	Regression equation [a]	R^2_{MK}[a]	R^2_H[b]
1	y = 2.0414x	0.970	0.981
2	y = 1.1761x	0.930	0.926
3	y = 1.3976x	0.890	0.993
4	y = 1.5441x	0.960	0.968
5	y = 2.0631x	0.970	0.934
6	y = 1.8751x	0.860	0.960
7	y = 1.954x	0.940	0.991
8	y = 1.7628x	0.960	0.992
9	y = 0.9542x	0.985	0.997
10	y = 2.1131x	0.935	0.991
11	y = 2.1139x	0.937	0.993
Mean		**0.982**	**0.992**

MK[a] = Modified Kostiatov's Model Simple Linear Recreation Coefficient $p < 0.005\%$
H[b] = Horton Model Simple Linear Recreation Coefficient $p < 0.005\%$

Table 3: Estimates of the Decay Time (min^{-1}) obtained for the Eleven Measurement Point

Measurement	K[a]	R^2
1	0.063	0.970
2	0.052	0.930
3	0.048	0.890
4	0.061	0.960
5	0.063	0.970
6	0.047	0.860
7	0.056	0.940
8	0.057	0.960
9	0.038	0.810
10	0.066	0.985
11	0.054	0.35

[a] Decay time constant from the experimental regression plot of $(f - fc/(fo - fc)$ versus time
The two-tailed T-test values between R^2 values for both Horton and modifies Kostiakov's were statistically not significant at P<0.005%, hence modified Kostiakov's can be alternatively used as substitute for Horton Model in estimate of infiltration rate in the University Farm (Table 4).

Table 4: Two-Tailed T-test Result between Modified Kostiatov's and Horton Models

Sources of Variation (SV)	Models	
	Modified Kostiatov's	**Horton Model**
Mean	0.982	0.992
Std. Deviation	464	462
Std. Error mean	167.3	166.4
$P < 0.005\%$[a]	NS	NS

[a] T-test value at $p < 0.005\%$.

Moisture Retention and Release

Table 5 shows simple linear correlation analysis between the bulk density and total porosity. The result indicated at both 0-15 and 15-30 cm, porosity was negatively correlated with bulk density. The implication is that, increase in bulk density will drastically reduce total porosity. Decrease in total porosity with increase in bulk density was similar to the trend reported by Abubakar (2015) in DNPK field in samaru. This trend was attributed to increase in bulk density and clay content with increase in depth. Abdulkadir and Habu (2013) reported that organic matter increases the availability of pores space. Therefore, decrease in organic matter down the profile was reported to affect total porosity. Abubakar (2015) also observed that increase in clay content in subsoil will swell and clog conducting pores thereby decreasing the total pore space in the soil.

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Table 5: Relationship between Bulk Density and Porosity of Site A and B at 0-15 and 15-30cm respectively.

Simple linear correlation	Soil Depth (cm)	Site A		Site B	
		Bulk density	Porosity	Bulk density	Porosity
Bulk density	0 – 15	1	- 0.96	1	- 0.98
	15 – 30	1	- 0.89	1	- 0.98
Porosity	0 – 15	- 0. 92	1	- 0.80	1
	15 – 30	- 0.90	1	- 0.87	1
P < 0.005%[a]		*	*	*	*

[a] Simple linear correlation p < 0.005%

As illustrated in Figure 5, at tensions of 0.33, 0.5, and 1 bar, sandy loam exhibits a negative correlation with clay soil. This suggests that sandy loam retains less water under these tensions at both 0-15 and 15-30cm, making it more readily available for plant uptake compared to the clay soil of the University farm. Furthermore, at tensions of 5, 10 and 15 bars, clay soil shows a negative correlation with sandy loam. This indicates that, at higher tensions, clay soil retains a greater amount of water than sandy loam. Weil *et al.,*(2015) and Fernando *et al.,* (2002) have defined plant-available water as that held at matric potentials ranging from -10 kPa (-0.1 bar) to -300kPa (-3 bar).

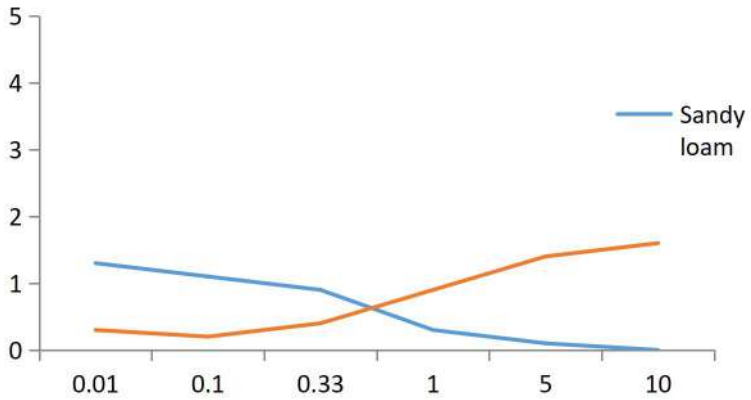

Figure 5*: Moisture Retention Curve for Sandy Loam (Site A) and Clay Soil (Site B) of the University Farm.*

CONCLUSION AND RECOMMENDATION

In conclusion, the linear curve fitting for both Horton and modified Kostrakov's infiltration equations yielded a positive coefficient of determination(R) of 0.992 and 0.982 respectively. The simple linear correlation between bulk density and total porosity at both 0-15 and 15-30cm indicated a negative correlation between total porosity and bulk density respectively. The results of the research ought to be integrated into plant response-based models as an element of precision agriculture. Therefore, it is recommended that sandy loam with preponderance of small, medium and large soil particles was capable of retaining soil moisture at different tension levels should be preferably used for farming activities in the University farm.

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MORPHOMETRIC CHARACTERISTICS OF RED SOKOTO GOATS IN SOME SELECTED LOCAL GOVERNMENT AREAS OF BAUCHI STATE, NIGERIA

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ABSTRACT
The study was conducted to determine the morphometric characteristics of Red Sokoto Goats (RSG) in Dambam, Gamawa and Misau Local Government Areas of Bauchi State. A total of six hundred (600) RSG were used for the study, out of which 121 were males and 479 were females. Body condition score (BCS) was assessed subjectively through principally massaging the loin region, abdominal fat and chest cavity and scored using the 5 points scale (where; 1 = very thin, 2 = thin, 3 = average, 4 = fat and 5 = Very fat/ obese) for both sexes. The effects of location and sex on morphometric characteristics were also determined. The qualitative traits recorded via visual observation included: coat colour, presence or absence of beard, wattle and supernumerary teat. Morphometric traits measured using tailor's tape and recorded in cm were: head length, ear length, horn length, chest girth, height at wither, body length, loin girth, rump length, rump height, rump width, tail length, udder length, udder circumference, teat length, scrotal circumference and scrotal length. The live body weight was measured using a digital weighing scale in kg. However, the study revealed that the RSG found in Gamawa had the highest values for all the significantly different parameters, while the least values were recorded on RSG in Misau (38.26±0.41 vs 24.16±0.41). Sex is confirmed to have influence on live weight ($P < 0.05$) where the male appeared to be heavier than the female animals. The effects of qualitative traits on morphometric characteristics were determined and found out that they have little to less impact on growth parameters.

Keywords: Beard, Body Condition Score**,** Morphometric characteristics, Goats.

INTRODUCTION
Small ruminants are valuable genetic resources in the tropics and subtropics, where they play a great role in the sustenance of the livelihoods of less able families especially in the rural communities. In Nigeria, they represent about 63.70% of the total grazing domestic animals (Yakubu *et al.,* 2010). The goat is a household animal and its importance cannot be over emphasized. This livestock asset could be seen as "bank account" and it is also an important source of family savings that can be used in years of low crop production, reducing income insecurity and household vulnerability (Elisa *et al.,* 2015). Goats perform the task of supplying human population with meat, milk, skin, hair and other products. The World Health Organization (WHO) recommended protein requirement of an adult is 0.5- 1.0g per kg body weight per day (65g per day) (Juliette, 2017). Goat milk is a vital source of protein, fat, calcium, iron, phosphorous, magnesium, and vitamins, particularly vitamin A. Recent studies have shown that several of these vitamins from goat milk are more easily absorbed than cow milk (Peacock, 2008). The small fat globule of goat milk makes it more easily digestible than cow milk and therefore particularly suitable for children and the sick (Sachin *et al.,* 2017). However, goat milk is more easily digested than cow milk due to the absence of agglutinins (Maria *et al.,* 2017).The characterization of local genetic resources depends on the knowledge of the variation of morphological traits, which have played a very essential role in the classification of livestock based on size and shape (Yakubu *et al*., 2010a). Size and conformation are important characteristics in meat animals especially ruminants. Traditionally, animals are usually assessed visually, which is a subjective method of judgment (Fajemilehin and Salako, 2008).Red Sokoto goats are one of the most important indigenous breed of goats in Nigeria. They are more adaptable to the climatic conditions of Northern Nigeria. These breed of goats are not adequately

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characterized and an appropriate design of breeding procedure is impossible for breeds that have not been adequately characterized either phenotypically and/or genetically (Mwacharo *et al.,* 2002).

MATERIALS AND METHODS

Study Location

The study was carried out in Dambam, Gamawa and Misau Local Government Areas of Bauchi State. Bauchi State occupies a total land area of 49,119 km^2 (18,965 sq mi) representing about 5.3% of Nigeria's total land mass and it is located between latitudes 9º 3'N and 12º 3'N of the equator and longitudes 8º 50' and 11ºE of the Green Which Meridian. Dambam, Gamawa and Misau are located between 11º 40' 48" N and 10º 42' 32" E, 12º 08' N and 10º 32' E, 11º 19' 6" N and 10º 28' 4" E, respectively. The State is bordered by seven States; Kano and Jigawa to the North, Taraba and Plateau to the South, Gombe and Yobe to the East and Kaduna to the West. Bauchi State has two distinctive vegetation zones, namely, the Sudan and the Sahel Savannah. Sudan savannah vegetation covers the Southern part of the State. Sahel type of the savannah, which is also known as the semi-desert vegetation, becomes manifest from the middle of the State as one moves from the State's South to its North. This type of vegetation comprises isolated stands of thorny shrubs. On the other hand, the Southwestern of the State is mountainous as a result of the continuation of the Jos Plateau, while the Northern part is generally sandy. The vegetation types are conditioned by the climatic factors, which in turn affects the amount of rainfall received in the area. For instance, the rainfall in Bauchi State ranges between 1,300 millimeters per annum in the South and only 700 millimeters per annum in the extreme North (https//www.bauchistate.gov.ng>history, 2019).

Method of Data Collection

Live weight in kg was measured along with sixteen (16) linear body measurements (LBM) in cm on each animal. The LBM were: head length (HDL), ear length (EL), horn length (HL), chest girth (CG), height at wither (HW), body length (BL), loin girth (LG), rump length (RL), rump height (RH), rump width (RW), tail length (TL), udder length (UL), udder circumference (UC), teat length (TTL), scrotal circumference (SC) and scrotal length (SL) all in cm. The height measurements (cm) were done using a graduated measuring stick. The length, circumference and the width measurements (cm) were done using a tape rule (Tailor's tape). While the weight (kg) was measured using a weighing scale.

Data Analysis

Body condition score, live weight (kg), linear body measurements (cm) and qualitative parameters of each of the animals were coded into spreadsheets. Data collected were subjected to descriptive statistics and were analyzed using Statistical Package for Social Sciences (SPSS version 22, 2013) using the General Linear Model (GLM) procedure. The effects of class variables were expressed as overall mean ± SE. Significantly different means were separated using Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Effect of Location on Body Condition Score, Live Weight and Morphometric Traits

Table 1 showed the mean effect of location on body condition score, live weight and morphometric traits of Red Sokoto goats. Live weight (kg) was significantly ($P<0.001$) higher in Gamawa than in Dambam and Misau (38.26±0.41,31.27±0.41and 24.16±0.41) respectively. There was no significant ($P>0.001$) difference in the body condition score among the locations. The result of this study was slightly higher than the report of Adamu *et al.*(2020) onRed Sokoto and Sahel goats**.**There were significant ($P<0.001$) effect of location in Head length, Ear length, Horn length, Chest girth, Height at wither, Body length, Loin girth, Rump length, Rump height, Rump width, Tail length, Udder length, Teat length , Scrotal circumference and Scrotal length.The RSG found in Gamawa local government had the highestvalues for all the significantly affected traits, while the leastvalues were recorded in Misau local government. This agrees with the work of Ijomanta, (2012) who reported that zone (Katsina, Daura and Malumfashi) had effect on body weight andmorphometric characteristics of Red Sokoto goats in Katsina State of Nigeria. This observed variationis attributed to

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varied feed availability and management practices in the study areas. Similar assertion was also made by Mekuriawa *et al*. (2013) and Tesfay *et al*. (2017).

Table 1 Effect of Location on Body Condition Score, Live Weight and Morphometric Traits

		Location			
Parameters	**Overall mean ± S.E**	**Dambam**	**Gamawa**	**Misau**	**LOS**
BCS	3.45±0.09	3.45±0.10	3.45±0.10	3.45±0.10	NS
LW	31.23±0.37	31.27±0.41^{b}	38.26±0.41^{a}	24.16±0.41^{c}	***
HDL	19.02±0.22	18.95±0.25^{b}	21.75±0.25^{a}	16.37±0.25^{c}	***
EL	16.82±0.31	16.97±0.35^{b}	18.97±0.35^{a}	14.52±0.35^{c}	***
HL	15.15±0.40	16.22±0.45^{b}	17.94±0.45^{a}	11.27±0.45^{c}	***
CG	70.98±1.26	70.55±1.42^{b}	78.65±1.42^{a}	63.73±1.42^{c}	***
HW	64.46±0.53	64.23±0.60^{b}	78.65±0.60^{a}	59.84±0.60^{c}	***
BL	65.70±0.67	65.05±0.76^{b}	76.05±0.76^{a}	55.99±0.76^{c}	***
LG	71.16±1.21	77.40±1.37^{b}	89.40±1.37^{a}	46.70±1.37^{c}	***
RL	15.46±0.45	15.75±0.51^{b}	18.26±0.51^{a}	12.37±0.51^{c}	***
RH	46.33±1.07	60.99±1.21^{b}	65.41±1.21^{a}	59.60±1.21^{c}	***
RW	14.45±0.44	14.76±0.49^{b}	17.48±0.49^{a}	11.11±0.49^{c}	***
TL	14.98±0.41	14.88±0.46^{b}	16.41±0.46^{a}	13.64±0.46^{c}	***
UL	14.88±0.28	14.51±0.36^{b}	16.75±0.36^{a}	13.40±0.36^{c}	***
UC	33.82±0.57	33.34±0.74	34.34±0.74	33.79±0.74	NS
TTL	3.81±0.10	3.73±0.12^{b}	4.37±0.12^{a}	3.34±0.12^{c}	***
SC	17.59±0.17	17.88±0.27^{a}	18.46±0.27^{a}	16.44±0.27^{b}	***
SL	13.83±0.17	13.85±0.27^{b}	15.01±0.27^{a}	12.62±0.27^{c}	***

BCS: Body condition score, LW: Live weight, HDL: Head length, EL: Ear length, HL: Horn length, CG: Chest girth, HW: Height at wither, BL: Body length, LG: Loin girth, RL: Rump length, RH: Rump height, RW: Rump width, TL: Tail length, UL: Udder length, UC: Udder circumference, TTL: Teat length, SC: Scrotal circumference, SL: Scrotal length.
S.E = Standard error, NS= No significant differences, LOS= Level of significant.
***= ($P < 0.001$). a, b, c= Numbers with diff. superscript within the same row are statistical different.

Effect of Sex on Body Condition Score, Live Weight and Morphometric Traits

Influence of sex on live weight and linear body measurements are shown in Table 2. The fact that sex had effect on live weight as reported in the present study agrees with the finding of Inthujaa *et al*. (2018) who reported that male Batticaloa goats native to Sri Lanka were 19 % (5.8 kg) heavier than females. The reports of Gelana and Belete (2016) in indigenous goats of South East Ethiopia depicted that bucks were superior to does in terms of live weight and linear body traits. Fajemilehin and Salako (2008) and Bedada *et al*. (2019) revealed that morphometric characteristics are sexually dimorphic and could be due to effect of androgenic hormones. Similarly, earlier report showed that Red Sokoto bucks had significantly higher live weight and chest girth than Red Sokoto does, while the latter had longer body length and higher height at wither than the former (Ojedapo *et al*., 2007). The work of Alemu (2015) among central highland goats of Abergelle showed that male kids were heavier at birth than females (2.34 ± 0.03 kg vs 2.25 ± 0.03 kg) and that this effect decreases as the animal ages. The author associated this early life differences (weight at birth) between the two sexes to hormonal variation which could probably be androgen. Working on Ethiopian native sheep, Aklilu *et al*. (2013) reported higher value for live weight in males than females and observed that most linear body traits are sexually dimorphic. The work of Tesfay *et al*. (2017) in some selected districts of Ehiopia (Tanqua-Abergelle, Kola-Tembien and Adwa) depicted the considerable effect of sex on body measurements and was attributed to differential effects of androgens and estrogens in males and females, respectively. Androgenic hormones promote larger muscle and longer bone development in males (Thiruvenkaden, 2005; Semakula *et al*., 2010; Taye *et al*., 2011). Sownade and Sobola (2008) linked the differences observed between the two sexes to genes located on sex chromosomes. The authors suggested that the higher growth rate and larger body size observed in males could be as a result of Y-chromosomes which initiate the production of sex hormone in bucks and other male

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livestock species. On the contrary, some investigators (Jimcy *et al*., 2011; Okpeku *et al*., 2011) reported that matured female does had higher values for both live weight and biometric traits than bucks. This is in conformity with the findings of Rotimi *et al*. (2016) who showed that matured does had higher body mass than bucks in Red Sokoto goats. This could be as a result of small sample size of bucks or negative selection where bigger males were castrated and fattened for economic purposes (Ijomanta, 2012). Similar assertion was also made by Osuhor *et al.*(2002).

Table 2: Average Body Condition Score, Live Weight and Morphometric Traits (Linear body measurements) According to Sex.

		Sex		
Parameters	**Overall mean ± S.E**	**Male**	**Female**	**LOS**
BCS	3.45±0.09	3.77±0.15	3.12±0.06	***
LW	31.23±0.37	31.96±0.63	30.50±0.24	*
HDL	19.02±0.22	19.33±0.39	18.71±0.15	NS
EL	16.82±0.31	17.51±0.54	16.14±0.21	**
HL	15.15±0.40	15.89±0.68	14.40±0.26	*
CG	70.98±1.26	73.02±2.16	68.93±0.83	NS
HW	64.46±0.53	66.32±0.91	62.61±0.35	***
BL	65.70±0.67	66.86±1.16	64.54±0.45	*
LG	71.16±1.21	73.24±2.08	69.08±0.80	*
RL	15.46±0.45	16.01±0.78	14.91±0.30	NS
RH	46.33±1.07	47.99±1.84	44.67±0.71	NS
RW	14.45±0.44	14.86±0.75	14.04±0.29	NS
TL	14.98±0.41	15.84±0.70	14.12±0.27	*

BCS: Body condition score, LW: Live weight, HDL: Head length, EL: Ear length, HL: Horn length, CG: Chest girth, HW: Height at wither, BL: Body length, LG: Loin girth, RL: Rump length, RH: Rump height, RW: Rump width, TL: Tail length.
S.E = Standard error, NS= No significant differences, LOS= Level of significant.
* = ($P < 0.05$), ** = ($P < 0.01$), *** = ($P < 0.001$).

CONCLUSION AND RECOMMENDATION

It can be concluded that the Red Sokoto goats (RSG) found in Gamawa L.G.A. had the highest values for all the significantly different parameters, while the least values were recorded on RSG in Misau L.G.A. (38.26±0.41 vs 24.16±0.41). Sex is confirmed to have influence on live weight ($P < 0.05$) where the male appeared to be heavier than the female animals. The effects of some qualitative traits on morphometric characteristics were determined and found out that they have little to less impact on growth parameters. Further study should be conducted on morphological and morphometric characteristics with a larger population of goats, as this could possibly help in selection, thereby, improving the productivity of goats.

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AN INVESTIGATION OF PROFIT EFFICIENCY OF DRY SEASON VEGETABLE FARMING BUSINESS ALONG RIVER BENUE BANK IN MAKURDI LOCAL GOVERNMENT AREA OF BENUE STATE, NIGERIA

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ABSTRACT
The study investigated the profit efficiency of dry season vegetable farming business along River Benue Bank in Makurdi Local Government Area of Benue State, Nigeria. The study described socioeconomic characteristics of the farmers and examined profit efficiency of dry season vegetable farming. Data were collected from 125 respondents that were selected using multistage sampling procedure. Descriptive and inferential statistics were used to analyse the data. The result showed that 64.80 % of the farmers were male with average age of 42.18 years and 84.00 % were married with average household size of about 7. Result of the Cobb-Douglas stochastic frontier profit model reveals an average profit efficiency of 0.49. The inefficiency model showed that age (-0.6509167) and education (-5.535188) have decreasing effects on profit inefficiency and household size (1.084588) has increasing effect on profit inefficiency. The study concludes the dry season vegetable farming profit efficiency is low and is significantly influenced by age, household size and level of education of the farmers. Also, dry season vegetable production in the study area is dominated by males who are still in their active age and married with household size that can supply family labour. The farmers can read and write. The study recommends that, there is need to encourage farmers to explore alternative marketing channels such as direct sales to consumers to increase profit margins; farmers should be advice to consider diversifying vegetable production to include high-value crops that can increase profitability; training and capacity building programmes should be provided to farmers through informal education using extension agents to improve production and marketing skills of the farmers; there is need to invest in infrastructure such as storage facilities and transportation networks to reduce spoilage and improve market access and policies such as provision of subsidies and credit facilities should be developed to support small-scale farmers.

Keywords: Profit, Efficiency, Vegetable, Dry Season, Irrigation.

INTRODUCTION
Agriculture sector is vital to the economy of Nigeria as it contributes significantly to gross domestic product (GDP), employment and food security of the country. Farming activities along the River Benue bank in Makurdi, Benue State, play a crucial role in supporting the livelihoods of local communities. The River Benue, one of Nigeria's major rivers, provides a reliable source of water for irrigation, making it an ideal location for dry season farming (Adebayo *et al*., 2017). Dry season farming is an important aspect of agriculture, especially in regions with limited rainfall. Access to irrigation water from nearby water bodies plays a vital role in sustaining crop production during this period (Adewumi and Laniyan, 2020). Irrigation water management is essential for improving agricultural productivity and food security, especially in the face of climate change (IPCC, 2019).

Growing crops during the dry season enables farmers to tap into markets with higher demand and prices which enhances their profit efficiency (Adebayo *et al*., 2020). This enables farming households to generate income throughout the year, improving their overall livelihoods (Olukosi *et al*., 2019).

Consumption of vegetable has continued to witness a global expansion that is greater than any other plant group (Yakubu *et al*., 2019). This is connected to their valued phytochemical contents and the diversity of plant species that can be exploited for their fruits, flowers, tubers or leaves as vegetables. Moreover, technological advancements have made their production more attractive due to

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less disease incidence and pest attack. Vegetables are now considered as key contributors to the pursuit of sustainable development especially in third world countries like Nigeria where they are cheap sources of vital nutrients and energy as well as a means of improving income equality and employment.

Vegetable production play important role by providing essential nutrients in diets, improving livelihoods and contributing to food security (Adeyeye *et al*., 2020). Vegetables are rich in vitamins, minerals and fiber making them a vital part of healthy diet (Oluwafemi *et al*., 2019). Vegetable production increases food availability and accessibility especially in rural area where access to other sources of nutrients may be limited. Vegetables farming generates income for farmers, creates employment opportunities and contributes to national economy (Olukosi *et al*., 2020). Vegetables have medicinal properties and can help prevent certain diseases (Afolabi *et al*., 2018).

Vegetable consumption in Nigeria is deemed to be lower than recommended daily intake with high costs and seasonality being major deterrents (Okoronkwo and Okoronkwo, 2020). This study provides empirical information on profit efficiency of dry season vegetable production along River Benue Bank within Makurdi Local Government Area of Benue State, Nigeria.

The persistent rise in prices of vegetables in Nigeria has significant consequences for households, including reduced food security, increased poverty, and decreased quality of life. The problem is further exacerbated by low output as a result inefficient production resource management and over dependence on rainfed seasonal production.

Dry season vegetable production along river banks is a vital agricultural activity that provides a source of income and food security for many farming households in Nigeria (Adeyeye *et al*., 2020). The proximity to water sources enables farmers to cultivate crops year-round, taking advantage of favorable market conditions during the dry season (Olaniyi *et al*., 2019).

Despite its potential, the profitability of this venture is often hindered by various factors that affect the efficiency and productivity of farmers. Dry season vegetable production along river banks may not be as profitable as it could be due to inefficient production practices, lack of access to markets, and inadequate pricing strategies (Adebayo *et al*., 2020). This can lead to reduced income for farmers, making it difficult for them to sustain their livelihoods and invest in their farms (Olukosi *et al*., 2020).

There is largely a limited understanding of the effects of climate change adaptation strategies on rice production efficiency especially in Benue State, Nigeria. As a result of the gap in quantitative assessments of efficiency of rice production under various climate change adaptation strategies and the inability to complement local practices with formal climate change adaptation strategies, there is need for more empirical research on the effects of climate change adaptation strategies on rice production efficiency.

Limited access to markets makes make it difficult for farmers to sell their produce, leading to reduced profitability. Farmers may have to rely on middlemen or traders, who may offer low prices for their produce. The high costs of inputs such as seeds, fertilizers, and pesticides can reduce the profitability of dry season vegetable production. Farmers may struggle to afford these inputs, leading to reduced yields and lower quality produce (Adeyemo *et al*., 2019).

Therefore, it is essential to investigate the economics of dry season vegetable production along River Benue Bank in Makurdi Local Government area of Benue State, Nigeria. The study described the social economic characteristics of the respondents; investigated the profit efficiency of dry season vegetable production and identified the constraints to dry season vegetable production.

METHODOLOGY

Study Area

The study area is Makurdi Local Government Areas (LGA) of Benue State, Nigeria. Makurdi LGA is located in the Northwest agricultural zone of the state. The clayey soil drains the soil poorly thereby making Makurdi area marshy and liable to flooding. However, the soil supports the cultivation of wetland rice and sesame. The climate is typically tropical, with marked dry season from November to March and wet season from April to October. Annuals rainfalls of 1,300 to 1,500mm are

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common. Average annuals temperatures are high, fluctuating between 28ºC and 32ºC. Dry woodland savannah is naturally found in the Makurdi area. Common trees are locust beans, shea butter and gmelina. Alluvial soils containing a lot of organic matter are common (Dada, 2006).

The estimated population of Makurdi LGA in 2024 based on 2006 Census is 472,000. It is the second most populous LGA in Benue State after Gboko LGA. The densely populated areas of High Level, Modern Market and Wurukum are business districts. The indigenes of Makurdi LGA are the Mbagwen, Nyiev, Mbawa, Kyoodu Usha (a section of Masev) and Ugondo. These are politically structured into ten council wards. Farming and trading are the main economic activities in Makurdi area. The farmers produce livestock, vegetables, soy beans, millet and sesame. Trading in provisions, electronics and other consumer goods are also common. Fishing on the River Benue is also done on medium scale (Dada, 2006).

Sampling Procedure

The employed a multi-stage sampling procedure. The multi-stage sampling procedure involves the following steps: Foremost, River Benue has North and South Banks in Makurdi LGA. Data were collected from both banks of the river as dry season farming is carried out on both banks the river.

The second stage involved the selection Council Wards. Five Council wards - two from North Bank and three from South Bank were selected purposively based on proximity with River Benue Bank, predominance in vegetable farming business and accessibility.

Third stage involved the random selection of vegetable farmers. Twenty-five (25) vegetable farmers were selected from each of the selected Council wards. This procedure will generate a sample size of one hundred and twenty-five (125).

Method of Data Collection

Data for the study were collected from primary source. Structured questionnaires were used to collect data for the study. The questionnaire focused on socioeconomic characteristics, cost of inputs, revenue and constraints to vegetable production. Content validity was used to ascertain the adequacy of the items included in the questionnaire. To ensure reliability of the questionnaire: pre-test, pilot-test and test-retest were conducted. All information provided by participants were kept in confidence and used solely for the purpose of the study.

Analytical Techniques

The study used descriptive statistics such as mean, frequency and percentage to describe and identify the socioeconomic characteristics of the respondents and constraints to dry season farming along River Benue Bank.

Stochastic frontier profit function was used to estimate and investigate the profit efficiency of vegetable farmers. The data were fitted into the Cobb-Douglas profit functional form. The model is specified as:

$$\ln(\text{profit}) = \beta_0 + \beta_1 \ln(\text{rent}) + \beta_2 \ln(\text{seed cost}) + \beta_3 \ln(\text{wages}) + \beta_4 \ln(\text{fertilizer cost}) + \beta_5 \ln(\text{herbicide cost}) + \beta_6 \ln(\text{pesticide cost}) + \beta_7 \ln(\text{irrigation cost}) + v_i + \mu_i \quad \text{.....(1)}$$

Where:
Profit was measured in Naira.
Rent was measured in Naira.
Seed cost was measured in Naira.
Wages were measured in Naira.
Fertilizer was measured in Naira.
Herbicide cost was measured in Naira.
Pesticide cost was measured in Naira.
Irrigation cost was measured in Naira.
β_0 is intercept.
β_1 to β_7 are parameters to be estimated.
v_i are random error terms.

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μ_i are inefficient effects.

$$\mu_i=\delta_0+\delta_1(\text{age})+ \delta_2(\text{household size})+ \delta_3(\text{education})+ \delta_4(\text{off farm income})+ \delta_5(\text{farm size}) \quad .....(2)$$

Where:
Age of the household head was measured in years.
Household size was measured as number of persons living together in given home.
Education was measured in years spent in formal education.
Off farm income is annual off farm income was measured in Naira.
Farm size was measured in hectares.

RESULT AND DISCUSSION

Socioeconomic Characteristics

The findings revealed that 64.80 % of the respondents were male and 35.20 % were female. This means that vegetable farming in the study area is dominated by males. This might call for increase female involvement in vegetable farming in the study area for gender balance. This result agrees with findings of Kebede *et al*. (2024) that majority of the farmers who practice irrigation water management in Jimma Zone of Ethiopia are male.

The result of the study in Table 1 showed that 43.20 % of the respondents were within the age of 41-50 years of age, 32.20 % were within the of 31-40 years of age, 14.40 % of the respondents were at least 50 years of age and 11.20 % were at most 30 years of age. The result reveals also that the average age of the respondents was 42.18 years. This result might mean that the respondents are relatively young and still in the active age. This implies that production can move towards an increase. The result contradicts Onuk *et al*. (2017) who found that the average age of dry season vegetable women farmers in Makurdi Local Government Area of Benue State, Nigeria is 35.9 years.

The results showed that 84.00 % of the respondents were married, 11.20 % were single, 3.20 % were widowed and 1.60 % were divorced. This means that majority of the vegetable farmers in the study area were married. This implies that the respondents are responsible and will be able minimise cost of production to improve profit efficiency in the farming business. This result corroborates the result of Onuk *et al*. (2017) that majority of dry season vegetable women farmers in Makurdi Local Government Area of Benue State, Nigeria are married.

Results in Table 1 indicated that 50 % of the respondents had household size of 6-10 persons while 36.80 %, 11.20 % and 1.60 % had household size of 6 persons or less, 11-15 and 16 persons and above respectively with an average household size 7 persons. This result means that the farmers have large household size and family labour could be readily available. This result is similar with the findings of Shuaibu *et al*. (2020) who reported an average household size of 8 among fluted pumpkin farmers in Sabon Gari Local Government Area of Kaduna State, Nigeria.

The results of this study as presented in Table 1 showed that 36.80 % of the respondents had tertiary education, 33.60 % of the respondents had secondary education, 24.00 % had no formal education and 5.60 % had primary education. This result means that most of the respondents had at least primary education or its equivalent and this implies that the farmers can read and write. This result contradicts the result of Dam (2012) who found that majority of dry season vegetables farmers in Floodplains of River Katsina-Ala in Katsina-Ala Town of Benue State, Nigeria had no formal education.

The results of the study presented in Table 1 revealed that 52.80 % of the respondents earn at most ₦100,000 from off farm employment annually, 27.20 % earn ₦100,001-₦200,000, 12.00 % earn ₦200,001-₦300,000 and 8.00 % earn at least ₦300,001 annually from off farm employment. The average annual off farm income of the vegetable farmers in the study area is ₦147,784. This might be used to support farming business in order improve economics of scale or scope.

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Table 1: Distribution of Respondents according to Socioeconomic Characteristics

Variables	Frequency	Percentage	Mean
Sex			
Female	44	35.20	
Male	81	64.80	
Age			**42.176**
≤30	14	11.20	
31-40	39	31.20	
41-50	54	43.20	
≥51	18	14.40	
Marital status			
Single	14	11.20	
Married	105	84.00	
Divorced	2	1.60	
Widowed	4	3.20	
Household size			**7.136**
≤5	46	36.80	
6-10	63	50.40	
11-15	14	11.20	
≥16	2	1.60	
Education level			
No education	30	24.00	
Primary	7	5.60	
Secondary	42	33.60	
Tertiary	46	36.80	
Off-farm income			**147,784**
≤100000	66	52.80	
100001-200000	34	27.20	
200001-300000	15	12.00	
≥300000	10	8.00	

Source: Field survey, 2025

Profit Efficiency of Dry Season Vegetable Farming

The result of the Cobb-Douglas stochastic frontier profit model shows that there was variation in profit efficiency among the dry season vegetable farmers in the study area. Table 2 show that 44.20 % of the farmers had profit efficiency of 0.31-0.60, 27.40 % of the respondents had profit efficiency of 0.30 or less 18.60 % had 0.61-0.91 profit efficiency and 9.80 % of the farmers had profit efficiency of 0.90 or more. The average profit efficiency varied from 0.11 to 0.99 with an average profit efficiency of about 0.49.

The Cobb-Douglas stochastic frontier profit model with inefficiency effects was used in this study as it best fit the data for the study. The Maximum Likelihood Estimates for the parameters were presented in Table 3. Rent for land (0.5626725), cost of planting material (0.3587662), wages for labour (0.0434469), cost of fertilizer (0.043465), cost of pesticide (-0.1515658), cost of herbicides (0.0481057) and irrigation cost (-0.0111802) were highly significant ($P<0.01$). The estimated value for the gamma (1.0000) and sigma square (27.96615) were all significant ($P<0.01$) level of probability and this indicates that the profit inefficiency is significant for dry season vegetable production in the study area. The gamma parameter shows the relative magnitude of the variance in profit associated with profit inefficiency. The derived coefficients from the Maximum Likelihood Estimates represent the percentage change in the explained variable as a result of the percentage change in the explanatory variables. The significance of the gamma (at 1% level of probability) implies that the variables included in the inefficiency effects as well as the cost of production resources significantly influenced profit efficiency of dry season vegetable farming business. The independent variables included in the inefficiency effects model are; age, household size, years of education, off farm income and farm size.

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The coefficient for age (-0.6509167) was negative and significant (P<0.01). This means that age had decreasing effect on profit inefficiency of dry season vegetable farming in the study area during. This implies that an increase in age will result in an increase in profit efficiency of dry season vegetable production in the study area. This result disagrees with the result of Ajapnwa *et al*. (2017) who found a negative relationship between efficiency of vegetable production and age of the producers in the humid tropics of Cameroon.

The estimated coefficient for household size (1.084588) was positive and significant (P<0.05). This result means that, an increase in household size will lead to increase in profit inefficiency. This result implies that profit efficiency of dry season vegetable production in the study area decreases with increase in household size. This result corroborates the findings of Mbanasor and Kalu (2008) who found a negative relationship between household size and economic efficiency of commercial vegetable production.

The study shows that, education has negative coefficient (-5.535188) and was statistically significant (P<0.01). This means that education decreased profit inefficiency and increased profit efficiency of dry season vegetable farmers in the study area during. This result contradicts the result of Mbanasor and Kalu (2008) who found a negative relationship between economic efficiency and education level of commercial vegetable producers in Akwa Ibom State, Nigeria.

Table 2: Distribution of the Respondents based on Profit Efficiency

Profit efficiency		**Frequency**	**Percentage**
≤0.30		69	27.40
0.31-0.60		111	44.20
0.61-0.90		47	18.60
≥0.91		24	9.80
Maximum	**0.99**		
Minimum	**0.11**		
Mean	**0.49**		

Source: Field survey, 2025

Table 3: Maximum Likelihood Estimates (MLE) of the Stochastic Frontier Profit Model

Variables	**Coefficient**	**St. Err.**	**t-value**	**p-value**	**Sig.**
Rent for land	0.5626725	0.000138	4.13	0.000	***
Cost of seed	0.3587662	0.000389	9.24	0.000	***
Wages of labour	0.0434469	0.000279	16.98	0.000	***
Cost of fertilizer	0.043465	0.000292	15.11	0.000	***
Cost of pesticide	-0.1515658	0.000113	-13.98	0.000	***
Cost of herbicide	0.0481057	0.000900	5.32	0.000	***
Cost of irrigation	-0.0111802	0.000649	-17.43	0.000	***
Constant	4.728646	0.000012	3.19	0.000	***
Inefficiency effects					
Age	-0.6509167	0.185599	-3.51	0.000	***
Household size	1.084588	0.535738	2.02	0.043	**
Education level	-5.535188	1.342825	-4.12	0.000	***
Off-farm income	0.000539	0.000014	0.39	0.695	
Farm size	2.205026	1.7816135	1.23	0.217	
Constant	2.577625	7.738687	0.33	0.739	
Diagnostic parameters					
Sigma squared	27.96615	0.029703	31.13	0.000	***
Gamma	1.000000	0.000021	3.85	0.000	***

Source: Field survey, 2025

CONCLUSION AND RECOMMENDATION

The study concludes the dry season vegetable farming profit efficiency is low and is significantly influenced by age, household size and level of education of the farmers. Also, dry season

vegetable production in the study area is dominated by males who are still in their active age and married with household size that can supply family labour. The farmers can read and write.

Based on the finding of the study, the following recommendations are made:

i. There is need to encourage farmers to explore alternative marketing channels such as direct sales to consumers to increase profit margins.
ii. Farmers should be advice to consider diversifying vegetable production to include high-value crops that can increase profitability.
iii. Training and capacity building programmes should be provided to farmers through informal education using extension agents to improve production and marketing skills of the farmers.
iv. There is need to invest in infrastructure such as storage facilities and transportation networks to reduce spoilage and improve market access.
v. Policies such as provision of subsidies and credit facilities should be developed to support small-scale farmers.

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EFFECT OF INSURGENCY ON FOOD CROP PRODUCTION IN THE ARID AGRO-ECOLOGICAL ZONE: A CASE STUDY OF FIKA LOCAL GOVERNMENT AREA, YOBE STATE, NIGERIA

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ABSTRACT
The study investigated the effect of insurgency on food crop production in the arid agro-ecological zone of Fika Local Government Area, Yobe State, Nigeria. Multistage sampling technique was used to select 390 respondents from the study area. Data were collected using structured questionnaires and analyzed using descriptive and inferential statistical tools. The results showed that majority (70%) of the farmers were male while 35.1% were within the economically active age bracket of 31–40 years, and 50% had moderate household sizes (5–8 members). Educational attainment was generally low, with 40% having no formal education. Farm sizes were predominantly small-scale (1–3 hectares), and 40% of respondents earned below ₦50,000 annually. Extension services and access to credit were limited, reaching only 40% and 30% of the farmers respectively. Respondents with the mean score (4.30) strongly agreed that insurgency led to reduced food crop production, farmland abandonment, inaccessibility of rural markets, loss of crops, increased food prices, reduced income, and widespread hunger. The results revealed that Hike in prices of commodities with mean score (4.50) strongly agree, social vices mean score (4.15) strongly agree respectively. The results further revealed that farmers adopted coping strategies such as backyard farming with the mean of (4.50) strongly agree, petty trading, reducing food quality and quantity with the mean sore (4.40) strongly agree. The results of regression analysis revealed that Age ($P<0.01$), education ($P<0.01$) farm size ($P<0.01$) and income ($P<0.01$) influenced the impact of insurgency on food crop production. The study concludes that insurgency has deeply disrupted food crop production in Fika LGA, worsening food insecurity and economic vulnerability in the arid region. The study recommends increased government investment in agricultural extension, rural credit, infrastructure, and education, alongside strengthened security and peacebuilding interventions. Promoting resilient livelihood strategies and alternative income sources is also vital to reduce.

Keywords: Insurgency, Food, Production, Arid, Rural, Resilience,

INTRODUCTION
Insurgency in Nigeria, which began in 2009, continues to undermine food security conditions, particularly in ecologically fragile regions. Since the escalation of violence in 2012, poor households in the northeastern part of the country, especially those in the arid agro-ecological zone, have experienced significant levels of food insecurity as a result of insurgency (Mudi, 2021). According to Bukar (2019), insurgency refers to a violent movement by individuals or groups who resist or oppose law enforcement or revolt against constituted authority. In the northeastern arid region of Nigeria, insurgency has displaced thousands of people—many of whom are subsistence farmers—thereby disrupting the primary source of livelihood for the rural population. The United Nations Development Programme (UNDP, 2020) emphasizes that insurgency has been a major constraint to agricultural development in West Africa, often resulting in socio-political and economic instability. Such violent conflicts frequently culminate in complex humanitarian crises, economic destruction, recurring famine, hunger, and malnutrition. For example, Flores (2014) noted that civil conflicts in Liberia and Sierra Leone during the 1990s caused long-term declines in agricultural productivity. In the same vein,

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the insurgency in northern Nigeria has led to high mortality rates, particularly among youths who constitute the majority of the agricultural labor force. Survivors are either conscripted into insurgent groups or join vigilante movements, thereby reducing the workforce available for farming (Adelaja & George, 2019). In Yobe State, particularly in Fika Local Government Area which lies within the arid agro-ecological zone—insurgency has adversely affected the cultivation of staple food crops such as maize, groundnut, beans, rice, and sorghum. Iweze (2020) noted that the insecurity has triggered rural-urban migration within Nigeria and to neighboring countries like Niger, Cameroon, and Chad. This migration primarily involves people in the productive age group, thereby diminishing the availability of farm labor. Adebayo (2014) highlighted that farmers now engage in agricultural activities at great personal risk due to rampant attacks, bombings, abductions, and killings. Such violent conditions have created an atmosphere of fear, thereby severely hindering agricultural operations. Bello, Sani, Bukar, and Rabiu (2017) asserted that national development is influenced by many factors, with security being a central element. When security deteriorates, both local and foreign investors are discouraged, stalling economic growth and employment creation. As Marvelous *et al*. (2019) explained, combating insurgency requires enormous human and material resources, which otherwise could have been allocated to development projects. For rural dwellers in arid zones, where agriculture remains the principal livelihood activity, insurgency disrupts the entire production system—from land preparation and planting to harvesting and marketing (Idris & Abubakar, 2022). In the arid zone of Fika LGA, understanding the scope of insurgency's impact on food crop production is vital for designing sustainable interventions. Displacement of farmers, restricted access to farmlands, resource scarcity, and market disruptions are just a few of the many challenges affecting agricultural productivity and food security in the region. Despite the importance of this issue, there remains a research gap concerning the localized effects of insurgency on food crop production in arid ecological zones like Fika. Existing studies often generalize the impacts of conflict on agriculture across broader regions without investigating specific dynamics such as insecurity, displacement, and ecological limitations at the local level. Therefore, this study aims to fill this gap by analyzing the effect of insurgency on food crop production within the arid agro-ecological zone of Fika Local Government Area, Yobe State, Nigeria. The main objective of the study is to analyze the effect of insurgency on food crop production in the arid agro-ecological zone of Fika Local Government Area, Yobe State, Nigeria. The specific objectives are to:

i. Examine the socio-economic characteristics of food crop farmers in Fika LGA of Yobe State, Nigeria;
ii. Determine the effect of insurgency on food crop production in the arid agro-ecological zone of Fika LGA;
iii. Assess the impact of insurgency on the socio-economic characteristics of food crop farmers in Fika LGA; and
iv. Examine coping strategies adopted by food crop farmers in Fika LGA during insurgency.

METHODOLOGY

Study Area

Fika Local Government Area (LGA) is situated in Yobe State, northeastern Nigeria, within the arid agro-ecological zone of the country. Geographically, the area lies between latitude 11°30′N and longitude 11°50′E. It is characterized by a semi-arid climate with an annual rainfall range of 500 mm to 800 mm and average daytime temperatures between 30°C and 40°C during the dry season. These climatic conditions support the cultivation of drought-tolerant crops such as millet, sorghum, maize, cowpeas, and groundnuts, which form the backbone of local subsistence agriculture (Yusuf *et al*., 2019).

As of 2023, the projected population of Fika LGA stands at approximately 150,000 people. Administratively, the LGA is divided into ten wards: Daya/Chana, Fika/Anze, Gadaka/Shembire, Gudi/Dozi/Godo Woli, Janga/Boza/Fa, Sawa/T. Nanai, Mubi/Fusami/Garin Wayo, Ngalda/Dumbulwa, Shoye/Garin Aba, Turmi/Maluri, and Zangaya/Mazawaun. In addition to crop production, the

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residents are also engaged in livestock rearing, including goats, sheep, poultry, and cattle—adapted to the harsh climatic conditions and serving as alternative sources of income (Ahmed, 2018).

Sampling Procedure

A multistage sampling technique was employed in selecting the respondents for the study. Stage 1: Four wards—Daya/Chana, Gadaka/Shembire, Shoye/Garin Aba, and Turmi/Maluri—were purposively selected based on their relative agricultural activity and exposure to insurgency-related challenges. Stage 2: From each selected ward, three (3) villages were randomly selected, resulting in twelve (12) villages in total. Stage 3: From each selected village, thirty-three (33) farmers were randomly selected using a farmer register or community list where available, bringing the total sample size to 396 respondents. For balance, this was rounded to 390 respondents, selecting approximately 32 or 33 per village.

Table 1: Selected Villages and Sample Size

Selected Ward	Selected Villages	Number of Sampled Farmers
Daya/Chana	Chana, Kukar Gadu, Yelwa	33, 32, 32
Gadaka/Shembire	Bulabulin, Dala, Hausari	33, 32, 32
Shoye/Garin Aba	Balde, Gashinge, Lampo	33, 32, 32
Turmi/Maluri	Gurjaje, Manawachi, Turmi	33, 32, 32
Total	12 Villages	390 Farmers

Analytical Techniques

Data for this study were analyzed using both descriptive and inferential statistics. Descriptive statistics such as frequencies, percentages, means, and standard deviations were used to summarize and describe the characteristics of the sampled respondents. The inferential statistics used was multiple linear regression. The explicit form of the model is expressed as follows;

$$Y = a + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + \beta_{10}X_{10} + e$$

Where:

Y = Effect of insurgency on food crop production using food insecurity index
a = Constant term
β_1–β_{10} = Regression coefficients
X_1 = Age (years)
X_2 = Gender (male = 1, female = 0)
X_3 = Marital status (married = 1, otherwise = 0)
X_4 = Education level (years)
X_5 = Farm size (hectares)
X_6 = Income (₦)
X_7 = Access to credit (yes = 1, no = 0)
X_8 = Extension contact (yes = 1, no = 0)
X_9 = Farming experience (years)
X_{10} = Household size
e = Error term

RESULTS AND DISCUSSION

Socioeconomic and Institutional Characteristics of Respondents

The demographic and institutional characteristics of the respondents revealed a farming population dominated by men (70%) and adults within the economically productive age bracket of 31–40 years (35.1%). This aligns with the findings of Adebayo and Dauda (2020), who reported similar demographic dominance in conflict-affected agrarian regions of northeastern Nigeria, where youth are less likely to stay in farming due to insecurity and migration. The average household size (5–8 members) reflects a potential labor force that, if adequately utilized, could support agricultural activities (Ahmed, 2018).

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Table 2: Socioeconomic Characteristics of the Respondents (n = 390)

Variable	Frequency	Percentage (%)
Gender (Male)	273	70.0
Age (31–40 years)	137	35.1
Household Size (5–8 members)	195	50.0
Marital Status (Married)	234	60.0
Educational Level		
No formal education	156	40.0
Primary education	117	30.0
Secondary education	78	20.0
Tertiary education	39	10.0
Farm Size (1–3 ha)	215	55.1
Annual Income (< ₦50,000)	156	40.0
Farming Experience (9–12 years)	175	44.9
Membership in Farmer Groups	117	30.0
Access to Extension Services	156	40.0
Access to Credit	117	30.0

Source**:** Field Survey, 2024

The results also revealed that education levels were generally low, with 40% of the respondents having no formal education, a situation that significantly impairs access to innovation and extension services. According to Mbah *et al*. (2017), illiteracy remains a major barrier to the adoption of improved agricultural technologies in conflict-prone zones. Moreover, limited farm sizes (1–3 ha) as reported by over half the respondents indicate a predominance of subsistence agriculture, corroborating earlier observations by Yusuf *et al*. (2019) in similar agro-ecological contexts. Furthermore, the results revealed that access to key institutional services remains poor. Only 40% of the respondents had access to extension services, and just 30% accessed credit facilities. These figures underscore systemic institutional deficiencies that hinder capacity building and resilience. Consistent with the work of Ezeomah and Okonkwo (2021), limited access to extension services in areas affected by insurgency reflects both physical insecurity and declining public sector engagement.

Effects of Insurgency on Food Crop Production

The results indicated a consensus among farmers that insurgency exerts a severe and multidimensional impact on food crop production. High mean scores for reduced production (4.30), farmland inaccessibility (4.10), and crop destruction (4.20) suggest that insurgency disrupts every aspect of the agricultural value chain—from planting to marketing. These findings are consistent with the work of Adelaja and George (2019), who reported that insurgent activities in northern Nigeria led to a drastic reduction in cultivated land and crop yields.

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Table 3: Effects of Insurgency on Food Crop Production

Effect	Mean Score	Decision
Low food crop production	4.30	Strongly Agree
Inaccessibility of farmland	4.10	Strongly Agree
Inaccessibility of rural markets	3.90	Agree
Loss of crops to insurgents	4.20	Strongly Agree
Hike in prices of commodities	4.50	Strongly Agree
Loss of invested money	4.00	Agree
Increased social vices	4.15	Strongly Agree
Increased hunger	4.40	Strongly Agree
Rural-urban migration	4.10	Strongly Agree
Reduced income	4.25	Strongly Agree

Source**:** Field Survey, 2024

Market disruption due to inaccessibility and insecurity was another significant outcome, as indicated by a high mean of 4.50 for commodity price hikes. This reflects not only scarcity in supply but also heightened transportation risks, as corroborated by Iweze (2020), who found that insecurity inflates food prices in conflict-prone areas due to disrupted logistics. Furthermore, the findings revealed that the rise in hunger (4.40), income loss (4.25), and social vices (4.15) reflects the broader socioeconomic decay induced by prolonged conflict. The forced migration of productive individuals, often youth (mean = 4.10), contributes to labor shortages, thereby compounding the decline in agricultural productivity (Bukar, 2019).

Coping Strategies During Insurgency

The results in Table 3 shows the coping strategies adopted by farmers demonstrate considerable resilience and ingenuity. The results revealed that backyard farming (4.50) emerges as the most common used strategy, serving to reduce risk exposure while maintaining minimal food supply. This aligns with findings from Yahaya *et al*. (2021), who noted that conflict-affected households often shift to small-scale subsistence gardening as a survival mechanism. Reducing food quality and quantity (4.40) illustrates the immediate effect of food insecurity on household welfare. Petty trading and migration also reflect attempts to diversify income sources and escape the most intense effects of conflict, which is consistent with the adaptive strategies observed by Agbiboa (2020) in northeastern Nigeria. Livestock rearing (4.00) provides a flexible and portable livelihood strategy, although it remains vulnerable to theft and lack of pasture in displacement contexts.

Table 4: Coping Strategies Adopted

Coping Strategy	Mean Score	Decision
Backyard farming	4.50	Strongly Agree
Reducing food quantity/quality	4.40	Strongly Agree
Petty trading	4.30	Strongly Agree
Migration	4.10	Strongly Agree
Business activities	4.20	Strongly Agree
Livestock rearing	4.00	Agree

Source**:** Field Survey, 2024

Factors Affecting Food Crop Production

The regression model shows a strong explanatory capacity ($R^2 = 0.75$), indicating that 75% of the variability in food crop production under insurgency conditions is explained by the included socioeconomic factors. Farm size ($P<0.01$) and income ($P<0.01$) were significant in influencing predictors, suggesting that larger land holdings and greater financial capital enhance resilience. These

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findings are consistent with the work of Idris and Abubakar (2022), who found that wealthier and more resource-endowed farmers in Borno and Adamawa States were better able to withstand conflict-related shocks. Education and age also significantly contribute to coping capacity, implying that older and better-educated farmers tend to adopt more effective adaptation strategies. Mbah *et al*. (2017) similarly observed that literacy and life experience play a vital role in conflict adaptation in rural agriculture. The significance of gender highlights gendered access to resources and information, echoing Ezeomah and Okonkwo's (2021) assertion that male farmers tend to benefit more from institutional support services in Nigeria.

This study critically examined the impact of insurgency on food crop production in the arid agro-ecological zone of Fika Local Government Area, Yobe State, Nigeria. Using structured questionnaires administered to 390 respondents, the study revealed a predominance of male smallholder farmers with low educational attainment and minimal access to institutional support such as credit and extension services. These socioeconomic and institutional limitations significantly affected the capacity of farmers to withstand the consequences of insurgency. Empirical results demonstrated that insurgency leads to reduced food crop production, abandonment of farmlands, loss of crops and income, market inaccessibility, and increased food insecurity. These outcomes align with prior findings by Adelaja and George (2019) and Iweze (2020), who similarly observed a collapse of the agricultural value chain in conflict-affected regions of northern Nigeria. Coping mechanisms among respondents included backyard farming, food rationing, migration, and petty trading, practices that mirror adaptive strategies reported by Yahaya *et al*. (2021) and Agbiboa (2020). Regression analysis revealed that farm size, income, age, gender, marital status, and education level significantly influenced farmers' resilience, echoing the findings of Idris and Abubakar (2022), who emphasized the centrality of socioeconomic capital in shaping agricultural adaptation under conflict conditions.

Table 5: **Factors Affecting Food Crop Production**

Variable	Coefficient	t-value	p-value
Age (X_1)	0.42	3.21	0.002**
Gender (X_2)	0.25	2.10	0.038*
Marital Status (X_3)	0.30	2.58	0.012*
Educational Level (X_4)	0.35	2.98	0.004**
Farm Size (X_5)	0.45	3.50	0.001**
Income (X_6)	0.40	3.15	0.002**

Model Summary:

- $R^2 = 0.75$
- Adjusted $R^2 = 0.73$
- F-statistic = 23.45 ($p < 0.01$)

Source: Field Survey, 2024

CONCLUSION AND RECOMMENDATION

The study concludes that insurgency presents a significant threat to agricultural sustainability and food security in the arid northeast of Nigeria. In Fika LGA, insurgency exacerbates existing vulnerabilities, particularly low literacy, poor income, and limited land access. While farmers have adopted a range of coping strategies, these responses are largely insufficient in offsetting the prolonged and multidimensional effects of conflict.

Based on the findings of this study, the following recommendations;

1. Government and relevant stakeholders should improve farmers access to extension and credit services through creating credit scheme that is affordable and accessible to all;
2. Stakeholders should strengthen food security systems through the introduction of drought resistance and climate resilient crops.

3. Government and other stakeholders should provide vocational training to farmers on alternative livelihood support program.
4. Government should enhance rural infrastructure such as feeder roads and solar powered irrigation system
5. Promote education and awareness and establish adult literacy centers and farmer field schools to increase farmers' capacity to absorb and apply technical knowledge.

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ANALYSIS OF SPATIAL AND TEMPORAL PRICE EFFICIENCY OF COWPEA (*Vigna unguiculata* [L] Walp) IN SELECTED LOCAL GOVERNMENT AREAS OF GOMBE STATE, NIGERIA

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ABSTRACT
The study analysed spatial and temporal price efficiency of cowpea (*Vigna unguiculata* [L.] Walp) in selected Local Government Areas of Gombe State, Nigeria. A multi-stage sampling technique was employed in selecting 130 cowpea merchants based on number of cowpea merchants in each market. Data were obtained from both primary and secondary sources. Secondary data were obtained on monthly average retail prices per 100kg bag of Cowpea for the period (2012 – 2019) from Bureau of Statistics, Gombe State. Data collected were analysed using spatial and temporal price models and net seasonal rise in price. The result revealed the existence of both positive and negative inter market price differential. The highest and lowest price spread for Billiri were recorded in June, 2015 (₦11,360) and February, 2018 (-₦13,700), whereas for Yamaltu Deba they were recorded in July, 2018 (₦18,400) and July, 2012 (-₦12,400), respectively. This could be due to inadequate information on prices and supply in the various markets, inefficient transportation system and other physical facilities. The highest percentage net seasonal increase in Gombe, Billiri and Yamaltu Deba were recorded in August 2012 (136.98), September 2012 (102.23) and July 2012 (160.54) respectively. It could be concluded that the pricing system of cowpea marketing in the study area was inefficient. The study recommends the establishment of adequate market infrastructures including physical buildings, road networks and storage facilities. Policy aimed at making the food distribution system efficient should be implemented. Large and sustained investment by stakeholders in cowpea marketing is also recommended so as to make cowpea production and marketing a focal business away from its present subsistence state. This can be achieved through provision of low interest loan to marketers for processing and storage activities.

Keywords: Cowpea, Marketing, Spatial, Temporal and Variation.

INTRODUCTION
The agricultural sector plays a significant role in providing employment across Africa, it is the biggest single industry employing a large proportion of labour force particularly in sub Saharan Africa where it contributes substantially to Gross Domestic Product and export. For instance, in 2023 the agricultural sector accounts for 30.1% as share of the total employment in Nigeria, (National Bureau of Statistics (NBS), 2024). The development of agriculture and the marketing systems should be at the heart of the economic growth process in less developed countries such as Nigeria. For many agricultural commodities, three facts dominate the process of marketing; agricultural commodities tend to be produced at considerable distance from centres of consumption, are often harvested within a distinct and short interval of time and consumption tends to be relatively evenly spaced in time (Nuhu *et al.,* 2009). The ability of the marketing system to allocate agricultural products over space and time has been a serious challenge. Farmers as any producers will want to sell their products at a fair profit. Hence, in order to ensure maximum profit, farmers must make their production decisions considering the most favourable place, time and form in which their products could be marketed (Haji, 2014).

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The Harvard Business School defines arbitrage as an investment strategy in which an investor simultaneously buys and sells an asset in different markets to take advantage of a price difference and generate a profit (Stobierski, 2021). Arbitrage is the process whereby a commodity is concurrently bought and sold in two separate markets to take advantage of a price variations between the two markets. Spatial pricing efficiency examines how prices in different markets over space are related, especially through transportation and other handling cost. An important step toward improving the functioning of markets in this case is to understand the nature and effects of transaction costs facing input suppliers, farmers, food retailers, and/or consumers (FAO, 2016). Post-harvest loss are direct physical and quality losses that reduce the economic value of crops, or may make them unsuitable for human consumption. In African countries, these losses have been estimated to range between 20% and 40%, which is highly significant considering the low agricultural productivity in several regions of Africa (Abass *et al.,* 2013). World Bank reported that, sub-Saharan Africa alone loses food grains worth about 4 billion United State Dollars every year (Ogundele, 2022; Zorya *et al.,* 2011). Despite nutritional and economic value of cowpea, its postharvest losses have been reported to exceed 45% worldwide (Ibrahim *et al.,* 2022). In Nigeria, Nigerian Institute of Social and Economic Research (NISER) post harvest food loss Survey 2013/14, showed that average food crop losses due to farm level activities was about 25%, the highest was recorded for cowpea (30.7%) and about 4.2% post harvest food loses of cowpea was due to marketing activities (Ogundele, 2022). Grain storage means the infrastructure and processes employed to keep harvested grain so as to balance seasonal production with all year round consumption, there by adding value through time, form and place utility while facilitating economic transportation and ensuring sufficient supply to final consumers (Kenkel, 2022).

Temporal price efficiency examines prices variations through the year by the relationship of current price and expected price to storage cost. Therefore, a seasonal crop is allocated through the year by the relationship of current price and expected future price adjusted for storage cost (Tomek & Kaiser, 2014).

This study was therefore designed to measure spatial and inter-temporal price efficiency of cowpea in selected Local Government Areas of Gombe State, Nigeria. It will specifically determine the inter-market price differentials in relation to transport and other handling costs and inter-temporal efficiency in relation to storage costs and suggest measures that could improve spatial and temporal efficiency of agricultural markets in the study area.

The broad objective of the study was to analyse spatial and inter-temporal price efficiency of cowpea (*Vigna unguiculata* [L.] Walp) in selected Local Government Areas of Gombe State, Nigeria. Whereas, the specific objectives were to:

i. analyse inter market price differentials in relation to transport and other handling costs; and
ii. estimate expected price rise for cowpea for the period of study.

METHODOLOGY

The Study Area

Gombe State located on longitudes 9° 30′E and 12° 30′ E and latitudes 8° 45′N and 11°45′N and has a land area of 18,768 square kilometre. The state is located in the Sudan Savannah region of the country. The western and northern parts of the state are noted for their undulating planes dissected by rivers and streams while ranges and hills are predominant features of the southern and eastern parts. Sudan Savannah climate prevails and the soil is characterised by stony and basement complex. The surface soil is free draining sandy loam and moderately deep which are suitable for cereals and legumes. The climate is hot and dry for some given period of time. It experiences an alternating dry and wet season; the rainy season begins mostly from May/June and ends at September/October. Average annual rainfall of 850mm and maximum shade temperatures of 104^0F has been recorded around April with humidity as low, varying from 20-30%. Average temperature is warm, not exceeding 30^0C. The vegetation is guinea savannah grass land with concentration of wood lands in the southeast and southwest. The highest part lies along the western boundary with height of 494m above sea level and lowest part lies along the eastern region with a height of 433 above sea level (Gombe

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State Ministry of Finance and Economic Development, (GMFED), 2006; National Population Commission (NPC), 2006). The state is the confluence of economic activities of the North Eastern part of Nigeria. It has a projected population of 3,772,2389 persons from population of 2,365,040 as at 2023 with a 3.5% annual growth rate, (Federal Republic of Nigeria (FRN) (2009). Gombe LGA, a market consuming community is multi-ethnic, mainly made up of Bolewa, Fulani, Tangale, Tera, Tula and Waja and it is mainly urban and a consumer settlement. Yamaltu-Deba and Billiri LGA's are both known for their high production and marketing of Cowpea (GMFED, 2006; NPC, 2006). The markets selected include; Gombe central, Tundun Hatsi and Pantami markets from Gombe LGA; Kuri, Dadin-kowa and Kwadon markets from Yamaltu-Deba LGA and Billiri, Bore and Ayaba markets from Billiri LGA which are all known for high intensity of cowpea marketing. Gombe central, Tundun Hatsi and Pantami markets are urban markets while Kuri, Dadin-kowa, Kwadon, Billiri, Bore and Ayaba markets are rural markets

Sampling Procedure and Sample Size

Multi-stage sampling procedure was employed. Gombe State was selected as the study area being known for cowpea production and marketing. The second stage involved purposive selection of three Local Government Areas (LGAs), one from each of the three zones of Gombe State that are prominent for cowpea production and marketing. In the third stage, three markets from each of the three LGAs were selected based on accessibility, quantity and intensity of cowpea marketers making a total of nine markets. The final stage involved simple random selection of respondent base on quota sampling from each selected market. The 10% condition for maximum sample size was adopted (Lamarana, 2024). A total population of 1090 was obtained as the population of cowpea wholesalers and retailers in the study area (Table 1). A simple random sampling base on proportionality as adopted from Adebayo (2008) in Mohammed (2019) was then employed to determine the number of respondents from each market as follows; $\mathbf{S_i = \frac{\rho_i}{P} \times \frac{Q}{1}}$

Where; S_i = Sample size for each market, ρ_i = Population of cowpea marketers in each market, P = Total population of cowpea marketers in the study area, Q = Total questionnaires that would be administered.

Table 1: Selection Procedure of Cowpea Marketers in the Study Area

LGA	Market	Sample Frame	Sample Size
Gombe	Tudun Hasti	472	56
	Gombe central	248	30
	Pantami	32	4
Billiri	Billiri	86	10
	Bore	42	5
	Ayaba	26	3
Yamaltu-Deba	Dadin-Kowa	84	10
	Kuri	56	7
	Kwadon	44	5
	Total	**1090**	**130**

Source: Pilot Survey, 2021

Method of Data Collection

Primary data were collected from both wholesale and retails of cowpea marketers using structured questionnaires complemented with oral interview to obtain information on storage, transportation and handling costs. The questionnaires were administered to members of Grain Merchant Association/Unions in the study area during the month of February, 2022. The secondary data were time series data for monthly average retail prices per 100kg bag of Cowpea for the period 2012 – 2019 obtained from Bureau of Statistics, Gombe State.

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Method of Data Analysis

Spatial Price Model

The analysis employs a model of spatial price relationship adopted as employed by Yusuf *et. al.* (2020). In the model, Gombe was considered as the reference market where the parity price was calculated. The model is represented as follows**:**

$PP_{ij} = P_i - (HC_{ji} + TC_{ji} + AS_{ji})$, Where:

PP_{ij} = the calculated parity price of one tonne of cowpea from the ith market (Gombe)in relation to the jth markets,1 and 2 which are Billiri and Yamaltu-Deba respectively

P_i = the actual retail price of one tonne of cowpea at the ith market.

HC_{ij} = handling cost involved in moving one tonne of cowpea from the jth to the ith market

TC_{ij} = transport cost for moving one tonne of cowpea from the jth to the ith market

AS_{ij} = the charge for the assemblers service in moving one ton of cowpea from the jth to the ith market.

The actual price spread between any two markets would be:

$PS_{ij} = PP_{ij} - P_j$, Where:

PS_{ij} = the price spread for one tonne of cowpea between the ith market and the jth market

P_j = the actual retail price of one tonne of cowpea in the jth market

PP_{ij} = the calculated parity price of one tonne of cowpea from the ith market (Gombe)in relation to the jth markets, 1 and 2 which are Billiri and Yamaltu-Deba respectively

Temporal Price Model and Net Seasonal Rise in Price

Economic theory has postulated that, in a perfectly competitive market, post-harvest price of cowpea would equal cost of storing it and thus, provides the opportunity for traders to make more than normal profit (Sani *et. al.,* 2023; Yusuf *et. al*., 2020). In trying to investigate the impact of inter – temporal price relationship for cowpea in the study area, inter-temporal price model was used for the analyses (Tomek & Kaiser, 2014; Yusuf *et. al*., 2020). Thus, the expected seasonal price rise in a perfect market is given as:

$E(P_{ti}) = P_{to} + t(R+I+C+D)$, Where:

$E(P_{ti})$=expected price per 100kg of cowpea stored in ith month

t = time in months; t=0, 1, 2, ……11months

P_{to} = price of 100kg of cowpea stored at harvest; t=0

R = rent per month per 100kg of cowpea stored

I = interest on capital needed for 100kg of cowpea

C = Cost of chemicals used in storing 100kg of cowpea

D = depreciation on sack used in storing 100kg of cowpea

The net seasonal rise in price (i.e rise above or below the price considered consistent with storage cost) for any period is given by;

$NSRP_{ti} = P_{ti} - E(P_{ti})$ Where: $NSRP_{ti}$ = net seasonal rise in price in ith month

P_{ti} = price of 100kg of cowpea stored in ith month; i=0,1,2……11months

In a perfectly competitive assumption, the net seasonal rise or increase in price should be equal to zero, employing that the net seasonal price rise should equal computed storage cost.

Interest rate on capital needed for 100kg of cowpea is determined as;

$An = P(1+ r\,n)$, where:

An = accrued amount at the end the month; P = Principal amount;

R = Interest rate per annum (16.5%); n = number of months (n=1)

$r = \frac{R}{100} \div 12\text{months}$

Depreciation on Sack Used in Storing 100kg of Cowpea is determined as;

$D = \frac{PV\text{-}SV}{N}$

Where: D = Depreciation, PV = Present value, SV = Salvage value, N = Number of years

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RESULTS AND DISCUSSION

Inter Market Price Differential of Cowpea

The results of the monthly price spreads between each of the supplying markets (Billiri and Yamaltu Deba) and the reference market (Gombe) are presented in Table 2 and 3 respectively. Negative price spread indicates difference less than transfer cost, while positive price spread indicates difference greater than transfer cost. Except in two instances where the price spread for Billiri was zero, the price spread was either positive (116) instances or negative (74) instances out of 192 price spreads calculated for both Billiri and Yamaltu Deba markets. The highest and lowest price spread for Billiri were recorded in June of 2015 (₦11,360) and February, 2018 (-₦13,700) respectively. Whereas, highest and lowest price spread for Yamaltu Deba were recorded in July of 2018 (₦18,400) and July, 2012 (-₦12,400), respectively (Table 2 and 3). From Table 2, the mean annual price spread was positive for the period of 2014 to 2017 while negative in 2012, 2013, 2018 and 2019 for Billiri and range between highest values of ₦5,807 in 2015 and lowest values of −₦3,193 in 2018. While from Table 3, the mean annual price spread was positive for all the period studied except in 2018 and 2019 for Yamaltu Deba with the range between high value of ₦2,333 and low value of -₦3,092. These positive prices spreads imply imperfections in the market and a departure from competitive conditions which, according to economic theory provides a potential opportunity for middle men to realise excessive profits, (Nuhu *et al.,* 2009; Yusuf *et. al*., 2020). They also noted however, that positive price spreads may not only result from exploitative practices of traders but are likely to be as a result of the nature of production and defects in the marketing system. Markets in this part of the country are assumed to lack market information on changes in supply and demand conditions as a result of the significant lags associated with production which may results to price linkages being imperfect. Spatial price relationships are determined largely by transfer cost between regions. Transfer costs, which include loading or handling as well as transportation charges, are often high in relation to the farm value of agricultural commodities. Farm prices differ depending on the distance of the production area and the principal or consuming market areas.

Producer prices are invariably lower and tend to be more unstable in distant areas (Nuhu *et al.,* 2009; Yusuf *et. al*., 2020). When transportation and marketing charges represent a high proportion of the consumer price, small change in retail demand can result in large percentage changes in producer returns. FAO (2015) observed that in developing countries, inefficient supply chains and transport logistics significantly raise consumer prices and reduce farmer profit. For instance, in Yamaltu Deba, (which is closest to Gombe) there are more positive price spreads (62 instances, prices exceed transfer cost) than Billiri (54 instances) out of 96 instances for each supplying market. The further away the supplying market is from the consuming market, the more negative price spread (i.e. less gain) and vice–versa (Nuhu *et al.,* 2009; Yusuf *et. al*., 2020). The ranges of price spread from negative to positive implies that price spreads are less than or exceeds cost of transfer, which means loss or gain. Some of the positive price spread meant marketers made more than normal gain and a part could be considered as a premium for extra risk inherent in grain marketing. It can therefore be said that the market was inefficient looking at the ranges of price spreads through the eight years studied. These results are similar to findings of Nuhu *et al.* (2009), Ani *et al.* (2017) and Kaka, *et al.* (2020), in their separate studies but differs from that Sunga (2017), and Zalkuwi *et al.* (2019).

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Table 2: Price Spread of Cowpea (₦/Kg) between Gombe and Billiri Markets

Month/Year	2012	2013	2014	2015	2016	2017	2018	2019
JAN	-2500	3500	-150	8720	2510	1600	1500	-6000
FEB	-3300	2700	650	6560	2510	2400	-13700	-6000
MAR	-1700	2700	1050	3360	2510	2400	2060	-7000
APR	300	-500	1050	3360	1710	0	-900	-2500
MAY	-4500	3500	250	3360	1710	800	-900	-1000
JUN	-4100	-500	250	11360	3310	0	-2100	1500
JUL	-8500	-3700	250	7360	3310	800	-5700	-3000
AUG	3500	-2100	1050	7360	3310	1600	-5700	-2000
SEP	-1300	-6100	1850	5760	3310	1600	-4900	-2000
OCT	-500	-4500	1050	5760	3310	-1840	-7940	-3000
NOV	9100	-4500	1050	5760	910	-800	4060	-4000
DEC	3500	-4500	1850	960	910	-5840	-4100	-1000
Mean	-833	-1167	850	5807	2443	226	-3193	-3000
S. E	1321	1027	181	808	269	623	1412	704
Min	-8500	-6100	-150	960	910	-580	-13700	-7000
Max	9100	3500	1850	1160	3310	240	4060	1500

Source: *Bureau of Statistics, Gombe State, 2022 and Author's Computation, 2023*

Table 3: Price Spread of Cowpea (₦/Kg) between Gombe and Yamaltu Deba Markets

Month/Year	2012		2013	2014	2015	2016	2017	2018	2019
JAN	400		7600	350	9860	210	3300	3600	-12200
FEB	-1200		5200	-50	-540	210	3300	-16000	-12200
MAR	-2400	2800	350		-1180	210	3300	400	-12200
APR	-400	6000	350	-540	-190		100	1200	-1400
MAY	-4400	10000	-50	2660	-590		1700	-800	-10200
JUN	-4400	2000	-50	1860	3410		100	-800	1100
JUL	-12400	2000	1150	1860	1010		900	18400	2100
AUG	-400	1200	350	7460	210		1700	4800	3100
SEP	3600	-2800	1150	5860	210		1700	3200	2000
OCT	7600	-3600	750	5860	210		-700	-2400	600
NOV	10800	-400	350	3460	210		-7100	-2400	-400
DEC	6000	-2000	1950	2660	1810		-700	-10400	2600
Mean	233	2333	550	273	577		633	-100	-3092
S. E	1790	1224	174	985	309		820	2405	1876
Min	-12400	-3600	-50	-1180	-590		-7100	-16000	-12200
Max	10800	10000	1950	9860	3410		3300	18400	3100

Source: *Bureau of Statistics, Gombe State, 2022 and Author's Computation, 2023*

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Expected Price Rise (EP_{ti}) and Net Seasonal Rise in Price ($NSRP_{ti}$) Relationship

The expected price rise (EP_{ti}) represents the expected price of a grain stored in any particular month including the cost incurred in storage. Tables 4, 5, and 6 showed the net seasonal rise in price expressed as a percentage greater or less than expected price for Gombe, Billiri and Yamaltu Deba respectively over a period of eight years (2012-2019). The result indicated a considerable amount of variation in seasonal prices between months within a year. Cowpea is usually harvested in November to January and seasonal price movements (Tables 4, 5, and 6) showed that high and low points are consistent with the harvest period. For instance, the percentage net seasonal increase in price were positive for the month of November (61.01) and December (26.75) 2012 in Gombe LGA while it was negative for November 2013 to 2019 (-48.59, -19.87, -32.68, -12.40, -27.73, -36.58, and -45.23) as well as December 2013 to 2019 (-49.32, -39.64, -33.73, -13.72, -28.84, -62.53 and -55.75). The highest percentage net seasonal increase in Gombe (2012 to 2019) was recorded in August (136.98) of 2012. In Billiri, the highest percentage net seasonal increase in price was obtained in September 2012 (102.23) while it was negative for the month of November 2012 to 2019 (-29.26, -14.85, -27.37, -26.81, -5.98, -21.23, -45.78 and -17.47) as well as December 2012 to 2019 (-19.63, -16.09, -52.31, -10.21, -7.44, -6.19, -50.66 and -31.05. In Yamaltu Deba, the highest percentage net seasonal increase in price was in July 2012 (160.54). In the month of November, only in 2015 (0.53), 2016 (12.43) and 2017 (7.20) was the price spread positive while in December it was positive only in 2016 (19.50). Therefore, purchasing at harvest and storing until the off season may not necessarily result in the highest profit per unit (Nuhu *et al.,* 2009; Yusuf, *et al*., 2016). As profits are not the only incentive which a market offer (Organisation for Economic Co-operation and Development (OECD), 2009). Thus, adequate and reliable information are necessarily important to attain high profit.

The net seasonal rise in price can be used to make hypothetical estimates of per unit profit of storing cowpea (Nuhu *et al.,* 2009; Yusuf, *et. al*., 2016). In Table 4, 5 and 6, the yearly average net seasonal rise in price of cowpea in 2012 was 47.88%, 28.05% and 55.58% in Gombe, Billiri and Yamaltu Deba markets respectively greater than expected price increase which indicates that considerable profit was made. However, results from this study indicates that only in eight of the twenty four instances for the three markets studied (Gombe; 2012, Billiri; 2012, 2015, 2017 and Yamaltu Deba; 2012, 2015, 2016, 2017) had the yearly average percentage net seasonal increase in cowpea prices exceeded the calculated expected increase (Tables 4, 5 and 6). This is an indication that traders might not have been making per unit profit in cowpea for almost all part of the eight years studied. This seems to suggest that traders' monthly purchases are about equal to monthly sales. The risk in storage, couple inadequate storage structures and high demand for cash by farmers at harvest after large investments during the production season necessitates for farmers to supply large amount of the product to the market at harvest. If improve storage techniques and technology can be provided, as well as loans for harvest activities, farmers can greatly benefit from storage activities which would generally improve the agricultural sector. This finding is similar to that of Nuhu *et al.* (2009), and Yusuf *et al*. (2016) but differs with the studies of Islam *et al.* (2020), Flaskerud and Johnson (2020), as they did not employ this method to study temporal price variations.

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Table 4: Net Seasonal Rise in Price (NSRPti) Expressed as a Percentage Greater or Less than Expected Price for Cowpea in Gombe LGA 2012 – 2019

MTH/YR	2012	2013	2014	2015	2016	2017	2018	2019	MEAN
JAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FEB	-1.91	-5.58	-7.21	-1.85	-1.76	-1.83	-50.9	-1.43	-9.06
MAR	-7.44	-7.1	-6.13	-3.63	-3.47	-3.59	-3.52	-2.83	-4.71
APR	9.03	-23.82	-10.36	-5.35	-5.11	-2.58	-5.19	-36.24	-9.95
MAY	42.75	-6.26	-1.48	11.59	-6.7	6.37	-6.81	-5.5	4.25
JUNE	40.22	-26.17	-3.1	9.67	7.05	4.56	-8.36	-46.83	-2.87
JUL	37.78	-27.29	5.38	7.82	5.31	10.52	-9.87	-47.54	-2.24
AUG	137	-28.38	3.7	6.02	3.63	13.76	-11.33	-48.23	9.52
SEPT	133	-47.07	2.08	-2.67	2.01	11.92	-12.74	-45.16	5.17
OCT	96.41	-47.84	-4.27	-4.23	0.43	-2.1	-46.32	-44.52	-6.56
NOV	61.01	-48.59	-19.87	-32.68	-12.4	-27.73	-36.58	-45.23	-20.26
DEC	26.75	-49.32	-39.64	-33.73	-13.72	-28.84	-62.53	-55.75	-32.1
MEAN	**47.88**	**-26.45**	**-6.74**	**-4.09**	**-2.06**	**-1.63**	**-21.18**	**-31.6**	

Source: *Bureau of Statistics, Gombe State, 2022 and Author's Computation, 2023*

Table 5: Net Seasonal Rise in Price (NSRPti) Expressed as a Percentage Greater or Less than Expected Price for Cowpea in Billiri LGA 2012 – 2019

MTH/YR	2012	2013	2014	2015	2016	2017	2018	2019	MEAN
JAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FEB	4.51	-1.71	-13.00	17.56	-1.83	-4.93	-4.48	-2.07	-0.74
MAR	-12.91	-3.37	-14.51	43.69	-3.59	-6.68	-5.42	0.74	-0.26
APR	-14.44	-4.97	-18.68	40.56	-1.65	3.47	2.38	-13.02	-0.79
MAY	50.14	-6.52	-4.06	71.96	-3.36	10.35	0.61	-21.63	12.19
JUNE	44.64	-8.02	-5.64	1.02	5.55	11.29	2.60	-34.44	2.13
JUL	74.15	8.63	3.14	31.95	3.78	15.00	11.82	-11.27	17.15
AUG	71.29	-1.97	-3.58	29.31	2.07	15.83	9.98	-12.90	13.75
SEPT	102.23	-3.47	-10.10	26.77	0.41	13.91	5.84	-14.48	15.14
OCT	65.84	-13.56	-11.49	24.33	-1.19	10.20	-21.77	-16.00	4.54
NOV	-29.26	-14.85	-27.37	-26.81	-5.98	-21.23	-45.78	-17.47	-23.59
DEC	-19.63	-16.09	-52.31	-10.21	-7.44	-6.19	-50.66	-31.05	-24.20
MEAN	**28.05**	**-5.49**	**-13.13**	**20.84**	**-1.10**	**3.42**	**-7.91**	**-14.47**	

Source: *Bureau of Statistics, Gombe State, 2022 and Author's Computation, 2023*

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Table 6: Net Seasonal Rise in Price (NSRPti) Expressed as a Percentage Greater or Less than Expected Price for Cowpea in Yamaltu Deba LGA 2012 – 2019

MTH/YR	2012	2013	2014	2015	2016	2017	2018	2019	MEAN
JAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FEB	14.39	11.26	-4.67	103.38	1.78	-1.78	10.94	-1.90	16.67
MAR	20.21	28.53	-6.33	105.02	3.50	-3.50	7.51	-3.74	18.90
APR	17.95	-24.25	-10.73	94.16	3.52	10.64	2.84	-37.12	7.13
MAY	92.96	-25.56	1.48	97.44	3.55	14.98	7.76	-7.20	23.18
JUNE	89.47	3.65	-0.21	100.59	5.15	19.18	5.89	-48.01	21.96
JUL	160.54	1.91	0.82	96.33	-2.63	23.24	-58.37	-48.91	21.62
AUG	155.99	6.12	4.42	42.40	-4.04	24.21	-15.57	-49.79	20.47
SEPT	115.65	4.40	-2.37	39.50	-2.39	22.24	-11.93	-47.01	14.76
OCT	41.34	8.44	-6.42	36.72	-0.79	14.6	-33.16	-46.59	1.77
NOV	-23.56	-15.74	-20.31	0.53	12.43	7.20	-22.05	-47.46	-13.62
DEC	-17.97	-5.98	-50.94	-14.55	19.5	-16.65	-28.07	-57.70	-21.54
MEAN	**55.58**	**-0.6**	**-7.94**	**58.46**	**3.3**	**9.53**	**-11.19**	**-32.95**	

Source: Bureau of Statistics, Gombe State, 2022 and Author's Computation, 2023

CONCLUSION AND RECOMMENDATIONS

The study concluded that that the pricing system of cowpea marketing in the study area are inefficient. Also, both positive and negative inter market price differential were present which could be due to inadequate information on prices and supply in the various markets, inefficient transportation system and other physical facilities. Considerable amount of variation was observed in seasonal prices between months within a year. Cowpea is usually harvested in November to January and seasonal price movements showed that high and low points are consistent with the harvest period. Only in eight, of the twenty four (24) instances for the three selected LGA markets studied had the yearly average seasonal increase in cowpea prices exceeded the calculated expected price increase. Marketing merchants might not have been making profit during most part of the period of study. The study recommends the establishment of adequate market infrastructures including physical buildings, road networks and storage facilities. Policy aimed at making the food distribution system efficient should be implemented. Large and sustained investment by stakeholders in cowpea marketing is also recommended so as to make cowpea production and marketing a focal business away from its present subsistence state. This can be achieved through provision of low interest loan to marketers for processing and storage activities.

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EFFECT OF REPLACING MAIZE WITH A MIXTURE OF RUMEN CONTENT AND BLOOD MEAL ON THE GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF WEANER RABBITS

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ABSTRACT
The study investigated the effect of replacing maize with varying levels of mixture of rumen content and blood meal (8:2) on the growth performance and carcass characteristics of weaner rabbits. 30 weaner rabbits were randomly allocated to five dietary treatments. The experimental diets incorporated rumen content and blood meal as substitutes for maize at inclusion levels of 0%, 25%, 50%, 75%, and 100%. Data were collected on growth performance, hematological parameters, nutrient digestibility, and carcass characteristics. The findings revealed that diets T3 and T4 (50% and 75% replacement levels) resulted in the highest growth performance, with mean daily weight gains of 20.15 g/day and 21.54 g/day, respectively. Average daily feed intake for diets T2–T4 ranged from 46.41 g to 46.74 g, which was significantly ($P<0.05$) higher than T1 (38.53 g). Rabbits fed T5 had the lowest (₦3,537.60) feed cost per kilogram of weight gain whereas T4 exhibited the most efficient feed conversion ratio (2.11). Carcass analysis revealed that T4 had the highest pre-slaughter weight (1398.00 g) and carcass weight (989.63 g), alongside a dressing percentage of 66.70%. In conclusion, incorporating rumen content and blood meal into weaner rabbit diets significantly improved growth performance and carcass quality, with optimal results achieved at 50–75% replacement levels. The findings suggest that rumen content and blood meal are cost-effective and sustainable alternatives to maize in rabbit diets. It is recommended that farmers include up to 75% replacement levels for enhanced growth and economic benefits.

Keywords: Rumen, Blood, Meal, Performance, Weaner, Rabbits

INTRODUCTION
Rabbits are fast-growing herbivores widely reared for meat in many developing countries due to their high reproductive rates, efficient feed conversion, and ability to thrive on a wide range of feedstuffs. However, one of the major constraints to commercial rabbit production is the high cost of conventional feed ingredients, especially cereals like maize, which are in direct competition with human food (Okorie *et al*., 2019). Maize is commonly used as a primary energy source in livestock diets, but its increasing price and fluctuating availability have prompted the need for alternative feed resources that are affordable and nutritionally adequate. One promising approach is the use of agro-industrial by-products and slaughterhouse waste, which are often underutilized or improperly disposed of, causing environmental pollution. Rumen content and blood meal are two such by-products that have shown potential as feed ingredients. Rumen content, a fibrous material obtained from the stomach of ruminant animals, is rich in microbial protein and partially digested plant matter, while blood meal is a protein-rich material derived from abattoirs, known for its high digestibility and amino acid profile (Olorunsanya *et al*., 2018).

Several studies have explored the nutritional potential of blood meal and rumen digesta when used individually or in combination with other feed ingredients. For instance, Ojebiyi *et al*. (2020) reported that blood meal can significantly improve protein intake and growth performance in monogastric animals when included at appropriate levels. Similarly, rumen content has been evaluated as a roughage or filler that can aid in gut health and nutrient absorption, especially in non-ruminants such as rabbits when processed properly (Aro *et al*., 2017). The combination of these two by-products could provide a cost-effective and balanced alternative to maize when adequately formulated. In rabbit nutrition, protein and energy are critical components influencing growth, feed intake, and overall health. Young rabbits (weaners) are particularly sensitive to dietary imbalances,

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making the careful formulation of alternative diets essential. A mixture of rumen content and blood meal may not only help reduce feed cost but also contribute essential nutrients that support growth and development. However, due to the high fiber content of rumen content and the risk of anti-nutritional factors or imbalanced amino acids in blood meal, it is necessary to evaluate the performance of animals fed such combinations carefully (Akinfala & Tewe, 2019). The incorporation of alternative ingredients like rumen content and blood meal into livestock diets is also aligned with sustainable agricultural practices. It supports waste recycling, reduces environmental pollution, and minimizes the pressure on conventional feed resources (Adesehinwa, 2021). In resource-limited regions, such sustainable feeding strategies are vital to improving food security and profitability among smallholder rabbit farmers. Therefore, this study seeks to investigate the effect of replacing maize with a graded mixture of rumen content and blood meal on the growth performance and carcass characteristic of weaner rabbits.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at the Teaching and Research farm of the Department of Animal Production, Abubakar Tafawa Balewa University, Bauchi, Nigeria. The state is located between latitudes $10^0 17'$ North and longitudes 9^0 49′ East at an altitude of 690.2m above the sea level (Abubakar and Burriah, 2013).

Experimental Rabbits and their Management

The feeding trial was conducted using thirty (30) weaner rabbits obtained from different rabbit farmers and open markets. The rabbits were randomly allotted to five different experimental diets (0, 25, 50, 75 and 100%). The weaner rabbits were managed intensively. Water and feeds were given *ad libi-tum*. The experiment lasted for a period of eight weeks.

Experimental Diets

The ingredients for diet formulation were maize, wheat offal, soyabean meal, rumen content, blood meal, groundnut haulms, bone meal, premix, lysine, methionine and salt. The rumen content and blood meal were mixed with other ingredients to compound a balanced diet for the weaner rabbits. Experimental diets were formulated to meet protein and energy requirements of weaner rabbits. Five diets were formulated with rumen content and blood meal mixture added to replace maize at varying levels; 0, 25, 50, 75 and 100% and the diets were labelled T1-T5 respectively.

Experimental Design

There were five treatments and each treatment was replicated three times with two rabbits per replicate in a Completely Randomized Design (CRD).

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Table 1: Percentage Composition of Experimental Diets

	Levels of Replacement of SBRC and blood meal (%)				
Ingredients	**T1**	**T2**	**T3**	**T4**	**T5**
Maize	37.30	27.97	18.65	9.33	0.00
SBM	20.00	20.00	20.00	20.00	20.00
RC/BM (80:20)	0.00	9.33	18.65	27.97	37.30
Rice Offal	25.00	25.00	25.00	25.00	25.00
GNH	15.00	15.00	15.00	15.00	15.00
Salt	0.25	0.25	0.25	0.25	0.25
Premix	0.25	0.25	0.25	0.25	0.25
Bone meal	2.00	2.00	2.00	2.00	2.00
Methionine	0.10	0.10	0.10	0.10	0.10
Lysine	0.10	0.10	0.10	0.10	0.10
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
Calculated Analysis					
Crude protein	15.81	15.89	15.97	16.18	16.20
Me/kcal/kg energy	2620.44	2610.22	2600.77	2599.89	2598.78
Crude fibre	9.40	9.93	10.45	10.98	11.50
Calcium	1.12	1.12	1.11	1.11	1.10
Phosphorus	0.93	0.88	0.86	0.82	0.78
Lysine	0.93	0.89	0.84	0.77	0.69
Methionine	0.32	0.29	0.29	0.28	0.24

RC/BM- Mixture of rumen content with blood meal; GNH- Groundnut haulms; SBRC-Sundried Bovine Rumen Content

Data Collection

Weekly measurements of body weight and feed intake, and feed conversion ratio (FCR) were taken to assess growth performance. At the end of the trial, two rabbits from each treatment were slaughtered for carcass analysis, which included measurements of dressed weight, dressing percentage, and organ weights.

Statistical Analysis

Data were analyzed using one-way ANOVA with the SPSS software package, and means were separated using Duncan's Multiple Range Test at a significance level of 5%.

RESULTS AND DISCUSSION

Growth Performance

The results in Table 2 revealed that there were no significant differences ($P>0.05$) in the average initial weights of the weaner rabbits across the treatment groups, indicating uniformity at the beginning of the experiment. Significant differences ($P<0.05$) were observed in final live weight, with rabbits on T2 (25%), T3 (50%), and T4 (75%) recording significantly higher weights compared to the control (T1) and T5 (100%). This trend indicates that the partial replacement of maize with the mixture of rumen content and blood meal up to 75% positively influenced weight gain. The highest weight gain was observed in T4 (75%), suggesting that this level of substitution provided a balanced nutrient composition that supported optimal growth. The slight reduction in T5 (100%) may be due to the excessive inclusion of the alternative mixture possibly affecting palatability or nutrient digestibility (Aro *et al*., 2017).

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Table 2: Performance of Weaner Rabbits Fed Mixture of Rumen Content and Blood Meal

Parameters	**Treatments**					
	T1 (0%)	**T2 (25%)**	**T3 (50%)**	**T4 (75%)**	**T5 (100%)**	**SEM**
Average initial weight (g)	277.89	278.67	278.83	278.83	277.89	14.99^{NS}
Average final live weight (g)	1249.17^{b}	1390.00^{a}	1395.00^{a}	1398.00^{a}	1326.00^{ab}	22.27*
Average daily feed intake ()	38.53^{b}	46.41^{a}	46.68^{a}	46.74^{a}	46.47^{a}	0.82*
Average daily weight gain (g)	17.41^{b}	20.11^{a}	20.15^{a}	21.54^{a}	19.28^{ab}	0.32*
Feed conversion ratio	2.84^{a}	2.79^{a}	2.50^{ab}	2.11^{c}	2.41^{c}	0.06*
Feed cost/kg of feed (₦)	350.88	348.22	330.17	320.32	301.11	-
Feed cost/kg gain (₦)	996.49	971.53	825.43	675.88	725.68	-

^{abc}: Means within the same row bearing different superscripts are significantly different (P<0.05)
NS: No significant difference

Average daily feed intake followed a similar trend, with significant increases observed in all treatment groups compared to the control. This increased feed intake could be attributed to the palatability and high protein content of blood meal, as previously reported by Olorunsanya *et al*. (2018). However, the marginal decline in intake at 100% replacement (T5) could be due to potential limitations in digestibility or acceptability at high levels of rumen content inclusion. Average daily weight gain was significantly higher in T2, T3, and T4 compared to T1 and T5, corroborating the earlier observation on final live weight. The result agrees with the findings of Ojebiyi *et al*. (2020), who observed improved weight gains in rabbits fed blood meal-supplemented diets. The enhanced growth performance at 75% replacement suggests that the mixture was efficient in supplying both energy and high-quality protein, which are essential during the weaner stage. The feed conversion ratio (FCR), which indicates feed efficiency, was best (lowest) in T4 (2.11), followed by T5 (2.41) and T3 (2.50). The poorest FCR was recorded in the control group (T1) with a value of 2.84. These results imply that diets with 50–75% replacement of maize led to better feed utilization, which aligns with Akinfala and Tewe (2019), who noted improved feed conversion in rabbits when unconventional protein sources were strategically incorporated in the diet.

The economic analysis of the feed indicates a progressive reduction in feed cost per kilogram as the level of replacement increased, from ₦350.88 in T1 to ₦301.11 in T5. This reflects the economic advantage of using cheap and available by-products like rumen content and blood meal. Furthermore, the cost per kilogram of weight gain was lowest in T4 (₦675.88), confirming the efficiency and profitability of this treatment level. This result supports the findings of Adesehinwa (2021), who emphasized that partial substitution of conventional feeds with agro-industrial by-products could reduce production costs and improve profit margins.

Carcass Characteristics

Table 3 revealed that, the pre-slaughter weight, carcass weight, and dressing percentage showed significant differences (P<0.05) among treatments. Rabbits fed diets with 25% to 75% replacement (T2–T4) had significantly higher pre-slaughter and carcass weights than the control (T1), with T4 showing the highest values. This confirms the growth performance trend observed earlier and highlights improved nutrient utilization due to the dietary mixture. The improved dressing percentage, particularly in T4 (66.70%), suggests better muscle deposition, likely due to the high protein quality of blood meal (Akinfala & Tewe, 2019). The weights of internal organs such as the heart and kidney did not differ significantly, indicating that the dietary treatment did not adversely affect the health of vital organs, which supports the safety of the dietary replacement. However, the lung and liver weights were significantly higher in T4, which could be attributed to increased metabolic activity or enhanced detoxification demands associated with processing animal by-product-based feeds (Ojebiyi *et al*., 2020). Nonetheless, the values remained within normal physiological ranges for rabbits (Aro *et al*., 2017).

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Table 3: Carcass Traits of Weaner Rabbits Fed Mixture of Rumen Content and Blood Meal

Parameters	Treatments					
	T1 (0%)	T2 (25%)	T3 (50%)	T4 (75%)	T5 (100%)	SEM
Pre-slaughter weight	1249.17^{b}	1390.00^{a}	1395.00^{a}	1398.00^{a}	1326.00^{ab}	22.27*
Carcass weight	775.98^{c}	959.10^{a}	963.07^{a}	989.63^{a}	899.54^{b}	10.15*
Dressing percentage	57.68^{b}	65.85^{a}	65.95^{a}	66.70^{a}	64.77^{a}	0.43*
Heart	0.28	0.27	0.27	0.31	0.29	0.01^{NS}
Lung	0.66^{b}	0.77^{ab}	0.82^{ab}	0.89^{a}	0.67^{b}	0.02*
Liver	3.26^{c}	3.81^{ab}	3.22^{c}	4.37^{a}	3.62^{b}	0.07*
Kidney	0.96	1.02	1.14	1.18	1.17	0.03^{NS}
Stomach	1.99^{a}	1.72^{a}	1.40^{b}	1.78^{a}	1.22^{b}	0.03*
Intestine	15.29^{c}	19.56^{b}	20.00^{ab}	21.90^{a}	19.50^{b}	0.40*
Head	12.13	11.77	11.08	12.33	11.56	0.25^{NS}
Skin	10.96^{ab}	12.59^{a}	10.73^{ab}	12.74^{a}	11.55^{ab}	0.25*
Feet	2.62	2.65	2.62	3.13	2.59	0.10^{NS}
Tail	1.I6	1.26	1.08	1.06	1.25	0.03^{NS}
Shoulder	25.66	23.90	26.99	27.42	25.66	0.31^{NS}
Loin	21.45^{a}	17.37^{b}	20.41^{ab}	27.78^{a}	19.86^{ab}	0.34*
Thigh	26.02	24.91	23.44	29.65	26.01	0.64^{NS}

^{abc}: means within the same row bearing different superscripts are significantly different (P<0.05)
NS: No significant difference (P>0.05)

A notable decrease in stomach weight in T3 and T5 may suggest better digestibility and less undigested residue, possibly due to improved protein digestibility from blood meal. Intestine weight increased significantly with the level of replacement, peaking at T4, suggesting enhanced nutrient absorption capacity or adaptation to fiber content from rumen content (Olorunsanya *et al*., 2018). For non-carcass components like head, feet, tail and shoulder, no significant differences were observed, indicating consistency in skeletal development across treatments. However, skin weight was significantly higher in T2 and T4, which may be linked to better fat deposition or hydration status. Loin weight, an indicator of meat yield, was highest in T4, supporting the superior performance and carcass value of rabbits fed 75% replacement.

CONCLUSION AND RECOMMENDATION

Inclusion of rumen content and blood meal mixture in the diets of weaner rabbits significantly improved their growth performance. The use of rumen content and blood meal in rabbit diets resulted in lower feed costs compared to the control diet. The dietary inclusion of rumen content and blood meal positively influenced carcass traits, with significant improvements observed in carcass weight, dressing percentage and weights of key organs. It can therefore be recommended that, rabbit farmers should include up to 75% replacement levels of rumen content and blood meal in weaner rabbit diets to achieve the best growth performance, carcass quality and reduced environmental pollution from abattoir wastes. Additional research should be conducted to explore the long-term effects of feeding rumen content and blood meal to rabbits, including their impact on reproductive performance, longevity and overall health

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EVALUATION OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICTs) IN THE DISSEMINATION OF AGRICULTURAL INFORMATION AMONG MAIZE FARMERS IN THE CENTRAL ZONE OF PLATEAU STATE, NIGERIA

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ABSTRACT
The study examined information communication technologies (ICTs) in disseminating agricultural information among maize farmers in the central zone of Plateau State, Nigeria. A multistage sampling technique was employed in selecting 120 respondents. Data were collected using a structured questionnaire and analysed using descriptive and inferential statistics. The results showed that the majority (93%) of the farmers were aware of ICT, and use mobile phones (51%) for the dissemination of agricultural information. Access to a mobile phone, television and computer was significant, with mean scores of 3.20, 3.65 and 3.42, respectively. The results also showed that the farmers' socioeconomic characteristics correlate with their access to and use of ICTs for disseminating agricultural information at $p<0.05$ and $p<0.1$. Factors that influence the use of ICTs include income level, price of ICT gadgets, inadequate power supply, and flexibility, among others. The constraints to the access and use of ICT gadgets include the high cost of the gadgets, poor farmer supply and level of knowledge on the use of the ICTs. The farmers were aware of the use of ICT. However, they were constrained by factors in the access and use for dissemination of agricultural information. Farmers should exploit credit institutions around them for credit facilities to enable them to access and use ICT gadgets to help them get information on agricultural innovations.

Keywords: ICTs, Evaluation, Dissemination, Extension, Maize

INTRODUCTION
Agricultural information dissemination plays a crucial role in the livelihoods and productivity of maize farmers. Access to timely, accurate, and relevant information can significantly enhance their decision-making processes, improve agricultural practices, and ultimately contribute to increased yields and income. Access to agricultural information enables maize producers to implement best practices in crop management, such as planting techniques, pest and disease control, soil fertility management, and irrigation systems (FAO, 2016). For example, timely information on weather patterns enables farmers to plan planting and harvesting activities more effectively, reducing losses due to severe weather conditions. Also, maize growing relies heavily on efficient resource utilisation, including seeds, fertilisers, and irrigation water. Agricultural data enables farmers to make informed decisions about optimal resource allocation based on soil conditions, market demand, and environmental considerations (De Brauw *et al.*, 2020). This reduces costs and promotes sustainable agriculture methods. Early warnings and preventive measures given by extension services and ICT platforms assist farmers in reducing crop losses and maintaining resilience in the face of agricultural uncertainty (Ouma *et al.*, 2019).

ICTs provide farmers with access to timely and relevant agricultural information, including weather forecasts, market prices, pest and disease management practices, and agronomic advice. Mobile phones, internet-based platforms, and agricultural applications (apps) enable farmers to make informed decisions in real time (Kumar *et al*., 2020). Also, ICTs bridge the gap between farmers and markets by providing market information, connecting farmers directly to buyers, and facilitating online transactions. E-commerce platforms and mobile-based marketplaces enable farmers to access wider markets, negotiate better prices, and reduce post-harvest losses (Qureshi *et al*., 2019). Furthermore, it facilitates agricultural extension services by delivering training modules, videos, and interactive content to farmers. Extension workers use mobile phones and tablets to reach remote areas,

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disseminate best practices, and provide technical support, thereby enhancing farmers' skills and knowledge (Kariuki *et al*., 2017). ICTs play a crucial role in climate resilience by providing early warning systems for extreme weather events, monitoring climate data, and supporting adaptive strategies. Farmers can adjust cropping patterns and practices based on climate forecasts to reduce vulnerability to climate change impacts (Deb & Kariyanna, 2021).

Maize (*Zea mays*) is one of Nigeria's most significant cereal crops, grown in a variety of agroecological zones due to its versatility and adaptation to changing soil and climatic circumstances. Maize farming is crucial for Nigerian food security as it is a staple crop that provides carbohydrates for millions of people. It is consumed in a variety of ways, including boiled and roasted maize, as well as flour for pap, cornmeal, and snacks (FAO, 2020). Maize is a key element in Nigerian animal feed production. Grain and byproducts such as maize bran and cornstalks are used to feed poultry, livestock, and fish, hence promoting livestock sector growth (Agboola *et al*., 2017). Nigeria's maize output also helps to export revenue. The country exports maize to neighbouring nations and international markets, increasing its foreign exchange profits and trade balance (Adekunle & Fatuase, 2019).

Despite its significance, maize cultivation in Nigeria confronts numerous obstacles. Maize crops are vulnerable to pests such as stem borer and diseases such as maize rust and maize streak virus, which can affect yields if not handled adequately (Oladiran *et al*., 2020), Also, climate change's unpredictable rainfall patterns and rising temperatures endanger maize production, reducing crop growth and yield (Balogun *et al*., 2019). In addition, smallholder farmers frequently lack access to enhanced maize varieties, quality seeds, fertilisers, and agrochemicals, limiting production (Oladosu *et al*. 2018). Therefore, inadequate storage facilities and poor post-harvest handling techniques lead to large maize losses after harvest, compromising food security and farmer income.

Consequently, the evaluation of information and communication technologies (ICTs) in the dissemination of agricultural information among maize farmers in the Central Zone of Plateau State, Nigeria is a very important task that must be accomplished. However, few empirical studies on evaluation of information and communication technologies (ICTs) in the dissemination of agricultural information among maize farmers in the Central Zone of Plateau State, Nigeria were in place. Thus, the need for this study was to provide information on the adoption of improved broiler and layer chicken production practices among farmers in the state. This study aimed to;

i. describe the awareness, use and accessibility of ICTs by the maize farmers;
ii. determine the relationship between the socio-economic characteristics of maize farmers and their access to ICTs as a source of information on agricultural technologies;
iii. determine the factors that influence maize farmers to use ICTs as a source of information on agricultural technologies; and
iv. identify and describe the constraints to the use of ICTs in disseminating agricultural information.

METHODOLOGY

The Study Area

The study was conducted in the Central zone of Plateau State. Plateau State is located in the north-central zone of Nigeria and lies between Latitude 8^0 30' and 10^0 30'N, Longitude $7^0$30' and $13^0$37'E with a land mass covering 30,913 sq. kilometres. The monthly maximum and minimum temperatures are 20°C and 15°C, respectively. The mean annual rainfall is about 1450mm, and the relative humidity of 60%. The state has an estimated population of 3,178,712 (NPC, 2007 estimate) and 3.78 million (NPC, 2013 est). It is bounded by Kaduna and Bauchi states on the north, Taraba on the east, and Nasarawa on the south and west. The Jos Plateau rises to about 5,250 feet (1600m) above sea level in the north-central state's part and the Benue River-Valley stretches along the south-east border (Price, 2019). Although there are wooded valleys in the southeast, the vegetation is mostly open grassland, which is suitable for grazing and farming.

Based on soils, climate, and typical farming systems, the state is classified into three distinct agro-ecological zones, namely the lowland moist savannah, which falls within southern Guinea, and

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the Savannah rain forest, having extensive low-lying flat land with high water holding capacity, favourable for the production of rice, yam, cassava, melon and groundnut. The mid-altitude zone (the area of study) falls within 500-1,500 meters above sea level, with soils that are sandy clay and heavy rains predominantly maize, Irish potato, and assorted vegetables are produced.

There is a high concentration of livestock and poultry, such as cattle, sheep, goats, layers, broilers, cross-breaded local chickens and quails, and production of crops like millet, groundnut, sorghum, and cowpea. It has open grassland vegetation usually used for grazing and farming with notable steep-sloping mountains around the area (FAO, 2018). Global System Mobile (GSM) Network services like Globacom, Airtel, Etisalat, and MTN exist.

Sampling Procedure and Sample Size

The sampling method used is the multistage sampling technique. The first stage involved a purposive sampling of 3 LGAs from the Central zone of Plateau due to the intensity of maize production. The second stage involved a simple random selection of respondents from 3 districts each, making a total of 9 districts. In the third stage, a total of 2,420 respondents were randomly selected to make up the sampling frame, while 5% which is 120 respondents, represents the sampling size for the study.

Data Collection

Primary data were collected using structured questionnaires. The questionnaires had both closed and open-ended style of questions. It has sections such on socio-economic characteristics, awareness, use and accessibility of ICTs, the effectiveness of the use of ICTs, factors that affect the use of ICTs, factors that influence maize farmers to use ICTs, and lastly the constraints to the use of ICTs for disseminating agricultural information. The questionnaire was pre-tested and proofread by experts to guarantee accuracy and reliability. Extension agents were recruited and trained as data collectors under the supervision of the researchers. Data collected were edited both in the field and in the office before they were analysed.

Data Analysis

The inferential and descriptive-analytical tools were used to achieve the objectives of the study. Descriptive statistical tools such as mean values, percentages, frequency distributions and ranking were presented in tables and used to achieve objective i, iii and iv, which is to; describe the awareness, use and accessibility of ICTs by the maize farmers, to determine the factors influencing the adoption of improved broiler and layer chicken production practices among farmer, and identify and describe the constraints to the use of ICTs in disseminating agricultural information.

The correlation model was used to evaluate the relationship between the socio-economic characteristics of the maize farmers and their access to ICTs:

$$R = \frac{n((\sum xy)) - (\sum x)(\sum y)}{\sqrt{[n(\sum x^2) - (\sum x)^2][n(\sum y^2) - (\sum y)^2}} \quad \ldots(1)$$

Where:

X = socio-economic characteristics of the respondent
y = access to ICTs gadget
n = Sample size
∑ = sign of summation

RESULTS AND DISCUSSION

Awareness, Use and Accessibility of ICTs in Disseminating Agricultural Information

The study described the awareness, utilisation and accessibility of ICTs in disseminating agricultural information. The result is presented in Table 1.

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Table 1: Awareness, Use and Accessibility of ICTs in Disseminating Agricultural Information by Maize Farmers

Variables	Local government areas			
	Mangu	**Bokkos**	**Kanam**	**Total**
Awareness of ICTs				
Yes	34 (87.20)	38 (97.40)	21 (9550)	93 (93.00)
No	5 (12.80)	1 (2.60)	1 (4.50)	7 (7.00)
Possession and Use of ICTs				
Mobile phone	17 (43.60)	23 (59.00)	11 (50.00)	51 (51.00)
Radio	10 (25.60)	7 (17.90)	7 (31.80)	24 (24.00)
Television	11 (2820)	8 (20.50)	3 (13.60)	22 (22.00)
Accessibility to ICTs gadgets				
Mobile phone	3.15	3.28	3.18	3.20
Radio	2.56	2.03	2.36	2.32
Television	3.62	3.69	3.64	3.65
Computer	3.62	3.13	3.50	3.42

Source: Field Survey, 2023 Threshold: 2.50

The results in Table 2 revealed that most (93.00%) of the respondents affirmed being aware of information and communication technologies, while only 7.00% of them claimed were not aware of the ICTs. The results also revealed that 51.00% of the respondents had and use mobile phones, while 24.00%, 22.00% and 3.00% had a radio, Television and computers, respectively.

The results further revealed that the respondents had access to radio, television, and mobile phones with mean scores of 3.65, 3.42, and 3.20, respectively. This implies that access to radio as ICTs may be a result of the fact that it is cheaper and has a high frequency that accommodates a network. Also, a transistor radio does not require power but has batteries that are common and affordable, in addition to its flexibility.

Mobile phones offer flexible and wider means of communication among the populace. It has many social platforms that ease communication with minimal costs. Mobile phones offer opportunities for both pictorial, voice, and motion information, making it more relevant in disseminating agricultural information. Agricultural size hosts research technologies that could be accessed by farmers freely.

Television is also accessible by the farms perhaps because they are relatively cheaper. Because of the ability to present motion pictures and voice messages, it is good for passing out information. Farmers learn a lot from agricultural programmes presented on Television in addition to other programmes of societal and social interest.

The majority of maize farmers appear to be aware of the potential benefits of technology in enhancing their farming practices, as evidenced by the high percentage of respondents (93.00%) who reported having some awareness of the technology. Awareness is a crucial first step towards adoption, as it helps farmers comprehend the benefits of using technology for communication, information access, and decision-making. This goes in line with the findings of Lawal *et al*. (2022), who found that farmers' willingness to adopt and use these technologies to improve agricultural productivity is strongly influenced by their awareness of ICTs.

The finding that 51.00% of the respondents had and used mobile phones highlights the widespread penetration of this technology among maize farmers. Mobile phones are versatile tools that facilitate communication, access to market information, weather forecasts, and extension services. Mobile phones are the most commonly used ICT tools among Nigerian farmers, providing them with essential information that can improve farm management and productivity. This is in line with Adebayo and Adesina (2021), who found that mobile phones are critical for disseminating agricultural information and enabling farmers to access vital resources and support.

Furthermore, Televisions and radios, which are owned by 22.00% and 24.00% of respondents respectively, also had a big impact. With the use of these instruments, farmers can improve their knowledge and practices by broadcasting agricultural programmes, market updates, and instructional

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content. Especially radios are good at reaching large audiences, even those who live in distant places. Ezeh and Nwankwo's (2021) findings stated that radio and television play a crucial role in providing farmers with agricultural information, hence aiding in their endeavours to enhance crop yields and optimise farming operations.

Relation between Socio-economic Characteristics of Farmers and Their Access to ICTs or Dissemination of Agricultural Information

The study determined the relationship between the socio-economic parameters and access to ICTs by the maize farmers. This was achieved via correlation. The result is presented in Table 2. The results in Table 2 show that age positively and significantly correlated with access to computers (0.048) and radio (0.105). Marital status, however, negatively and significantly correlated with access to computers (-0.045) and radio (-0.254), but positively and significantly correlated with access to mobile phones (0.210) and television (0.200). Household size shows a positive and significant correlation with access to computers (0.092) by the farmers, however, negative and significant with radio access (-0.0.46) and television (-0.0117).

Education revealed a significant relationship with access to mobile phones (-0.274). Education influences the economic decisions of an individual. Therefore, enlightened people had higher incomes and, hence, can easily have access and the capacity to acquire ICTs gadgets.

The result of farm size shows a significant correlation with mobile phones (-0.269), computers (-.0.210), radio (0.056), and television (-00218). This means that the larger the farm size of a respondent, the more likely they are to have expanded enterprise, with the consequence of increased income. This can favour access to ICTs.

The source of capital significantly correlates with the computer (0.241), radio (-0.260), and television (-0.107). The more an individual has access to capital he or she will be able to access ICTs gadgets.

Occupation of the respondent significantly correlates with mobile phone (0.123). Communication is an important factor in the well-being of every occupation. Mobile provides a significant platform for information dissemination by organizations, agencies, and groups of friends, among others. This enhances productivity by curbing time.

Table 2: Relationship between Socio-economic Characteristics of Farmers and their Access to ICTs for Dissemination of Agricultural Information

Socio-economic characteristics	Access to ICTs Mobile phone	Computer	Radio	Television
Age	-0.015	0.048 *	0.105 **	0.014
Marital status	0.210 **	-0.045*	-0.254**	0.200 **
Household size	-0.015	0.092**	-0.046*	-0.117**
Education	-0.294**	-0.015	0.017	-0.006
Farm size	-0.269**	-0.210**	0.056**	-0.218**
Source of capital	-0.022	0.241**	-0.260**	-0.107**
Occupation	0.123**	-0.033	-0.023	0.010

Source: Field Survey, 2023

Factors Influencing Use of ICTs by the Respondents

The study determined the factors that influence the use of ICTs by maize farmers. The results are presented in Table 3. The income level of the respondent, price (phone), individual differences, inadequate power supply, and availability influence the use of phones with mean scores of 2.98, 2.73, 2.55, 2.70 and 2.78, respectively. Similarly, the use of computers is influenced by the income level of the farmers, the price of the computer, individual differences, level of knowledge, inadequate power supply, and availability and flexibility of the computer, with mean scores of 3.32, 3.57, 2.50, 3.45,2.73, 2.96 and 2.53, respectively.

In addition, the use of radio is influenced by individual differences, with mean scores of 3.13, availability (3.14) and flexibility (2.90), implying that they influence the use of the radio by the respondents. The result may be that most phones now have radio stations, so they pay less attention to

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the use of transistor radios. On Television, the income level of the farmer and inadequate power supply are significant in influencing the use of television by the farmers. The result of the study demonstrates that the income level of the farmers is an important factor in the use of ICTs. The affordability of the ICT depends largely on the level of income of the farmer. The price of the ICTs gadget is also a significant factor in the use of ICTs, except for radio. This result is true in the sense that the income of an individual and price determine the amount and quality of goods and services consumed.

Table 3: Factors Influencing the Use of ICTs by Maize Farmers

S/n	ICTs gadget	Factors	Mean score sheet			
			Mangu	Bokkos	Kanam	Average
1.	**Mobile Phone**	Income Level	2.92	3.03	3.00	2.98
		Price of The Phone	3.00	2.13	3.05	2.73
		Individual Difference (Taste)	2.54	2.74	2.36	2.55
		Level of Knowledge	2.44	2.44	2.50	2.46
		Inadequate Power Supply	2.59	2.74	2.77	2.70
		Availability	2.74	2.74	2.86	2.78
		Flexibility	2.51	2.51	2.45	2.49
2.	**Computer**	Income Level	3.36	3.36	3.23	3.32
		Price of The computer	3.51	3.51	3.68	3.57
		Individual Difference (Taste)	2.38	3.38	2.73	2.50
		Level of Knowledge	3.38	3.38	3.59	3.45
		Inadequate Power Supply	2.71	2.72	2.77	2.73
		Availability	3.08	3.07	2.73	2.96
		Flexibility	2.64	2.64	2.27	2.52
3.	**Radio**	Income Level	1.95	2.10	2.00	2.02
		Price of The Radio	1.95	1.74	1.73	1.81
		Individual Difference (Taste)	3.15	3.15	3.09	3.13
		Level of Knowledge	2.00	2.00	1.91	1.97
		Inadequate Power Supply	2.46	2.46	2.55	2.49
		Availability	3.15	3.21	3.05	3.14
		Flexibility	2.82	2.92	2.95	2.90
4.	**Television**	Income Level	3.00	2.87	3.05	2.97
		Price of The Television	3.15	3.23	3.32	3.23
		Individual Difference (Taste)	1.94	1.82	2.23	2.00
		Level of Knowledge	1.97	2.00	1.95	1.93
		Inadequate Power Supply	3.38	3.38	3.41	3.39
		Availability	2.49	2.61	1.95	2.35
		Flexibility	2.21	2.59	2.59	2.33

Source: Field Survey, 2023

Constraints to Use of ICTs in the Dissemination of Agricultural Information

The results in Table 4 revealed that most (96.00%) of respondents reported that high cost of ICT gadgets was the major constraint to the use of ICTs in the dissemination of Agricultural information. This was followed by a poor power supply (93.00%), low level of knowledge and high cost of air time/data constituted 77.00% and 75.00%, respectively.

The implication of high cost of ICTs devices as a primary obstacle is a good indicator of the monetary hurdles preventing certain people from accessing necessary technologies. In rural areas, where farmers frequently have minimal financial resources, this problem is especially acute as posited by Oladele and Afolayan (2020) who asserted that, one important factor influencing smallholder farmers' adoption and usage of ICTs is their cost. Due to exorbitant prices, many farmers are unable to buy the equipment they need, which restricts their access to vital agricultural services and information.

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The results indicates that a prevalent issue in numerous rural regions is the limited power supply, as reported by 73% of participants. Ensuring persistent access to information and charging ICTs devices require dependable electricity. Insufficient power supply impairs the functionality of computers, radios, televisions, and cell phones. The adoption of ICTs in rural agricultural communities is severely hampered by insufficient infrastructure, especially unstable energy, as noted by Adejumobi and Ogunlade (2022).

According to the results, 77.00% of the respondents view inadequate ICTs knowledge as a major barrier. This emphasizes how farmers must become more digitally literate to use ICTs tools efficiently. To close this knowledge gap, educational initiatives, and training programmes are crucial. Adebayo *et al*. (2021) claim that raising farmers' levels of digital literacy can help them become more adept at using ICTs tools, which will maximise the advantages of technology in farming.

Using ICTs is a big barrier for maize farmers because of the high cost of data and airtime. Farmers may be discouraged from routinely use of smartphones, the internet, and other digital tools that are necessary to obtain market pricing, weather updates, agricultural information, and extension services due to these costs. Consequently, farmers can overlook vital information that could improve their decision-making and output. This finding is in tandem with the report by Ojo and Adebayo (2021) which highlights that the high cost of airtime and data is a significant impediment to the effective use of mobile phones and other ICTs tools among smallholder farmers in Nigeria. It indicates that the financial burden of maintaining continuous connectivity restricts farmers' access to vital agricultural information, ultimately affecting their productivity and livelihood, which suggests that reducing the cost of airtime and data through policy interventions and subsidies could significantly enhance ICTs adoption and utilization among farmers.

Table 4: Constraints to the Use of ICTs in Dissemination of Agricultural Information

Constraints	**Mangu**	**Bokkos**	**Kanam**	**Total**
High cost of ICT Gadget	37 (94.90)	38 (94.90)	21 (95.50)	96 (96.00)
Low level of knowledge	27 (69.20)	33 (84.62)	17 (77.30)	77 (77.00)
High cost of airtime/data	26 (66.70)	33 (84.60)	16 (72.70)	75 (75.00)
Poor power supply	35 (89.70)	38 (97.43)	20 (90.90)	93 (93.00)

Source: Field Survey, 2023 Figures in parentheses are the percentages

CONCLUSION AND RECOMMENDATION

The study concluded that majority of the farmers are aware of the use of information communication technology for dissemination of agricultural information. The farmers have access to mobile phone, television and computer and are effective in dissemination of agricultural information. The socio-economic characteristics of the farmers significantly correlate with access and use of ICT for dissemination of agricultural information were level of income of the farmers, price of the ICT gadget, taste, inadequate power supply and flexibility influence the use of ICT in dissemination of agricultural information. High cost of gadget and poor power supply are the highest-ranking constraints of use of ICT for agricultural purposes by the farmers.

The following recommendations were made based on the study:

i. Farmers should diversify sources of income to increase their purchasing power to enable them access ICTs gadgets for informed agricultural innovations.
ii. Farmers subscribe to independent sources of power such as solar, and use a smaller generator to power ICT gadgets for effective use and dissemination of agricultural activities. Also, rural electronic programmes by government and non-governmental organisations (NGOs) may help in connecting farmers in the rural areas to national grid.
iii. Farmers should join cooperative organizations to access soft loans to enable them to purchase ICT gadgets which can assist them in their maize agro-businesses.

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EFFECTS OF NEEM SEED KERNEL EXTRACT FOR THE CONTROL OF COWPEA FIELD PESTS IN BAUCHI STATE, NIGERIA

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ABSTRACT
Field trial was conducted during the rainy season of 2024 at Abubakar Tafawa Balewa University, Teaching and Research Farm Bauchi, Gubi campus to investigate the effect of neem seed kernel extract for the control of cowpea insect pests. The treatments consisted of neem seed kernel oil (0.5L/ha, 1L/ha and 1.5L/ha), one cowpea variety obtained from Institute for Agricultural Research, Samaru (Sampea-13), 2%Acetamiprid+1.5% Lamdacyhalothrine EC (1L/ha) and zero application (control). These were combined to give 5 treatments and replicated three times. The result revealeda significant ($P \leq 0.01$) differenceamong the treatments on number of aphids per plant, proportion (%) of plants infested by aphids, number of maruca larva per flower, proportion of flowers infested by the larva, number of damaged pods, number of clavigralla per plants and number and percentage of shriveled pods. Cowpea treated with either neem seed kernel (1.5L/ha) or 2.5%Acetamiprid+1.5%Lamdacyhalothrine had the lowest number of aphids per plant, while untreated cowpea plants had the highest proportion of plants infested by aphids as well as number of aphid per plant, followed by neem seed kernel (0.5L/ha). Cowpea plants treated with 2.5%Acetamiprid+1.5%Lamdacyhalothrine had the lowest percentage of plants infested by aphids, flowers infested by maruca larva, shriveled pods and number of damaged pods followed by neem seed kernel (1.5L/ha). Yield and yield components on the other hand,plants treated with either neem seed kernel (1.5L/ha) or 2.5%Acetamiprid+1.5%Lamdacyhalothrine had the highest number of seeds per pod and highest grain yield (8933.33kg/ha and 909.17kg/ha).Neem seed kernel extract had significantly impacted cowpea yield and insect pest infestation; it is therefore recommended to treat cowpea with 1.5L/ha of neem seed kernel for the control of cowpea field pests and higher yield.

Keywords: Cowpea, Neem, Seed, Kernel, Field, Pests,

INTRODUCTION
Cowpea (*Vigna unguiculata*) is a leguminous crop that plays a vital role in food security and income generation for millions of people in Africa (Fatokun*et al*., 2019). It is a rich source of protein, fiber, and other essential nutrients, making it an ideal crop for improving nutrition and health (Singh *et al*., 2017). Cowpea is also an important crop for sustainable agriculture due to its ability to fix nitrogen, tolerate drought, and resist pests and diseases (Ehlers *et al*., 2017). Cowpea is native to Africa, where it has been cultivated for over 10,000 years (Singh *et al*., 2017). It is widely grown in West Africa, particularly in Nigeria, Ghana, and Senegal (Fatokun*et al*., 2019). Cowpea is a nutrient-rich crop, providing: - High-quality protein (20-25% of dry matter) Fiber (5-7% of dry matter) Minerals (potassium, phosphorus, magnesium) and Vitamins (folate, thiamin, niacin) Cowpea is an important crop for smallholder farmers in Africa, providing income generation through sale of grains and leaves, employment opportunities for rural communities, food security through provision of nutritious grains and leaves.

Neem seed is a natural pesticide that has been used for centuries to control insect pests (Schmutterer, 2018). The seeds contain a compound called azadirachtin, which has insecticidal, repellent, and growth-regulating properties (Kumar *et al*., 2019). Neem is native to India and Southeast Asia, where it has been used for centuries in traditional medicine and agriculture (Schmutterer, 2018). Neem seed extracts have been shown to be effective against a wide range of insect pests. Azadirachtin, the active compound in neem seed, works by: Disrupting insect hormone systems, inhibiting insect growth and development and repelling insects from treated areas. Cowpea is

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susceptible to various insect pests, including: Aphids (*Aphis craccivora)*: . Thrips (*Megalurothripssjostedti*): Thrips are tiny, insects that feed on plant sap, causing stunted growth and distorted leaves (CABI, 2020). Pod borers (*Marucavitrata)*: These caterpillars feed on cowpea pods, causing significant yield losses (Oghiakhe*et al*., 2019). Flower thrips (*Frankliniellaoccidentalis*): These thrips feed on cowpea flowers, reducing seed set andyield (Annan *et al*., 2019).

A number of management techniques are available to control cowpea insect pests. Integrated pest management (IPM) strategies are recommended for managing cowpea insect pests, including: Use of resistant varieties, crop rotation and sanitation, biological control using natural enemies and chemical control using insecticides, Chemical control methods involve using insecticides to control pest populations. However, the use of synthetic insecticides can have negative impacts on human health and the environment. Health problems: Exposure to synthetic insecticides has been linked to various health problems, including cancer, neurological disorders, and reproductive issues (Aktar*et al*., 2018). Environmental problems: Synthetic insecticides can contaminate soil, water, and air, and can harm non-target organisms, such as bees and butterflies (Potts *et al*., 2019).Poor resource farmers in developing countries use different plant materials to protect stored grains against pest infestation by mixing grains with protectants made up of plant products. This idea is supported with the fact that the use of naturally occurring plant materials to protect agricultural produce against a variety of insect pests is an old-age practice in some parts of the world

MATERIALS AND METHODS

Study Area

Field experiment was conducted at the Abubakar Tafawa Balewa University Teaching and Research Farm Bauchi during the rainy season of 2024 Located in Gubi campus between latitude 10° 16’ 54.804’’N and longitude 9° 47’ 39.192’’E situated at 602m above sea level

Collection and Preparation of Neem Seed Kernel Extract (*Azadirachtaindica)*

Ripened neem fruits were collected and the seeds were separated from the pulp and dried under shade. The kernels were ground into a fine powder. The powdered kernels of about 5kg were mixed with 10L of water, and the mixture was stirred and left to steep overnight. The mixture was then filtered, and the resulting liquid was collected as the aqueous neem seed kernel extract.

Treatments and Experimental Design

The treatment consisted of neem seed kernel extract (0.5L/ha, 1L/ha and 1.5L/ha), 2%Acetamiprid+1.5%Lamdacyhalothrine EC (1L/ha) and a control. These were combined to give 5 treatments, laid out in a Randomized Complete Block Design (RCBD) and replicated three times.

Land Preparation and Field Layout

The land was cleared, ploughed and then harrowed into fine tilt soil and levelled flat. It was then marked into three blocks each containing ten plots. Each plot measured $9m^2$. A path of 0.5m and 1m was allowed within and between blocks respectively, the boundary of each plot was demarcated by ropes and sticks, tagged with its treatment number. The total area of the land used was $392m^2$. Seeds were sown as per treatment at 25x75cm spacing, two seeds were sown per hole and later thinned to one plant per stand, the land was kept weed free by manual weeding.

Application of Treatments

The neem seed kernel extracts were applied at the rate of 0.5L/ha, 1.0L/ha and 1.5L/ha weekly. The Acetamaprid2%+Lamdacyhalothrine1.5% was applied biweekly according to the manufacturer’s instruction at the rate of 1.0L/ha.

Data Collection

Data were collected from 10 randomly tagged plants at various stages of the plant growth on the following parameters;

Aphis craccivora

Infestation was assessed in the morning weekly for six weeks for aphid colony. Aphid on each stand was counted visually. Mean for the six weeks was taken and recorded.

Marucavitrata

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Infestation of cowpea flowers by *Maruca* was assessed by counting in the field in the evening. The presence of holes and larva on the flowers were the *Maruca* damage index. Ten flowers from the tagged plants of each plot were chosen randomly, carefully opened and examined on the spot. There were five observations at 5 days' intervals and the mean was taken and recorded.

Clavigrallatomentosicollis

Number of clavigralla were counted weekly, in the morning. at six weeks after sowing. Four observations were made. Number of damaged pods: These were visually scored in the field when the pods were filled, matured but still green. Pod damaged was visually rated. The presence of holes and frass on pods and sticking together of pods were used as *Maruca* damage.

Number of shriveled pods

These were also visually scored in the field when the pods were filled, matured but still green. Pods that were deformed, discloured and or dried prematurely were counted and were used as Clavigralla damage.

Number of pod/plants

Number of pods per plant were counted from the tagged plants and the mean number of pod/plants was recorded.

Number of seed/pods

Number of seeds in each pod of the tagged plants were counted and the mean number of seeds/pods was recorded.

Grain Yield(kg/ha)

The data was collected by weighing the grains in each plot after threshing using measuring scale and was calculated in kg and then projected per hectare.

Data Analysis

All the data collected were subjected to analysis of variance (ANOVA) to test the level of significant of all the treatment. Duncan's Multiple Range Test (DMRT) was adopted to separate significantly different treatment means

RESULTS AND DISCUSSION

Effect of Neem Seed Kernel Extract on Aphid (*Aphis craccivora*) Infestation

Result on the impact of insecticidal treatments on *Aphis craccivora* infestation in cowpea as presented in Table 1 indicated a significant ($P \leq 0.01$) differencein aphid infestation levels across insecticide treatments.Cowpea plots sprayed with 1.5 L/ha neem seed kernel extract or 2.5% Acetamiprid + 1.5% Lambda-cyhalothrin recorded the lowest number of aphids per plant and lowest proportion of plants infested. In contrast, untreated plots had the highest aphid population, followed by those treated with the lowest neem concentration (0.5 L/ha). The efficacy of neem seed kernel extract at 1.5 L/ha against aphids is consistent with studies by Mohammed and Salisu (2020), who reported significant aphid suppression using neem extracts in Bauchi State. Azadirachtin's antifeedant and growth-disrupting properties are known to reduce aphid survival and reproduction (Buba*et al*., 2022). Although chemical insecticides showed superior control, neem extract remains a viable eco-friendly option, especially at higher doses.

Table 1: Effect of Neem Seed Kernel Extract on Aphid (*Aphis craccivora*) Infestation

TREATMENTS	**No. of Aphids/plant**	**%(proportion) of plants infested** by Aphids
INSECTICIDE(L/HA)		
Control	4.92[a]	34.50[a]
NSK-0.5	4.50[b]	18.33[b]
NSK-1.0	3.33[c]	6.83[cd]
NSK-1.5	1.75[d]	3.33[d]
Chemical-1.0	0.92[d]	1.42[d]
LS	**	**
SE±	0.171	1.616

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Means followed by different letter within the same column are significantly different using DMRT. LS: Level of Significance, NSK: Neem Seed Kernel Extract, Chemical: 2.5%Acetamiprid+1.5%Lamdacyhalothrine EC, **: Significant at 0.01%

Effect of Neem Seed Kernel Extract on Pod Borer (*Maruca vitrata*) Infestation

The result as presented in Table 2 revealed that, a significant difference ($P \leq 0.01$) were observed between the treatments throughout the study period. The result further indicated that, pod borer infestation was higher in untreated cowpea, with a greater number of larvae per flower, higher flower damage, and more pod damage. The synthetic chemical (1 L/ha) provided the best control, followed by 1.5 L/ha neem extract. Untreated plants recorded the highest infestation levels.Neem's efficacy in reducing larval numbers corroborates the findings of Ibrahim *et al*. (2023), who reported a significant reductions in *Maruca* larval density using neem oil formulations in North-central Nigeria.

Table 2: Effect of Neem seed kernel extract on *M.vitrata* infestation

TREATMENTS	No. of M.Vitrata larvae per Flower	%(proportion) of flowers infested by larva	No.of damaged pods
INSECTICIDE(L/HA)			
Control	23.92[a]	68[a]	4.01[a]
NSK-0.5	13.75[b]	42.90[b]	3.27[b]
NSK-1.0	4.60[c]	31.70[c]	2.83[c]
NSK-1.5	2.00[d]	15.00[d]	2.03[d]
Chemical-1.0	1.00[e]	8.70[e]	1.29[e]
LS	**	**	**
SE±	0.139	0.737	0.042

Means followed by different letter within the same column are significantly different using DMRT. LS: Level of Significance, NSK: Neem Seed Kernel Extract, Chemical: 2.5%Acetamiprid+1.5%Lamdacyhalothrine EC, **: Significant at 0.01%

Effect of Neem Seed Kernel Extract on Pod Sucking Bug (*Clavigralla tomentosicollis*) Infestation

Result on the effect insecticidal treatment on *Clavigralla tomentosicollis* infestation as presented in Table 3 showed that, there was significant ($P \leq 0.01$) difference between the treatments. The synthetic insecticide (1 L/ha) was most effective in reducing bug infestation, followed by 1.5 L/ha neem extract. The performance of neem at 1.5 L/ha further validates its potential as a botanical insecticide, this is in line with the results reported by Okonkwo and Umeh (2019), where neem seed oil extract reduced pod damage without harming pollinators. Although chemical insecticides remain the most effective option, the use of high-concentration neem seed kernel extract offers an effective and environmentally sustainable alternative for managing pod bugs, especially for resource-limited farmers.

Table 3: Effect of Neem seed kernel extract on Clavigralla infestation

TREATMENTS	No.ofC.Tomentosicollis per plant	No.of shriveled pods	% proportion of shriveled pods
INSECTICIDE(L/HA)			
Control	4.21[a]	1.86[a]	19.86[a]
NSK-0.5	3.73[b]	1.43[b]	11.33[b]
NSK-1.0	3.35[c]	1.23[c]	8.60[c]
NSK-1.5	2.10[d]	0.94[d]	4.92[d]
Chemical-1.0	1.19[e]	0.75[e]	3.60[e]
LS	**	**	**
SE±	0.033	0.017	0.251

Means followed by different letter within the same column are significantly different using DMRT. LS: Level of Significance, NSK: Neem Seed Kernel Extract, Chemical: 2.5%Acetamiprid+1.5%Lamdacyhalothrine EC, **: Significant at 0.01%

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Effect of Neem Seed Kernel Extract on Yield and Yield Components of Cowpea

The results as presented in Table 4 revealed that, number of pods per plant, number of seeds per pod, grain yield, and pod length were all significantly ($p \leq 0.01$) higher in cowpea treated with 1.5 L/ha neem seed kernel extract or 2.5% Acetamiprid + 1.5% Lambda-cyhalothrin. The yield improvement as observed in plots treated with neem seed kernel extract at 1.5 L/ha aligns with the findings of Mohammed *et al*. (2020), who reported that neem extract application significantly enhanced cowpea yield parameters in Bauchi State by minimizing pest damage during critical growth stages.

Table 4: Effect of Neem seed kernel extract on Yield and Yield components of Cowpea

TREATMENTS	No.of pods Per Plant	No.of seeds Per Pod	Pod length(cm)	Grain Yield(kg/ha)
INSECTICIDE(L/HA)				
Control	9.42^{e}	8.83^{d}	13.00^{d}	384.50^{d}
NSK-0.5	12.67^{d}	11.92^{c}	13.75^{c}	533.75^{c}
NSK-1.0	14.92^{c}	12.92^{b}	15.10^{b}	616.67^{b}
NSK-1.5	19.25^{b}	14.67^{a}	16.42 ^{a}	893.33^{a}
Chemical-1.0	20.75^{a}	15.17^{a}	16.83^{a}	909.17^{a}
LS	**	**	**	**
SE±	0.194	0.236	0.190	10.790

Means followed by different letter within the same column are significantly different using DMRT. LS: Level of Significance, NSK: Neem Seed Kernel Extract, Chemical: 2.5%Acetamiprid+1.5%Lamdacyhalothrine EC, **: Significant at 0.01%

CONCLUSION AND RECOMMENDATION

The findings from this study confirm that Neem seed kernel extract at 1.5 L/ha effectively suppressed major insect pests of cowpea, particularly aphids, *Maruca vitrata*, and *Cavigralla tomentosicollis*, and improved plant performance and yield. Its efficacy was comparable to that of the synthetic insecticide, indicating its potential as a sustainable and eco-friendly alternative for insect pest management in cowpea farming systems. Neem seed kernel extract at 1.5 L/ha is recommended for effective control of field pests of cowpea. It provides a viable, environmentally friendly, and cost-effective alternative to synthetic insecticides.

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EFFECT OF COW DUNG AND COW URINE COMBINATION FOR THE CONTROL OF COWPEA FIELD PESTS IN BAUCHI STATE, NIGERIA

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ABSTRACT
Field trial was conducted during the rainy season of 2024at Abubakar Tafawa Balewa University, Teaching and Research Farm Bauchi, to investigate the effect of cow dung and cow urine combination for the control of cowpea field pests. The treatments consisted of three (3) rates of cow dung + cow urine (2.5, 5.0 and 7.5 l/ha), 2%Acetamiprid+1.5%Lamdacyhalothrine EC (1 l/ha) and a control. These were combined to give 5 treatments, laid out in a randomized complete block design and replicated three times. The result revealed a significant difference (P≤0.01) among the treatments on number of aphids per plant, proportion (%) of plants infested by aphids, number of maruca larva per flower, proportion of flowers infested by larva, number of damaged pods, number of clavigralla per plants, number and percentage of shriveled pods. The result also showed that cowpea treated with either cow dung+cow urine (7.5 l/ha) or 2%Acetamiprid+1.5%Lamdacyhalothrine had the lowest number of aphids, maruca and clavigralla infestation. Control plot on the other hand, had the highest proportion of plants infested by aphids, maruca as well as clavigralla. Yield and yield components on the other hand, cowpea treated with either cow dung+cow urine (7.5L/ha) or 2%Acetamiprid+1.5%Lamdacyhalothrine had the highest number of seeds per pod and highest grain yield (913.23 kg/ha and 927.10 kg/ha). Cow dung and cow urine combination had significantly impacted cowpea yield and insect pest infestation, therefore, it is recommended to treat cowpea with 7.5 l/ha cow dung and cow urine combination for the control of cowpea field pests and higher yield.

Keywords: Cow, Dung, Urine, Pest, Field, Cowpea.

INTRODUCTION
Cowpea (*Vignaunguiculata* L. Walp) is a vital legume crop extensively cultivated in sub-Saharan Africa, particularly in Nigeria, which is among the leading producers globally. It serves as a significant source of protein for human consumption and provides nutritious fodder for livestock. Cowpea is a significant source of protein, calories, and micronutrients. It is a valuable crop for soil fertility improvement, as it fixes atmospheric nitrogen through symbiotic relationships with rhizobia (Kumar *et al*., 2020). Globally, cowpea production is estimated to be around 6 million metric tons, with Africa accounting for over 70% of global production.

Despite its importance, cowpea production faces substantial challenges from various insect pests, leading to significant yield losses. Key pests include: Aphids (*Aphis craccivora*): These sap-sucking insects cause direct damage by feeding on plant sap and indirectly by transmitting viral diseases.Legume Flower Thrips (*Megalurothripssjostedti*): They damage flowers, leading to reduced pod formation.Legume Pod Borer (*Marucavitrata*): This pest feeds on flower buds, flowers, and young pods, causing yield losses ranging from 20% to 80% if uncontrolled .Pod-Sucking Bugs (e.g., *Clavigrallatomentosicollis*): They pierce pods, leading to seed damage and reduced quality.These pests can cause up to 70% grain yield reduction in cowpea if not effectively managed.

Cowpea is susceptible to various insect pests, including: Aphids (*Aphis craccivora)*: These small, soft-bodied insects feed on plant sap, causing curled or distorted leaves Thrips (*Megalurothripssjostedti*): Thrips are tiny, insects that feed on plant sap, causing stunted growth and distorted leaves. Pod borers (*Marucavitrata)*: These caterpillars feed on cowpea pods, causing significant yield losses (Oghiakhe*et al*., 2019). Flower thrips (*Frankliniellaoccidentalis*): These thrips feed on cowpea flowers, reducing seed set and yield (Annan *et al*., 2019).

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Synthetic insecticides have been widely used to control cowpea insect pests due to their efficacy and rapid knockdown effects. However, the over-reliance on synthetic insecticides has led to concerns about environmental pollution, human health risks, and the development of pesticide-resistant pest populations (Kumar *et al*., 2020). Moreover, the high cost of synthetic insecticides can be a significant burden for smallholder farmers in developing countries. In recent years, there has been a growing interest in exploring alternative pest management strategies that are environmentally friendly, sustainable, and cost-effective. One promising approach is the use of botanicals or organic amendments, such as cow dung and cow urine, which have been shown to possess insecticidal properties (Rathore*et al*., 2021).. Cow dung and cow urine are readily available, inexpensive, and biodegradable, making them attractive options for smallholder farmers. Several studies have demonstrated the efficacy of cow dung and cow urine in controlling various insect pests, including aphids, whiteflies, and beetles (Kumar *et al*., 2022; Singh *et al*., 2020). However, there is limited research on the use of cow dung and cow urine for controlling cowpea insect pests, particularly on different cowpea varieties. This study aims to investigate the effectiveness of cow dung and cow urine in controlling insect pests on two varieties of cowpea, with a view to developing a sustainable and eco-friendly pest management strategy.

MATERIALS AND METHODS

Study Area

The research was conducted at the Abubakar Tafawa Balewa University Teaching and Research Farm Bauchi. The experiments were carried during the rainy season of 2024. Bauchi is located at 10° 74'E latitude and 9°47'E and situated at 690.3m above sea level in savannah zone of Nigeria.

Collection and Preparation of Cow Dung and Cow Urine

Cow dung and cow urine were collected from Abubakar Tafawa Balewa University Farm Bauchi, dried under shade. Cow dung of about 5kg was diluted in to 5L of water and 5L of cow urine was added.

The resulting solution was fermented for four days in an enclosed container in a shaded area and then 100g of lime was added neutralize the toxic phenols and acid released.

Treatments and Experimental Design

The treatment consisted of cow dung+cow urine (2.5L/ha, 5.0L/ha and 7.5L/ha), 2.5%Acetamiprid+1.5%Lamdacyhalothrine EC (1L/ha) and zero application (control). These were combined to give five treatment combinations, randomized and replicated three times. The experiment was laid out in Randomized Complete Block Design (RCBD).

Land Preparation and Field Layout

The land was cleared, ploughed and then harrowed into fine tilt soil and levelled flat. It was then marked into three blocks each containing ten plots. Each plot measured $9m^2$. A path of 0.5m and 1m was allowed within and between blocks respectively, the boundary of each plot was demarcated by ropes and sticks, tagged with its treatment number. The total area of the land used was $392m^2$. Seeds were sown as per treatment at 25x75cm spacing, two seeds were sown per hole and later thinned to one plant per stand, the land was kept weed free by manual weeding.

Application of Treatments

The cow dung+cow urine were applied at the rate of 2.5L/ha, 5.0L/ha and 7.5L/ha weekly. The Acetamaprid2%+Lamdacyhalothrine1.5% was applied biweekly according to the manufacturer's instruction at the rate of 1.0L/ha

Data Collection

Data were collected from 10 randomly tagged plants at various stages of the plant growth on the following parameters;

Aphis craccivora

Infestation was assessed in the morning between 8 and 10 a.m., from the two middle rows of each plot at the age of 2 weeks for aphid colony. The size on each stand was counted visually. Six weekly observations were made

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Maruca vitrata

Infestation of cowpea flowers by*Maruca* was assessed by counting in the field between 3 and 5 p.m. The presence of holes and larva on the flowers were the *Maruca* damage index. Ten flowers in the two outer rows of each plot were chosen randomly, carefully opened and examined on the spot. There were five observations at 5 days' intervals.

Clavigralla tomentosicollis

Population of PSBs which rested on cowpea stands in the two middle rows were counted weekly, between 8 and 10 a.m. at the age of six weeks. Four observations were made

Number of Damaged Pods

These were visually scored in the field when the pods were filled, matured but still green. Pod damaged was visually rated. The presence of holes and frass on pods and sticking together of pods were used as*Maruca*damage

Number of Shriveled Pods

These were also visually scored in the field when the pods were filled, matured but still green. Pod that were deformed, discloured and or dried prematurely were counted and were used as Clavigralla damage.

Number of Pods/plant

Number of pods per plant were counted from the tagged plants and the mean number of pods/plant was recorded

Number of Seeds/pod

Number of seeds in each pod of the tagged plants were counted and the mean number of seeds/pod was recorded

Grain Yield(kg/ha)

The data was collected by weighing the grains in each plot after threshing using measuring scale and was calculated in kg and then projected per hectare.

Data Analysis

All the data collected were subjected to analysis of variance (ANOVA) to test the level of significant of all the treatment. Duncan's Multiple Range Test (DMRT) was adopted to separate significantly different treatment means

RESULTS AND DISCUSSION

Effect of Cow Dung and Cow Urine Combination on Aphid (*Aphis craccivora*) Infestation

Table 1 presents result of the influence of cow dung + cow urine treatments on *Aphis craccivora* (aphid) infestation in cowpea. The results indicated a significant difference ($P \leq 0.01$) in both the number of aphids per plant and the percentage of plants infested across the treatments. Both 2.5% Acetamiprid + 1.5% Lambda-cyhalothrin and 7.5 L/ha cow dung + cow urine significantly reduced aphid infestation. Conversely, untreated cowpea plots recorded the highest aphid population and infestation rate. Among all treatments, synthetic insecticide application recorded the lowest aphid infestation, closely followed by the organic cow dung + cow urine mixture at 7.5 L/ha.

The efficacy of both synthetic and organic treatments in suppressing aphid populations confirms their potential as key components of integrated pest management (IPM). The active ingredients in Acetamiprid and Lambda-cyhalothrin disrupt the nervous system of aphids, causing rapid knockdown and mortality. Meanwhile, cow dung and cow urine contain natural compounds with insect-repellent and anti-feedant properties, which can either repel aphids or inhibit their feeding and reproduction. Moreover, organic treatments may improve plant vigor, enhancing tolerance to pest pressure.

Importantly, the fact that 7.5 L/ha of cow dung + cow urine reduced aphid infestation almost as effectively as the synthetic insecticide underscores the practical value of organic formulations in pest control, especially in low-resource settings. This finding is consistent with the study by Yusuf *et al*. (2019), who demonstrated that animal waste-based treatments significantly reduced aphid populations in cowpea fields.

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Table 1: Effect of Cow Dung and Cow Urine Combination on Aphid (*Aphis craccivora*) Infestation

TREATMENTS	No. of Aphids/plant	%(proportion) of plants infested by Aphids
INSECTICIDE(L/HA)		
Control	5.67[a]	38.83[a]
CD+CU-2.5	5.75[a]	22.42[b]
CD+CU-5.0	4.75[b]	9.08[c]
CD+CU-7.5	3.58[c]	5.42[cd]
Chemical-1.0	2.92[c]	3.00[d]
LS	**	**
SE±	0.250	1.673

Means followed by different letter within the same column are significantly different using DMRT. LS:Level of Significance, CD+CU:cowdung+cow urine, Chemical: 2.5%Acetamiprid+1.5%Lamdacyhalothrine EC, **: Significant at 0.01%

Effect of Cow Dung and Cow Urine Combination on Cowpea Pod Borer (*Maruca vitrata*) Infestation Table 2 shows results of the influence of cow dung + cow urine treatments on the infestation level of the cowpea pod borer (*Marucavitrata*). The results revealed that there was significant difference ($p \leq 0.01$) between the insecticide treatments. The infestation level measured by the number of larvae per flower, proportion of flowers infested, and number of damaged pods was considerably higher in untreated cowpea plots. In contrast, the lowest *M. vitrata* infestation was recorded in plots treated with the chemical insecticide (1 L/ha), followed by plots treated with cow dung + cow urine at 7.5 L/ha.

The superior performance of both the synthetic insecticide and the cow dung + cow urine treatment in reducing *M. vitrata* infestation underscores the effectiveness of external control measures. While synthetic insecticides directly disrupt the nervous system of the larvae, cow dung and cow urine may act through a combination of repellent, antifeedant, and oviposition-deterring properties, discouraging the pest from colonizing flowers and pods. This finding supports the work of Usman *et al*. (2021), who found that organic formulations based on animal waste reduced pod borer infestation significantly when applied at appropriate concentrations.

Notably, the effectiveness of the 7.5 L/ha cow dung + cow urine treatment in reducing infestation to levels comparable to synthetic insecticides demonstrates its potential as a sustainable and environmentally friendly option for *M. vitrata* management. Its affordability and ease of preparation make it particularly suitable for smallholder farmers who may lack access to commercial insecticides.

Table 2: Effect of Cow Dung and Cow Urine Combination on Cowpea Pod Borer (*Maruca vitrata*)

TREATMENTS	No. of M.Vitrata larvae per Flower	%(proportion) of flowers infested by larva	No.of damaged pods
INSECTICIDE(L/HA)			
Control	25.92[a]	63.58[a]	3.81[a]
CD+CU-2.5	15.67[b]	38.92[b]	3.06[b]
CD+CU-5.0	5.83[c]	29.00[c]	2.62[c]
CD+CU-7.5	3.00[d]	15.50[d]	1.83[d]
Chemical-1.0	2.08[e]	7.67[e]	1.09[e]
LS	**	**	**
SE±	0.158	0.271	0.042

Means followed by different letter within the same column are significantly different using DMRT. LS: Level of Significance, CD+CU:cowdung+cow urine, Chemical: 2.5%Acetamiprid+1.5%Lamdacyhalothrine EC, **: Significant at 0.01%

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Effect of Cow Dung and Cow Urine Combination on Cowpea Pod Sucking Bug (*Clavigralla tomentosicollis*) Infestation

Table 3 presents the result on effect of pest control treatments on the infestation level of the cowpea pod sucking bug, *Clavigralla tomentosicollis*. The results revealed that there was significant difference ($p \leq 0.01$) among insecticide treatments. The number of *C. tomentosicollis* per plant, the number of shriveled pods, and the proportion of shriveled pods were highest in untreated cowpea plots. In contrast, the lowest infestation levels were recorded in plots treated with the chemical insecticide (1 L/ha), followed by those treated with cow dung + cow urine at 7.5 L/ha.

Cow dung and cow urine applied at 7.5 L/ha also reduced bug populations and pod damage, likely due to their repellent odor, physical interference with pest attachment, or anti-feedant compounds present in the mixture. The reduction in the number of shriveled pods in treated plots, especially with the organic input, suggests that cow dung and urine not only deterred insect feeding but also allowed uninterrupted pod filling and development. This supports the report of Yusuf *et al*. (2019), who found that cow dung and urine reduced damage from pod sucking pests and improved pod quality and seed recovery in cowpea.

Table 3: Effect of Cow Dung and Cow Urine Combination on Cowpea Pod Sucking Bug (*Clavigralla tomentosicollis*) Infestation

TREATMENTS	No.ofC.Tomentosicollis per plant	No.of shriveled pods	% proportion of shriveled pods
INSECTICIDE(L/HA)			
Control	4.01[a]	1.76[a]	17.85[a]
CD+CU-2.5	3.53[b]	1.35[b]	10.32[b]
CD+CU-5.0	3.15[c]	1.17[c]	7.45[c]
CD+CU-7.5	1.87[d]	0.92[d]	4.75[d]
Chemical-1.0	0.99[e]	0.65[e]	3.17[e]
LS	**	**	**
SE±	0.033	0.042	0.249

Means followed by different letter within the same column are significantly different using DMRT. LS: Level of Significance, CD+CU:cowdung+cow urine, Chemical: 2.5%Acetamiprid+1.5%Lamdacyhalothrine EC, **: Significant at 0.01%

Effect of Cow Dung and Cow Urine Combination on Yield and Yield Components of Cowpea Table 4 presented result of the effects of application of cow dung + cow urine and insecticides on yield and yield components of cowpea. The measured parameters include number of pods per plant, number of seeds per pod, pod length, and grain yield. The result revealed that all the components pods per plant, seeds per pod, pod length, and grain yield were significantly ($p \leq 0.01$) higher in cowpea treated with cow dung + cow urine (7.5 L/ha) or 2.5% Acetamiprid + 1.5% Lambda-cyhalothrin. Untreated cowpea produced the lowest yield and yield components.

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The effectiveness of both chemical and organic treatments in enhancing yield and its components is linked to their role in insect pest suppression. Reduced pest pressure particularly from flower- and pod-feeding insects like *Marucavitrata* and *Clavigrallatomentosicollis* allows the cowpea plants to retain more flowers and fill more pods, leading to higher seed set and grain output. Moreover, cow dung and cow urine may have provided supplemental nutrients that further improved plant vigor and reproductive output. This dual actionpest suppression and nutrient supply was also demonstrated by Usman *et al*. (2021), who noted improved pod and grain yield in cowpea treated with organic waste formulations.

Interestingly, the organic treatment at 7.5 L/ha performed comparably to synthetic insecticide, suggesting its viability as a low-cost and eco-friendly alternative for smallholder farmers. This observation confirms earlier findings by Akinbode*et al*. (2018), who reported similar grain yield responses in cowpea under organic and chemical pest control regimes.

Table 4: Effect of Cow dung and Cow Urine combination on Yield and Yield components of Cowpea

TREATMENTS	No.of pods Per Plant	No.of seeds Per Pod	Pod length(cm)	Grain Yield(kg/ha)
INSECTICIDE(L/HA)				
Control	8.33^{e}	7.83^{d}	12.00^{d}	402.50^{d}
CD+CU-2.5	11.67^{d}	10.92^{c}	13.00^{c}	552.92^{c}
CD+CU-5.0	13.92^{c}	11.92^{b}	14.00^{b}	636.70^{b}
CD+CU-7.5	17.33^{b}	13.67^{a}	15.00 ^{a}	913.23^{a}
Chemical-1.0	18.75^{a}	14.17^{a}	15.08^{a}	927.10^{a}
LS	**	**	**	**
SE±	0.194	0.236	0.158	10.687

Means followed by different letter within the same column are significantly different using DMRT. LS: Level of Significance, CD+CU:cowdung+cow urine, Chemical: 2.5%Acetamiprid+1.5%Lamdacyhalothrine EC, **: Significant at 0.01%

CONCLUSION AND RECOMMENDATION

The findings of this study clearly indicated that: Cow dung + cow urine at 7.5 L/ha was highly effective in both reducing field pest infestation and enhancing plant performance, showing comparable results to synthetic insecticide. The integration of affordable, locally available organic inputs such as cow dung and cow urine can significantly reduce reliance on synthetic insecticides while maintaining productivity. For effective insect pest management and enhanced yield, cowpea farmers especially in northern Nigeria are advised to apply cow dung + cow urine at 7.5 L/ha, this organic insecticide formulation should be promoted as a cost-effective, environmentally friendly alternative to chemical insecticides in low-resource farming communities.

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EFFECTS OF CONFLICT BETWEEN CROP AND LIVESTOCK FARMERS ON AGRICULTURAL PRODUCTION IN NORTHERN PLATEAU STATE, NIGERIA

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ABSTRACT
The study examined the effect of conflicts between crop and livestock farmers on agricultural production in the Northern Plateau State. A multistage sampling technique was used to select 81 crop and 55 livestock farmers for the research. Primary data were collected using a structured questionnaire. Data were analysed using both descriptive and inferential statistics. The results for the study showed that the majority (66.13%) of both crop and livestock farmers were male and above 50 years old. It also revealed that both crop and livestock farmers appeared to be formally educated (33.87%). More so, farm size, output, and the herd size of farmers before and after the conflict were all compared. The result showed that they were significantly different at $p<0.001$. It therefore revealed that conflict has a positive effect on farm size, output and herd size of farmers. The major constraints to conflict resolution include the use of law enforcement structures with mean scores of (5.87, 6.11), a lack of punishing conflict perpetrators (4.90, 5.58), weak policies (4.58) and a poor implementation of policies by the government (5.58). The study concluded that conflict had a positive effect on agricultural production (farm size, output, and herd size of farmers). The study recommended that dialogue, instead of the use of law enforcement structures, ranching, educating crop and livestock farmers, punishing perpetrators of conflict and full implementation of policies by the government, among others, will go a long way in resolving conflict in the study area.

Keywords: Conflicts, Farmers, Effects, Crops, Livestock.

INTRODUCTION
Agricultural production in Nigeria remains the backbone of rural livelihoods, especially in the northern regions where both crop and livestock farming are dominant. However, the growing incidence of conflict between crop farmers and livestock herders poses a significant threat to agricultural productivity and rural food security (Bolarinwa *et al.,* 2021). In Northern Plateau State, the increasing frequency and intensity of these conflicts have destroyed crops, lost of livestock, displaced farmers, and disrupted agricultural activities, ultimately threatening the region's food systems and socio-economic stability (Omomowo, 2021).

These conflicts are primarily driven by competition over access to land and water resources, exacerbated by climate variability, population growth, and weak enforcement of land use and grazing regulations (Blench, 2019). Traditional transhumance patterns by pastoralists often clash with sedentary farming practices, leading to disputes over farmland encroachment and cattle grazing. This phenomenon, when poorly managed, escalates into violent clashes with devastating consequences for agricultural communities (Ahmed & Adisa, 2020). The persistent nature of these conflicts has caused widespread displacement of farming populations and significant reductions in crop yields and livestock assets (Edeh *et al.,* 2020).

The effects are more pronounced in Northern Plateau State due to its agro-pastoral composition and history of farmer-herder interactions. Research shows that such conflicts not only reduce the quantity and quality of agricultural output but also discourage investment in agriculture, limit access to markets, and increase poverty among rural households (Ayanlade *et al*., 2020; Okoli *et al*., 2023). Therefore, understanding the specific impacts of crop-livestock conflict on agricultural

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production in this region is vital for informing conflict-sensitive agricultural policies and sustainable rural development strategies.

The study aimed to assess the effects of conflicts between crop and livestock farmers on agricultural production in Northern Plateau State, Nigeria. The specific objectives were to;

i. describe the socio-economic characteristics of the respondents in the study area;
ii. determine the effects of conflict between crop and livestock farmers on agricultural production in the study area, and;
iii. identify constraints to resolving conflict between crop and livestock farmers.

MATERIALS AND METHODS

The Study Area

The study was conducted in the Central zone of Plateau State. Plateau State is located in the north-central zone of Nigeria and lies between Latitude 8^0 30' and 10^0 30'N, Longitude $7^0$30' and $13^0$37'E with a land mass covering 30,913 sq. kilometres. The monthly maximum and minimum temperatures are 20°C and 15°C, respectively. The mean annual rainfall is about 1450mm, and the relative humidity of 60%. The state has an estimated population of 3,178,712 (NPC, 2007 estimate), and 3.78 million (NPC, 2013 est). It is bounded by Kaduna and Bauchi states on the north, Taraba on the east, and Nasarawa on the south and west. The Jos Plateau rises to about 5,250 feet (1600m) above sea level in the north-central state's part, and the Benue River Valley stretches along the southeast border (Price, 2019). Although there are wooded valleys in the southeast, the vegetation is mostly open grassland, which is suitable for grazing and farming.

Based on soils, climate, and typical farming systems, the state is classified into three distinct agro-ecological zones, namely, the lowland moist savannah, which falls within southern Guinea, and the Savannah rain forest, having extensive low-lying flat land with high water holding capacity favourable for the production of rice, yam, cassava, melon and groundnut. The mid-altitude zone (the area of study) falls within 500-1,500 meters above sea level, with soils that are sandy clay and heavy rains. Predominantly, maize, Irish potato, and assorted vegetables are produced.

There is a high concentration of livestock and poultry, such as cattle, sheep, goats, layers, broilers, cross-bred local chickens and quails, and production of crops like millet, groundnut, sorghum, and cowpea. It has open grassland vegetation usually used for grazing and farming with notable steep-sloping mountains around the area (FAO, 2018). Global System Mobile (GSM) Network services like Globacom, Airtel, Etisalat, and MTN exist.

Sampling Procedure and Sampling Size

The target populations for this study are the crop and livestock farmers. A multi-stage sampling technique was used to select the respondents for the study. The first stage involved a purposive selection Northern Zone of Plateau State. This selection was based on the frequency of occurrence of conflicts between crop and livestock farmers in the study area. The second stage also involves the purposive selection of two local governments in the Northern zone, namely Barkin Ladi and Riyom, as a result of the frequent occurrence of conflict.

The third stage involved purposive sampling of four communities in Barkin Ladi and two in Riyom Local Government Areas. The selection of these communities is a result of the frequent occurrence of conflict between crop farmers and livestock farmers in those communities. In the fourth stage, a total of 81 crop farmers and 55 livestock farmers were randomly selected from the communities, giving a total sample size of 136 respondents, as shown in Table 1.

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Table 1: Sample Size Selection Plan for Crop and Livestock Farmers

LGA	Community	Crop Farmers		Livestock farmers		Total sample size (10%)
		N_1	n_1	N_2	n_2	$n_1 + n_2$
BarkinLadi	Gashish	215	21	153	15	36
	Ropp	113	11	98	9	20
	Fan	110	11	75	7	18
	Foron	90	9	51	5	14
Riyom	Jol	97	9	92	9	18
	Bachit	211	20	102	10	30
Total		**836**	**81**	**571**	**55**	**136**

N_1= Population of crop farmers; n_1 = sample size of crop farmers
N_2= Population of livestock farmers; n_2 = sample size of livestock farmers

Method of Data Collection

Data for the study were collected from primary sources using a questionnaire. Trained enumerators from PADP were used to administer the questionnaire to the respondents and retrieve them. The questionnaire consisted of six (6) sections: A, B, C, D, E and F. Section A covers socio economic characteristics of the respondents, section B covered information on the causes of conflict among the respondents in the study area, section C captured information on methods of conflict resolution as perceived by the respondents, Section D sought information on the effect of conflict between crop and livestock farmers, and section E collected information on constraints to conflict resolutions.

Analytical Techniques

Data were analysed using both descriptive and inferential statistics.

Descriptive statistics

Descriptive statistics such as frequency distribution, percentages and means were used to analyse and describe the socio-economic characteristics of the crop and livestock farmers. Frequency distribution is an organised display of data that shows the number of observations from the data set that fall into each of a set of mutually exclusive class. Frequency distribution is to organize the data items into a more compact form without obscuring the essential information contained in the values. Thus, a frequency distribution is simply the classification of a group of data items according to some observable features. It is explained by the model:

$$y = \frac{\Sigma xf}{n} \times 100 \quad \ldots \quad (1)$$

Where:

y = observed variable
f = frequency
n = sample size

Five-point Likert scale

A five-point Likert scale was adopted (as applied by Lawal *et al.,* 2013): strongly agree (5), agree (4), undecided (3), disagree (2), strongly disagree (1). The mean value for the perceived causes of conflict was determined as:

$$\bar{x}_s = \frac{\Sigma x}{n} \quad \ldots \quad (2)$$

Where, $\bar{x}$ of each constraint was computed by multiplying the frequency of each response scale with its appropriate nominal value and dividing the sum by the study sample size.

Where:

$\bar{x}$= mean score;
Σ= summation;
F= frequency;
n = nominal value;
nr = number of respondents

$$\bar{x} = \frac{1+2+3+4+5}{5} = 3$$

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From these responses, a mean score below 3 was regarded as not being a severe constraint to conflict resolution, while a mean score above 3 was regarded as being severe.

Student's Test

The t-test, according to Bevans (2023), is used to compare two sample distributions, which should be approximately normal, with data collected on either an interval or ratio scale of measurement. For a two-sample test, the Student's t-test is given by:

$$t=\frac{/\bar{x}-\bar{y}/}{\sqrt{\frac{sx^2}{Nx}+\frac{sy^2}{Ny}}} \quad \ldots (4)$$

Where:
t = Student t-test
$\bar{x}$=Observed mean of crop farmers before and after conflict
$\bar{y}$=Observed mean of livestock farmers before and after conflict
sx^2= square of the standard deviation of arable farmers
sy^2= square of the standard deviation of livestock farmers
Nx= sample size of arable farmers
Ny= sample size of livestock farmers

Statistical package for social sciences (SPSS), Version 23, was used to compare the farm size cultivated by crop farmers before and after conflict, output and number of livestock before and after conflict. This explained the effect of conflict on agricultural production with respect to crop and livestock production. According to Bevans (2023), the higher the value of *t* in a t-test statistic, it shows the there is a significant difference between the means of the two samples.

RESULTS AND DISCUSSION

Socio-Economic Characteristics of the Respondents

The socio-economic parameters examined in this study include: age, sex, marital status, household size, educational background, experience in farming and rearing of livestock, farm and land size, and occupation (as seen in Tables 2 & 3).

Gender describes the position of an individual in terms of feminine and masculine. These are put as male and female. The pooled results presented in Table 2 show that 66.13% of the respondents were male, suggesting that men are more involved in activities that lead to resource-based conflicts. This supports the argument that men are predominantly responsible for herding and land management in Nigeria, hence more exposed to inter-farmer disputes (Edeh *et al*., 2020). Male dominance in these sectors often results in more aggressive territorial defence during conflict situations (Ayinde *et al*., 2022). This implies that gender dynamics may influence the intensity and management of conflict, with men being key actors in both escalation and resolution.

Age refers to the stage of development of an individual, either young or old. The results on age revealed 28.2% of crop farmers were older than 30 years of age. Those within the ranges of 11 - 20 years and 21 -30 years constituted 6.4% and 16.7% of the respondents, respectively (Table 2). Similarly, the livestock farmers older than 30 years represented 21.7% while those in the age brackets of 11-20 years and 21-30 years made up 4.3% and 19.6% respectively. The pooled result, however, revealed that both farmers and livestock farmers were within 51 years and above. These age groups are often the economically responsible population who manage farms and herds, and are thus highly susceptible to the negative impacts of conflicts (Ahmed & Adisa, 2020). This productive age group bears the brunt of farm destruction and livestock theft, which undermines food production and rural stability. The implication is that conflict affects the most active demography in agriculture, reducing regional output and food security.

Marital status means living singly or in a matrimonial relationship, which includes past and present positions such as divorced, widowed and so on. Table 2 revealed that 66.7% and 71.7% of the crop and livestock farmers were married, respectively. Those who were single represented 17.9% and 17.4% for crop and livestock farmers, respectively. The widows constituted 15.4% and 8.7% of the crop and livestock farmers on the whole. The higher proportion of the married respondents may be

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explained by the age bracket in the results of this study. Large households require more resources, which increases dependency on staple farming activities, often disrupted by crop-livestock conflict (Omomowo, 2021). Conflict can therefore lead to economic stress on family units, affecting household welfare and food consumption patterns.

Household size refers to the total number of individuals (wives, children, grandchildren and extended family members) that live with and feed from the household. The pooled result of the study on household size shows that 59.68% of the respondents (arable crop and livestock farmers) had a household size of between 6 and 10 persons, which places pressure on land and income resources. Larger families are also more affected by farm damage and income loss from conflict, compounding food insecurity (Edeh *et al.,* 2020). Those with household sizes of 1 to 5 persons, 11 and 15 persons and greater than 15 persons constituted 25.81%, 11.29% and 3.22%, respectively. Even though high household size is an important indicator of farm labour, it increases vulnerability and decreases adaptive capacity during periods of agricultural disruption.

Education connotes the formal training an individual has obtained. This is represented by the number of years a person spent in formal school. It is believed that educated persons may be more open to dialogue during conflicts (Sani *et al.,*2021). Educationally, about 33.37% of the pooled results in the study area showed that the respondents had a tertiary level of education. The respondents (Arable crop and livestock farmers) with secondary and primary levels of education constituted 29.03% and 5.64% of the respondents, respectively. The respondents with informal education make up 15.32%.37.2% of the arable crop farmers had secondary levels of education, while 29.5% had tertiary education. The arable crop farmers who had informal education were 1.3%, for the livestock farmers, 41.3% had tertiary education, while 39.1% had informal education, 15.2% had secondary level of education, and 4.3% had tertiary education. Based on the findings of this study, it can be inferred that most crop and livestock farmers were literate. They could read and write, a healthy situation that exposes them to the adoption of technology, which improves their farming activities. Additionally, education plays a crucial role in conflict management and adaptation by providing knowledge of rights and land-use laws. Lower educational attainment among pastoralists may limit their understanding of land use policies or conflict mitigation strategies (Blench, 2019). Conversely, better-educated farmers may have greater access to information and negotiation channels.

Farming experience is the skill and knowledge an individual has acquired over time as a result of repeated/constant practice in a trade. It is similar to education. Experience enhances efficiency and productivity. This is in line with the findings of Kehinde (2011), who said, constant practices result in perfection. Table 2 revealed that crop farmers with farming experience of 21 years and above represented 35.90%, those with experience of 16 and 20 years, 5 and fewer years, 6 and 10 years and 11-15 years made up 24.4%, 16.7%, 15.4% and 7.7% respectively. The livestock farmers had fewer years of experience. Those with 6-10 years of experience accounted for 43.5%. The livestock farmers with 5 and less, 21years and above,11- 15 years, and 16 - 20 years of experience accounted for 21.7%, 17.4%, 10.9%, and 6.5% respectively. The pooled data for crop and livestock farmers experience which are 21 years and above accounted for 29.03%. Those with 6 - 10 years were 25.81%, those with 5 years and below were 18.55%, those with 16 and 20 years were17.74%, and those with 11 and 15 years were 8.8%. The mean years of experience for the crop and livestock farmers were 15 and 10 years, respectively. This is in tandem with the findings of Ayinde *et al*. (2022), who stated that long-term farmers are more likely to have faced repeated conflict cycles and may experience greater cumulative losses. These experienced farmers also understand the historical roots of conflicts, which may help in designing targeted interventions. The implication is that prolonged farming experience can both deepen loss and inform sustainable conflict response strategies.

Farm size refers to the size of agricultural land managed mostly by the farmers. Douglas (2018). The pooled result on farm size shows that farmers with farm sizes of between 3-4 hectares represented 44.9%, those with 1-2 hectares accounted for 38.50%, those with 5-6 hectares and 7 hectares and above represent 9% and 7.7% respectively. This means that the arable crop farmers in the study area are into subsistence farming. This may be due to high pressure on land due to an increase in population, vis-à-vis the traditional land tenure of inheritance, whereby the land is usually

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divided into pieces and shared among several family members. The implication is an increase in the tendency of the farmers to encroach on land reserves and livestock tracts, especially cattle routes, thereby creating room for conflict. Smaller farm sizes increase the risk of overlap with grazing routes, particularly in communal land settings, which often triggers disputes (Okoli *et al.,* 2023). Limited land availability intensifies the struggle for space between crop and livestock farmers. This means that smaller and communal landholdings amplify land-use conflict, especially during peak cultivation or grazing seasons.

On herd size, 52.2% of the livestock farmers in the study area had 20 and a smaller number of animals. Those with 21 - 40 animals constituted 21.7%, those with 81-100 animals were 15.20%, and those with 41-60 and 61-80 animals represented 4.30% each. Herdsmen who had more than 100 animals accounted for 2.2%. According to Bolarinwa *et al* (2021), larger herds are more likely to stray into farms, causing damage and igniting tensions. Also, herders with large stocks suffer more when retaliatory attacks or cattle rustling occur. It implies that herd size correlates with both the likelihood of conflict and the scale of economic loss suffered.

Occupation refers to a specific and sustained activity a person does to earn a living. Concerning major occupation, the result of the study shows that 63.71% of the crop farmers had farming as their primary occupation, while 60.90% are livestock farmers. This suggests that there was almost an equal distribution of the two groups in the study area. The result means that the respondents were into agricultural production activities, which makes competition for farming and grazing over land resources between the two groups and a possible consequence of conflict. (Okoli *et al*.2014).

Table 2: Distribution of Respondents Based on Age, Sex, Age, Marital Status, Household size and, educational status.

Socio- economic parameters	Crop Farmers (78)		Livestock Farmers (46)		Pooled Data (120)	
	F	%	F	%	F	%
Gender						
Male	41	52.6	41	89.1	82	66.13
Female	37	47.4	5	10.9	42	33.87
Age (years)						
11-20	5	6.4	2	4.3	7	5.65
21-30	13	16.7	9	19.6	22	17.74
31-40	22	28.2	10	21.7	32	25.81
41-50	18	23.1	10	21.7	28	22.58
51-60	20	25.6	15	32.6	35	28.22
Marital Status						
Single	14	17.9	8	17.4	22	17.74
Married	52	66.7	33	71.7	85	68.55
Widow	12	15.4	4	8.7	16	12.90
Divorce	-	-	1	2.2	1	0.81
Household size						
1-5	15	19.2	17	37.0	32	25.81
6-10	54	69.2	20	43.5	74	59.68
11-15	6	7.7	8	17.4	14	1.29
16-20	3	3.8	1	2.2	4	3.22
Education						
No formal Edu.	1	1.3	18	39.1	19	15.32
Primary	5	6.4	2	4.3	7	5.64
Secondary	29	37.2	7	15.2	36	29.03
Tertiary	23	29.5	19	41.3	42	33.87

Source: Field Survey, 2020 Keys: F = Frequency, % = Percentage

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Table 3: Distribution of Respondents Based on Farming Experience, Farm Size, Herd and Occupation.

Socio- economic parameters	Arable Farmers (78)		Livestock Farmers (46)		Pooled Data (120)	
	F	%	F	%	F	%
Farming Experience						
1-5	13	16.7	10	21.7	23	18.55
6-10	12	15.4	20	43.5	32	25.81
11-15	6	7.7	5	10.9	11	8.87
16-20	19	24.4	3	6.5	22	17.74
21above	28	35.9	8	17.4	36	29.03
Farm size(ha)						
1-2	30	38.5			30	38.5
3-4	35	44.9			35	44.9
5-6	7	9.0			7	9.0
7&>	6	7.7			6	7.7
Herd size(no.)						
1-20			24	52.2	24	52.2
21-40			10	21.7	10	21.7
41-60			2	4.3	2	4.3
61-80			2	4.3	2	4.3
81-100			7	13.2	7	15.2
100&>			1	2.2	1	2.2
Occupation						
Farming	67	88.5	10	21.7	79	63.71
Trading	7	9.0	4	8.7	11	8.87
Other	1	1.3	-	-	1	0.81
Livestock rearing	-	-	28	60.9	28	60.9
Non- Agric trade	-	-	4	8.7	4	8.7

Source: Field Survey, 2020

Effect of Conflict on Crop and Livestock Products

The effect of conflict between crop and livestock farmers was determined using a paired t-test. A comparative analysis of the farm size and output of crop farmers before and after conflict was conducted to find out if or not there was a significant difference. Similarly, the herd size of livestock farmers before and after conflict was compared to determine if there were effects of conflict on livestock production. (as shown in Table 5). The result revealed that the mean farm size of crop farmers before and after conflict was (mean 4.83, SD 2.48) and (mean 3.25, SD 1.94), with a difference of 1.58 hectares and t-value (77) 9.51, significant at $P<0.001$. The result further showed a significant reduction in the farm size of the crop farmers. The reduction in the farm size under cultivation by arable crop farmers may be attributed to the conflict between them and the livestock farmers. The implication of the reduction in farm size is low output. This agrees with the findings of Adelakun *et al.* (2015), who found that the majority of farmers suffered severe losses from farmer-pastoralist conflict, leading to a reduction in output.

Similarly, the mean output of crop farmers before and after conflict was (mean 35.93, SD 29.53) and (mean 29.23, SD 29.19), respectively, with a difference of 6.7. The t-value (77) 4.73, which was significant ($P<0.001$). The significant difference suggests a reduction in the output of crop farmers as a result of the conflict. This means that conflict had a reducing effect on crop production. Falanta *et al*. (2018) revealed that farmer-herder conflict often leads to loss of crop, livestock and even human lives

On the herd size of the livestock farmers, a mean herd size before and after the conflict (mean 47.17 SD 39.28) and (mean 31.34 SD 29.59) was recorded, respectively. The mean difference was 16 herd sizes with t-value (45) 6.41, which was significant ($P<0.001$). The result shows a reduction in herds' size of the livestock farmers, which could be a result of conflict. The reduction in the herd's size may result from either the loss of animals due to killing or rustling. The implication of this is a reduction in the supply of animals and a low income.

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Together, the results of this research revealed that conflict has a positive effect on agricultural production (farm size, output, and herd size of farmers). This is supported by the work of Moritz (2010), who found that farmer-herder conflict not only has a direct impact on the lives and livelihoods of those involved but also disrupts and threatens the sustainability of agriculture and pastoral production

Table 4: Effect of Conflict on Agricultural Production before and after Conflict

Parameters	Mean	SD	T	Df	Sig
Farm size before	4.83	2.48			
			9.51	77	0.000***
Farm size after	3.25	1.94			
Output before	35.93	29.53			
			4.73	77	0.000***
Output after	29.23	29.66			
Herd size before	47.13	39.28			
			6.41	45	0.000***
Herd size after	31.34	29.59			

***Significant at $p< .001$

Constraints to Conflict Resolution amongst Arable and Livestock Farmers

The study examined challenges to conflict resolution between crop and livestock farmers. The constraints were ranked in order as perceived by the respondents according to their severity in Table 8. The most severe constraint was the use of law enforcement structure in handling conflict, which was ranked 1st by both the crop farmers and livestock farmers as a very serious constraint to handling disputes among them. This was followed by a lack of punishing conflict perpetrators, as was ranked 2nd by the crop farmers, while the livestock farmers ranked the lack of educating conflicting parties 2nd as a constraint to resolving conflict among them.

Both the crop and livestock farmers agreed that the lack of policy implementation by the government is a constraint to conflict resolution, as ranked 3rd. The crop farmers ranked the lack of educating conflicting parties 4th, and the livestock farmers revealed that ethnic rivalry ranked 4th as a constraint to resolving conflict among them. On the other hand, the crop farmers ranked ethnic rivalry 5th, and the livestock farmers ranked lack of goodwill among conflicting parties 5th in that order, respectively.

The crop and livestock farmers agreed that the lack of compensation to affected persons is one of the constraints to resolving conflict in the study area. This was ranked 7th and 6threspectively. This was revealed in the work of Mohammed *et al*. (2020), who state that from all the recommendations for solutions to farmer-herder conflict, respondents voted in favour of paying compensation, which reduces the tendency of reprisal attack, and encourages resettlement for a new productive life.

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Table 5: Constraints to Resolving Conflict between Crop and Livestock Farmers

	Crop farmers			Livestock farmers		
Constraints	**F**	**Mean**	**Rank**	**F**	**mean**	**Rank**
Use of law enforcement structure by the government	40	5.87	(1st)	16	6.11	1st
Inadequate punishment for the perpetrator	23	4.90	(2nd)	16	5.58	2nd
Weak policies and poor implementation by the government	21	4.58	(3rd)	21	5.58	2nd
Inadequate education for the conflicting parties	27	4.00	(4th)	12	4.71	3rd
Ethnic Rivalry among crop and livestock farmers	21	3.98	(5th)	13	4.36	4th
Poor goodwill among conflicting parties	17	3.55	(6th)	12	3.91	5th
Inadequate compensation for affected persons by defaulters of the government		3.38	(7th)		3.79	6th

Source: Field Survey, 2020

CONCLUSION AND RECOMMENDATIONS

Crop-livestock farmers 'conflicts are destructive and hurt agricultural production in Northern Plateau State, Nigeria. From the study, it was discovered that both crop and livestock farmers felt the negative effects of conflict on their production. The study further revealed that scarcity of land due to urbanisation, among others, was a major cause of the conflict. lack of access to water, stealing of crops and inadequate grazing reserves are some of the major causes of conflict in the study area

Conflict resolution mechanisms among crop and livestock farmers include: intervention by traditional leaders, payment of compensation to affected victims by defaulters, and educating crop and livestock farmers on the effects of conflict. Conflict among crop and livestock farmers reduces farmland size under cultivation and the herd size, thereby reducing crop and livestock production.

From the findings, the following recommendations were made:

i) Dialogue should be employed as a means of conflict resolution instead of using law enforcement personnel

ii) Compensation should be given to the affected victims of the arable crop and livestock farmers' conflict. This will cushion the effect of the loss and reduce tension buildup and possible reprisal attacks.

iii) Government policies should be properly implemented. If this is possible, it will gain people's confidence in the government to address the conflict situation between livestock and arable crop farmers.

iv) Traditional leaders should be well involved in finding solutions to crop and livestock farmers' conflicts, having representation from local leadership.

v) Extension agents should be involved in educating crop and livestock farmers, as this will lead to better understanding and awareness of realistic conflict resolution mechanisms.

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ASSESSMENT OF ADOPTION OF GOOD AGRICULTURAL PRACTICES AND MOST CULTIVATED ARABLE CROPS AMONG ARABLE CROP FARMERS IN BORNO STATE, NIGERIA

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ABSTRACT
The study examined the adoption of Good Agricultural Practices (GAPs) and the most cultivated arable crops among farmers in Borno State, Nigeria. A multistage sampling technique was used to select 410 respondents from the study areas. Data were collected using structured questionnaires and analyzed using descriptive and inferential statistics. Male (73.85%) dominated arable crop production, (32.82%) had secondary education. The findings revealed that maize (82.56%), Bambara nut (76.15%) and groundnut (73.07%) were the most commonly cultivated crops. The most frequently adopted GAPs include fertilizer application (80.17%), seed treatment (65.91%), and proper spacing (64.79%). The results of Logistic regression analysis showed that farm size ($P<0.05$), cooperative membership ($P<0.01$), and access to credit ($P<0.01$) were significant in influencing the adoption of GAP in the study area. The results also revealed that the major constraints to adoption of GAP were inadequate input supply (78.46%), lack of attending meeting and training (74.6%), insecurity (74.6%), and poor storage facilities (73.08%) to mention few. The study concluded that farm size, membership of association and access to credit were the factor influencing the adoption of GAP in the study area. This study recommends that; Development partners and NGOs should collaborate with research institutions to introduce and scale up climate-smart GAP technologies that are adaptable to the local environment. Risk management tools such as weather-indexed insurance schemes should also be introduced.

Keywords: GAP, Arable, Crops, Adoption, Constraints

INTRODUCTION
One key objective of Nigeria's agricultural development is to shift from low-yield subsistence farming to a high-output, agro-industrial system through improved technology (Nkwuagba and Nkamnebe, 2024). Since many rural poor depend on crop farming (Mathew, 2024), Good Agricultural Practices (GAPs) are promoted to enhance productivity, efficiency, and income (Abiodun, 2016). Introduced by FAO, GAPs ensure sustainable, environmentally sound production while improving food quality, safety, and market access (FAO, 2021). Adoption stabilizes yields, reduces post-harvest losses, and boosts market value, though increased supply may affect incomes (Adetarani *et al*., 2021). Farmers also use GAPs to avoid disadvantages from poor practices and to meet food safety standards in competitive markets (Adetarani *et al*., 2021).

FAO's framework highlights soil and water management, crop and animal health, processing, and worker safety, all vital for national food security (Omolehin *et al*., 2019). Yet, Nigerian agriculture faces challenges including land degradation, pests, outdated techniques, and limited technologies (Bedru *et al*., 2022; Onoja, 2023), alongside market constraints such as poor credit and weak farmer-market linkages (Adetarani *et al*., 2021). Though programs like Fadama, FAO, N2Africa, and BOSAP promote GAPs in Borno State to raise productivity and livelihoods (Borno State Government, 2016), food insecurity persists. Empirical data on adoption in the state remain scarce. This study therefore seeks to assess adoption levels to guide policies for enhancing uptake among arable crop farmers in Borno State, Nigeria.

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i. Determine the socio-economic characteristics of the farmers;
ii. Determine the most cultivated arable crop cultivated by the farmers;
iii. Assess the most adopted Good Agricultural Practices among farmers (GAPs);
iv. Determine the socio-economic factors influencing the level of adoption of Good Agricultural Practices; and
v. Examine the constraints to the adoption of Good Agricultural Practices.

METHODOLOGY

The Study Area

Borno State, located at latitude 12°08′60″N and longitude 12°53′59.99″E, spans an area of 61,435 km² and borders Niger, Chad, Cameroon, and the Nigerian states of Adamawa, Gombe, and Yobe. It comprises 27 Local Government Areas with a projected 2024 population of 7,171,104, based on a 3% annual growth rate from the 2006 census figure of 4,171,104 (National Population Commission, NPC, 2021). Agriculture is the backbone of the economy, predominantly practiced at the smallholder and subsistence level (Ayuba, 2017). Rainfall ranges from 600 mm in the north to 1,200 mm in the south, with a growing season of 100–180 days. Temperatures fluctuate between 13.6°C–31.9°C in January and 9.0°C–28.5°C in August (Quick Projects, 2018). The state cultivates a wide variety of arable crops, fruits, vegetables, tree crops, and livestock (NBS, 2019).

Sampling Technique and Sample Size

Borno State has (3) three Agricultural zones namely; (Zone 1, Zone 2 and Zone 3). Each of the Agricultural zone comprises of (9) nine local government areas. The first stage involved purposive selection of (3) three local government areas from each zone based on the intensity of agricultural production which were Zone 1; Biu, Kwaya Kusar and Bayo were selected in zone 1, in zone 2; Bama, Konduga and Jere, in zone 3; Magumeri, Nganzai and Monguno giving a total of 9 LGAs. The Second stage involved proportionate selection of 131 Agricultural blocks and 119 extension cells. In the third stage, the list of the 15450 registered farmers were obtained from BOSADP which was used as a sampling frame. From the list, farmers were randomly selected proportionate to the registered farmers from each of the selected extension cells. A total of 410 farmers were selected using Yamane (1969) formula.

Thus,

$$n = \frac{N}{1+N(e)^2} \text{ ---------- (3.1)}$$

n=390

n= Sample size

N= the finite population of crop farmers

1= constant

e = margin error

$$n = \frac{15450}{1+15450(0.05)^2}$$

n=390

Thus, the required sample size is 390, the sample size is adjusted by 5 percent to 410 because some of the entries were invalid. In the last stage, the sample size is distributed proportionally to all the selected Local Governments in the study area based on the registered farmers' population size.

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Table 1: Sampling Procedure

S/N	L.G. A	Extension Blocks	Extension Block Selected	Extension Cells	Extension Cells Selected	Registered Farmers	Farmers Selected
1.	Biu	16	11	30	15	2900	77
2.	Bayo	10	7	12	9	1100	29
3.	KwayaKusar	13	9	16	10	1400	37
4.	Bama	80	54	28	14	1500	40
5.	Konduga	11	8	16	9	1000	27
6.	Jere	14	10	12	8	1600	42
7.	Magumeri	15	11	20	13	2000	53
8.	Nganzai	12	10	12	9	1000	27
9.	Monguno	16	11	25	14	2950	78
Total	9	187	131	171	119	15450	410

Source: Field Survey, 2023

Methods of Data Collection and Analysis

Data were collected using structured questionnaires. Trained enumerators where used to collect data. Descriptive statistics and inferential statistics were used in the analysis of data collected for this study. Descriptive statistics in the form of frequencies, mean and percentage were used to achieve objectives (i, ii, iii, iv, v and vii). A five-point Likert scale (was used to further determine objective v) of the mean score in the determination of the mean score to determine the level of adoption of GAPs: 5+4+3+2+1= 15/5= 3……(3.2)

The mean value of the scale of 3 and was used as the cutoff point to rank the responses. Any mean response of ≥ 3 is considered high adopter, while a mean score of ≤ 2 is considered a low adopter. Inferential statistics in the form of binary logit regression was used to achieve objective (vi) which is the socio-economic factors influencing the level of adoption of Good Agricultural Practices (GAPs). Logistics regression was used to measure the influence of socio-economic institutional factors on level of adoption of GAPs among farmers. Ochieng *et al.* (2017) used binary logit regression to analyze the level of adoption of GAPs in Kenya. The model is stated thus:

$$Log(Y_i) = Ln\left[\frac{P_1}{1-P_1}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + e \ldots (3.4)$$

$$Y_i = \begin{cases} 1 \text{ if the } i_{th} \text{ farmer is High Adopter*} \\ 0 \text{ if the } i_{th} \text{ farmer is Low Adopter} \end{cases}$$

*If an ith farmer's mean score in the level of adoption of GAP is 3 and above, s/he is considered a high adopter and but if the mean score is less than 3, the farmer is considered a low adopter.

Where:

X_1= Sex (1=Male, 0=Female)
X_2 = Education (Number of years spent in formal education)
X_3 = Farm size (hectares)
X_4= Membership of Farmer Cooperative (1=Yes, No =0)
X_5= Access to credit (1=Yes, 0=No)
X_6 = Access to Extension contact (1=Yes, 0=No)

RESULT AND DISCUSSIONS

Socio- economic Characteristics of the Respondents

The findings revealed that arable crop farming in Borno State is predominantly male-dominated (73.85%), likely due to traditional responsibilities such as providing for the family, aligning with Okon and Enete (2022). Low female participation is attributed to socio-cultural and religious factors, though contrasting findings by Nwaiju (2015) and Chisenga (2015) highlight women's significant role in farming in southeastern Nigeria and rural areas, respectively. Majority

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(76.15%) of the respondents were married, supporting the view that marital status promotes farming involvement (Adebayo *et al.,* 2021; Ibidapo *et al.,* 2018). The results also showed that there was relatively high literacy, with 36.15% having tertiary and 32.82% secondary education, suggesting improved access in Borno compared to findings by Alabi and Adams (2020). Education, though beneficial, is one of many factors influencing adoption of Good Agricultural Practices (GAPs), including age, culture, peer interaction, finances, and extension services.

Table 2: Distribution of Respondents based on Socio-economic Factors (n=390)

Gender	**Frequency**	**Percentage**
Male	102	73.85
Female	288	26.15
Marital status		
Divorced	25	6.41
Married	297	76.15
Single	68	17.44
Level of Education		
Non-formal	80	20.51
Primary	41	10.51
Secondary	128	32.82
Tertiary	141	36.15
Membership of Cooperatives		
No	184	47.18
Yes	206	52.82
Access to credit		
No	284	72.82
Yes	106	27.18
Total	390	100
Access to extension services		
No	365	93.59
Yes	25	6.41
System of land ownership		
Family	137	35.13
Hired	150	38.46
None	1	0.26
Others	20	5.13
Personal	82	21.03

Source: field Survey (2023)

Education significantly influences adoption of climate-resilient technologies (Onya *et al*., 2019; Umeh & Igwe, 2019; Adam *et al*., 2022). In Borno State, 52.82% of farmers belong to cooperatives that improve access to inputs and credit (Yusuf *et al*., 2021; Ekweanya *et al.,* 2018). However, 72.82% lack credit and only 27.18% access extension services, much lower than elsewhere (Olagunju & Ayanwale, 2019). Credit is vital for inputs and adoption (Nwaru *et al*., 2011; Afolabi, 2010; Ololade & Olagunju, 2013; Oboh & Kushwaha, 2009; Philip, 2013), while extension drives technology use like GAPs (Oluwatayo & Oluwaseyo, 2024), yet only 6.41% benefit in Borno versus 77% in Ghana (Akomdo *et al.,* 2023). Land remains constrained, mostly rented or inherited, often fragmented (Fasona *et al.,* 2020; Idowu, 2021; Ibrahim & Nabage, 2023)

Table 3: Descriptive Statistics of some Socio-economic Continuous Variables

Variables	**Mean**	**Std**	**Minimum**	**Maximum**
Age	43.015	12.778	19	80
Household Size	8.104	5.92	1	34
Farm size	3.314	2.02	0.45	10
Average Annual income	1176219	1438386	10,000	9,000,000

Source: field Survey (2023)

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The results from Table 3 showed that the average age of farmers in Borno State was 43 years, indicating a productive and economically active population, consistent with findings by Adebo and Sekumade (2019), Kundiri *et al*. (2022), Onya *et al.* (2019), Achukwu *et al*. (2023), and Omolehin (2019). The results further revealed that the average household size was 8 members, supporting rural labor needs but potentially increasing resource strain, as noted by Oladeji *et al*. (2020) and Ibrahim *et al.* (2023). The average farm size was 3.31 hectares, aligning with Onyekuru and Marchant (2021) and suggesting smallholder, subsistence-based farming. Larger farm holdings are associated with increased adoption of conservation practices (Kolapoa *et al.,* 2023). The mean cultivated area is 8.59 hectares, slightly below the 4.66-hectare average with improved yield potential found in Kebbi State (Idowu, 2021). The results further revealed that the respondents earned an average annual income of ₦1.18 million, though disparities are wide. This surpasses the ₦850,000 average reported by Oseni and Winters (2021), potentially due to better market conditions or crop types. However, many farmers still face structural constraints like inadequate credit and extension services

The Most Cultivated Arable Crops by the Respondents

Table 4 identifies 15 arable crops cultivated by respondents, with maize being the most widely grown (82.56%), followed by Bambara nut (76.15%), groundnut (73.07%), and sesame (70.76%). Tomato, sorghum, and millet each accounted for 70.05% of cultivation. These findings indicate that maize is the dominant cereal, while Bambara nut and groundnut are the leading leguminous crops. Sesame also plays a significant role. The widespread cultivation of these crops suggests they are culturally accepted and well-suited to the soil and climate conditions of Borno State.

Table 4: Distribution of Respondents based on Most Cultivated Arable Crops (n=390)

Arable Crops	*Frequency	Percentage	Rank
Maize	322	82.56	1st
Bambara nut	297	76.15	2nd
Ground nut	285	73.07	3rd
Sesame	276	70.76	4th
Tomatoes	273	70.00	5th
Sorghum	273	70.00	5th
Millet	273	70.00	5th
Rice	265	67.94	8th
Soybean	263	67.43	9th
Cowpea	256	65.64	10th
Onion	245	62.82	11th
Sweet Melon	244	62.56	12th
Okra	156	40.00	13th
Sweet potatoes	123	31.53	14th
Cocoyam	17	4.35	15th

Source: field Survey. 2023 *Multiple responses.

The findings identified additional arable crops based on cultivation proportion: rice (67.94%, ranked 8th), soybean (67.43%, 9th), cowpea (65.64%, 10th), and onion (62.82%, 11th). Rice was noted as the 6th most cultivated crop, though maize remains the most preferred and widely produced. Other crops cultivated include sweet melon (62.56%, 12th), okra (40.0%, 13th), sweet potato (31.53%, 14th), other crops (9.48%, 14th), and cocoyam (4.35%, 15th). Similar findings by Mudi *et al.* (2019) revealed cultivation of maize, millet, sorghum, groundnut, and cowpea, while Tahir *et al.* (2020) identified maize, sorghum, groundnut, cowpea, pepper, and onion in Borno State.

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Most Adopted Good Agricultural Practices (GAPs)

Table 5: Distribution of Respondents based on Most Adopted Good Agricultural Practices

Most Adopted GAPs	Frequency*	Percentage
Fertilizer for Planting	285	80.97
Seed Treatment	232	65.91
Intra and Inter Raw Recommended Spacing	228	64.77
Improved Storage Method	223	63.35
Timely Land Preparation	215	61.08
Timely and Clean weeding	212	60.23

Source: field Survey (2023) * Multiple response exists

Table 5 shows that the most widely adopted Good Agricultural Practice (GAP) among arable crop farmers in Borno State. The findings revealed that fertilizer use (80.97%) was one of the widely used GAPs, highlighting its role in improving soil fertility and yields (Abdoulaye & Sanders, 2005; Morris *et al*., 2007). The results also revealed that seed treatment (65.91%) and recommended plant spacing (64.77%) were also widely used, aiding pest protection, better germination, and efficient resource use (Ojiako *et al*., 2007; FAO, 2010). Improved storage methods (63.35%) help reduce post-harvest losses (World Bank, 2011; Kader, 2005), while timely land preparation (61.08%) and clean weeding (60.23%) support better soil structure and reduce competition from weeds (Erenstein *et al*., 2006; Zimdahl, 2013; These adoption patterns reflect broader sustainable farming trends that aim to enhance productivity and resilience (Tilman *et al*., 2002; Bennett *et al*., 2012)

Socio-economic Factors Influencing Level of Adoption of GAPs

A logistic regression analysis of 352 farmers showed that socio-economic factors significantly influence GAPs adoption (LR $Chi^2 = 21.61$, $p = 0.0014$). The model has low multicollinearity (mean VIF = 1.24) and no major outliers (hatsq $p = 0.493$). The constant term (1.873584, $p < 0.001$) indicates baseline adoption odds. Access to credit increases adoption, while agricultural association membership unexpectedly has a negative effect. Farm size also negatively affects adoption (-0.1250464, $p = 0.039$), suggesting smaller farms are more likely adopters—possibly due to local conditions.

Table 6: Factors Influencing Level of Adoption of GAPs

Variables	Coefficient	Standard error	z-value	Prob >|z|
Sex	-0.0238925	0.2944263	-0.08	0.935
Education	-0.0704216	0.3695659	-0.19	0.849
Farm Size	-0.1250464**	0.0606829	-2.06	0.039
Membership of Cooperatives	-0.9392567***	0.3042572	-3.09	0.002
Access to credit	1.240503***	0.3491348	3.55	0.000
Access to extension service	-0.1028168	0.292443	-0.35	0.725
Constant	1.873584	0.5216463	3.59	0.000
LR Chi2	21.61***			
Prob > Chi2	0.0014			
Mean VIF	1.24			
Hatsq	-0.1900711	0.2773972	-0.69	0.493
Pearson Chi2	108.90			
Prob > Chi2	0.3776			

Field Survey, 2023 *** Significant at 1% level ** Significant at 5% level, LR is Log likelihood

The study reveals a strong positive relationship between credit access and GAP adoption (coef. = 1.240503, $p < 0.001$), confirming that credit is essential for technology uptake (Akudugu *et al.,* 2010; Oyewole & Olaguji, 2024). Credit eases liquidity constraints, enabling smallholders to afford inputs like seeds, fertilizer, and labor, thereby enhancing productivity (Bolarinwa & Fakoya, 2011). It also provides a buffer against risks, encouraging adoption in uncertain conditions (Nuryartono *et al.,* 2005). In Nigeria, formal credit has been shown to boost improved seed and fertilizer use, raising output (Awotide *et al*., 2015; Oyewole & Olaguji, 2024).

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Constraints to the Adoption of Good Agricultural Practices (GAPs)

The adoption of Good Agricultural Practices (GAPs) in Borno State is significantly limited by inadequate access to essential inputs like seeds, fertilizers, and pesticides, as reported by 78.46% of farmers. This constraint negatively affects productivity and adoption willingness, consistent with findings by Meijer *et al*. (2015) and Adesina and Oluwatayo (2024), who also identified input shortages as a major barrier for smallholder farmers.

Table 7: Distribution based on Constraints to the Adoption of Good Agricultural Practices

Constraints	Frequency*	Percentage	Rank
Inadequate supply of inputs (seeds, fertilizer, pesticides)	306	78.46	1st
Lack of time to attend training and meetings	291	74.62	2nd
Insecurity problems	291	74.62	2nd
Poor storage facilities	285	73.08	4th
Insurgency	285	73.08	4th
Lack of interest to adoption in GAPs	279	71.54	6th
Local politics	277	71.03	7th
Fear of risk or uncertainty	277	71.03	7th
Poor/ inadequate information	271	69.49	9th
Climate change	270	69.23	10th
Lack of incentives	269	68.97	11th
Incompatibility of GAPs technologies	268	68.72	12th
Late distribution of inputs	263	67.44	13th
Difficulty of accessing technical information	255	65.38	14th
Language barrier	248	63.59	15th
Illiteracy and poor education	246	63.08	16th
Lack of farming equipment for land preparation	242	62.05	17th
Lackadaisical attitudes of farmers and trainers	216	55.38	18th
Late dissemination of technical information	169	43.33	19th
Inadequate financial institutions / Capital	157	40.26	20th

Source: Field survey: 2023 * Multiple Response

Other significant constraints include lack of time to attend training (74.62%), insecurity (74.62%), poor storage facilities (73.08%), and the ongoing insurgency (73.08%), all of which disrupt the farming environment and limit farmer engagement with GAPs. Issues such as local politics, fear of risk, poor information access, and climate change were also notable, each affecting over 65% of respondents. These challenges highlight the need for targeted interventions to improve input delivery, information dissemination, and farmer security in the region.

CONCLUSION AND RECOMMENDATION

The study that farm size, cooperative membership, and access to credit were the significantly influenced adoption of GAPs in the study area. Also, the most cultivated crops were maize, Bambara nut and Groundnut. To enhance the adoption of Good Agricultural Practices (GAPs) in Borno State the study recommended that,

i. The government should provide subsidized inputs and invest in rural infrastructure. Strengthening extension services through recruitment and training is vital for continuous farmer education.
ii. Security must be improved to support safe farming activities. Supporting farmer cooperatives will boost credit access and market efficiency.
iii. Climate-smart and risk-resilient practices should be promoted through collaboration with NGOs and research institutions.
iv. Lastly, effective policy implementation requires robust monitoring and evaluation systems to track progress and ensure impact.

v. The findings highlight the need for improved input delivery systems, enhanced security, and stronger farmer support services to boost GAP adoption and arable crop productivity in the region.

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PERFORMANCE AND ECONOMIC BENEFITS OF BROILER CHICKENS FED DIETARY LEVELS OF SICKLE POD (*CASSIA TORA)* AND SUNFLOWER SEED MEAL

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ABSTRACT
The study was conducted to evaluate the performance and economic benefits of broiler chicken production using sickle pod seed (*cassia tora*) and sunflower seed meals based diets. Five diets each for both starter (23% CP) and finisher (20% CP) were formulated in which *Cassia tora* meal replaced sunflower meal at 0, 20, 30, 40 and 50% levels coded as diets A, B, C, D and E respectively. Three hundred (300) day old broiler chicks were randomly allocated to the five diets in four replicates of fifteen birds each. The experimental diets and water were supplied to the birds *ad libitum* and the research lasted for seven weeks. Daily feed intake and body weight changes were taken across the replicates on daily and weekly basis respectively. The result indicted that only final weight was significantly ($P<0.001$) affected by the dietary levels of *Cassia tora*. At the starter phase, daily feed intake (71.57 – 85.44g), daily weight gain (17.11 - 24.17g) and feed conversion ratio (3.32 - 3.88) were not influenced by the dietary treatments. At the finisher phase however, daily feed intake (106.91-135.50g) and feed conversion ratio (2.70-4.27) were significantly ($P<0.001$) affected by the levels of *Cassia tora* in the diets whereas no significant difference was found on daily weight gain (30.81-43.26), The overall phase showed significant difference ($P<0.001$) for feed conversion ratio with values ranging between 3.06-4.08 on diets 3 and 4 respectively. It was concluded that sickle pod (*Cassia tora*) seed meal can replace sunflower seed meal at 30% level in the diets of broiler chickens with no detrimental effects on growth performance with economic advantage in reducing feed cost by 17.71%. Therefore, 30% of sickle pod seed meal is recommended for use in broiler chicken diets.

Keywords: Broiler, Performance, Sickle, Pod, Sunflower, Diets

INTRODUCTION
Shortages and increasing cost of conventional protein sources continue to affect poultry production. Soya bean and groundnut cake have traditionally been the main protein sources in poultry feeds, but with the growth of the sector and the world's population, they are failing to meet the increasing demand (Frempong *et al.,* 2019). For this reason, poultry products have been inadequate with subsequent increase in their prices. A possible way to reduce poultry feed costs is finding alternatives to conventional protein sources that are inexpensive, efficient and locally available. Nigeria with low per caput animal protein consumption qualifies as one of the less developed countries in which the animal protein consumption has consistently declined in recent years. The trend is sequel to the decline in livestock production occasioned by the high cost of feed materials which account for about 70-80% of the cost of production (Ogbuewe *et al*., 2019).The cost of feed is also attributed to the competition between man and livestock for the available grain and the government policies militating against feed importation (Okachukwu, 2015). Consequently, more than 50% of poultry farms have closed and about 30% forced to reduce their production capacity due to scarcity of feed ingredients (Esonu, *et al*., 2001. Kwari *et al.,* 2023). Several unconventional legume seeds such as pigeon pea, sword beans and mucuna species have been studied and evaluated for inclusion in the livestock diets in Nigeria. Other unconventional legume seeds that are still underutilized and little is known about their chemical composition and nutritional values include sickle pod (*Cassia tora)*, bambara nut and sunflower seeds.

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METHODOLOGY

Experimental Site

The research was conducted at the poultry unit of Teaching and Research farm of the Federal College of Horticulture (FCH) Dadin kowa, Gombe State, Nigeria. Dadin kowa is in the North-Eastern Agro-ecological zone of Nigeria in the humid tropical area of West Africa and is situated at 10.3145°N 11.5308°E with altitude of 240 meters above sea level and has temperature of about 24^0C-40^0C with mean annual rainfall of about 960- 1110 millimeters, and relative humidity is about 38^0C - 50^0C all year round (FCH 2022).

Experimental Diets

Five experimental diets each for both starter (23% CP) and finisher (20% CP) were formulated in which *Cassia tora* meal replaced sunflower meal at 0, 20, 30, 40 and 50% coded as diets A, B, C, D and E respectively. Other ingredients used were maize, soyabean, fishmeal, wheat offal, bone meal, limestone, salt, vitamin/mineral premixes, methionine and lysine. The ingredients and percentage composition of the diets are presented in Tables 1 and 2.

Table 1: Ingredients and Percentage Compositions of *Cassia tora* and Sunflower Seeds Meal Diets Fed to Starter Broiler Chickens (2-4 Weeks)

Diets					
Ingredients	A (0%)	B (20%)	C (30%)	D (40%)	E (50%)
Maize	47.00	47.00	47.00	47.00	47.00
Full fat soyabean	14.00	14.00	14.00	14.00	14.00
Sunflower seed	20.00	16.00	14.00	12.00	10.00
Cassia tora	0.00	4.00	6.00	8.00	10.00
Fish Meal	5.00	5.50	6.00	6.50	7.00
Wheat Offal	10.00	9.50	9.00	8.50	8.00
Bone Meal	2.00	2.00	2.00	2.00	2.00
Lime stone	1.30	1.30	1.30	1.30	1.30
Salt	0.25	0.25	0.25	0.25	0.25
Premix*(starter)	0.25	0.25	0.25	0.25	0.25
Methionine	0.10	0.10	0.10	0.10	0.10
Lysine	0.10	1.10	1.10	1.10	1.10
Total	**100**	**100**	**100**	**100**	**100**
Calculated Analyses (%)					
M. E. (Kcal/kg)	2818.30	2831.18	2844.07	2856.95	2869.84
Crude Protein	23	23	23	23	23
Crude Fibre	5.94	5.78	5.62	5.46	5.30
Ether Extract	3.38	3.40	3.42	3.45	3.47
Calcium	1.36	1.37	1.39	1.38	1.38
Phosphorus	1.05	1.08	1.12	1.15	1.19
Methionine	0.41	0.42	0.43	0.44	0.45
Lysine	0.72	0.80	0.88	0.96	1.04

*Vit/Mineral Premix Supplied/Kg of Diet: Vit A, 12500 IU, Vit D3 2500 IU; Vit E, 30IU; Vit K, 2.5 Mg, Riboflavin, 6mg, Pantothenic Acid, 10mg; Vit B2, 4mg; Niacin, 20mg; Vit B_{12}, 22mg; Biotin, 0.75mg; Folic Acid, 0.5mg; Vit B6, 1.5mg; Vit B, 1.6mg; Choline Chloride, 175mg; Cobalt,0.2mg; Copper 3mg; Iodine, 1mg; iron, 20mg; Manganese, 40mg; Selenium, 0.2mg; Zinc 20mg, Antioxidant 1.25mg

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Table 2: Ingredients and Percentage Compositions of *Cassia tora* and Sunflower Seed Meal Based Diets Fed Finisher Broiler Chickens (5-7 Weeks)

	Diets				
Ingredients	**A (0%)**	**B (20%)**	**C(30%)**	**D(40%)**	**E(50%)**
Maize	52.70	52.70	52.70	52.70	52.70
Full fat soya bean meal	8.00	8.00	8.00	8.00	8.00
Sunflower Seed	20.00	16.00	14.00	12.00	10.00
Cassia tora	0.00	4.00	6.00	8.00	10.00
Fish Meal	2.00	2.00	2.00	2.00	2.00
Wheat Offal	13.30	13.00	13.00	13.00	13.00
Bone Meal	2.00	2.00	2.00	2.00	2.00
Limestone	1.30	1.30	1.30	1.30	1.30
Salt	0.25	0.25	0.25	0.25	0.25
Premix*(finisher)	0.25	0.25	0.25	0.25	0.25
Methionine	0.10	0.10	0.10	0.10	0.10
Lysine	0.10	0.10	0.10	0.10	0.10
Total	100	100	100	100	100
Calculated Analyses (%)					
M. E. (Kcal/kg)	2892.01	2904.86	2917.62	2930.47	2943.23
Crude protein	20	20	20	20	20
Crude fibre	5.44	5.34	5.18	5.05	4.92
Ether extract	3.28	3.27	3.34	3.37	3.40
Calcium	1.5	1.5	1.5	1.5	1.5
Phosphorus	0.88	0.88	0.89	0.89	0.89
Methionine	0.45	0.46	0.46	0.46	0.47
Lysine	0.71	0.77	0.83	0.88	0.94

Vit/Mineral Premix Supplied/Kg of Diet: Vit A, 12500 IU, Vit D3 2500 IU; Vit E, 30IU; Vit K, 2.5 Mg, Riboflavin, 6mg, Pantothenic Acid, 10mg; Vit B2, 4mg; Niacin, 20mg; Vit B_{12}, 22mg; Biotin, 0.75mg; Folic Acid, 0.5mg; Vit B6, 1.5mg; Vit B, 1.6mg; Choline Chloride, 175mg; Cobalt,0.2mg; Copper 3mg; Iodine, 1mg; Iron, 20mg; Manganese, 40mg; Selenium, 0.2mg; Zinc 20mg, Antioxidant 1.25mg.

Experimental Birds and their Management

A total of 300 unsexed day old broiler chicks were used for the study. Prior to their arrival, both the brooding and rearing houses were cleaned and disinfected. On arrival the birds were served with oral dose of glucose and multivitamin to reduce stress on transit. They were brooded for one week during which charcoal and electric bulbs were used to provide heat and light when needed. Commercial feed and water were adequately supplied. At the end of the brooding period, birds were randomly allocated to the five dietary treatments in four replicates of 15 chicks in a completely randomized design. The floor was covered with a wood shavings throughout the period of the research. Experimental feeds and water was served *ad libitum.* All necessary routine management practices were strictly adhered to, and the experiment lasted for fifty six (56) days (28 and 21 days for starter and finisher phases respectively).

Data Collection

Quantity and costs of each ingredient used in the research were obtained. Initial weights and number of birds in each replicate were recorded. Feed Intake (FI) and body weight changes were also taken on daily and weekly basis respectively. Feed conversion ratio (FCR) and feed efficiency (FE) were calculated from the data on FI and DWG. Mortality was recorded as it occurred. Data generated was prepared and analyzed using version 17 MINITAB software.

RESULTS AND DISCUSSION

Growth performance of broiler chickens fed diets containing *Cassia tora* as partial replacement for sunflower seed meal is presented in Table 3.

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Table 3: Performance of Broiler Chickens Fed Diets Containing Graded Levels of Sickle – Pod Seed (*cassia tora*) and Sunflower Seed Meals

	Diets					
Parameters	**A (0%)**	**B (20%)**	**C (30%)**	**D (40%)**	**E (50%)**	**SEM**
Productive performance						
Initial weight (g)	152.56	149.	146.78	148.05	145.79	0.88^{NS}
Weight at week 4 (g)	757.68	729.36	823.77	727.07	812.43	13.40^{NS}
Final weight (g)	1268.30^{c}	1430.30^{c}	1730.50^{a}	1396.60^{c}	1525.90^{b}	22.01***
Total weight gain (g)	1127.20	1280.30	1583.60	951.10	1380.10	64.45^{NS}
Starter Phase (2-4weeks)						
Daily feed intake (g)	74.98	71.57	84.84	83.13	85.44	2.85^{NS}
Daily weight gain (g)	17.11	20.69	24.17	21.57	23.81	1.15^{NS}
Feed conversion ratio	3.61	3.50	3.32	3.88	3.72	0.16^{NS}
Mortality (Number)	0	1	1	0	0	
Finisher phase (5-7 weeks)						
Daily feed intake (g)	106.91	110.61	124.83	135.50	125.50	1.92***
Daily weight gain (g)	31.38	39.65	43.26	30.81	35.72	2.21^{NS}
Feed conversion ratio	3.58	3.28	2.70	4.27	3.46	0.14***
Mortality (number	0	0	1	2	1	
Overall Phase (2-7 weeks)						
Daily feed intake (g)	92.18	91.08	102.34	116.32	106.18	2.93^{NS}
Daily weight gain (g)	26.51	28.18	33.68	26.19	22.15	1.65^{NS}
Feed conversion ratio	3.61	3.39	3.06	4.08	3.53	11.22***
Mortality (Number)	0	1	2	2	1	

abc=Means bearing different super script within the same row differ ***= (P<0.001)NS = Not significant, SEM = Standard Error of the Means.

Among the productive performance parameters initial weight, week 4 weight, final weight and total weight gain were not affected except final weight that was significantly (P<0.001) affected by the dietary levels of *Cassia tora*. Similarly at the starter phase, daily feed intake (71.57 – 85.44), daily weight gain (17.11 - 24.17) and feed conversion ratio (3.32 - 3.88) were not influenced by the dietary treatments. Values on daily weight gain were higher than those obtained by Isa *et al* (2024a) and Amaza *et al.* (2020) on replacing *Cassia tora* seed meal with full fat soya bean in broiler diets. At the finisher phase however, daily feed intake (106.91-135.50) and feed conversion ratio (2.70-4.27) were highly (P<0.001) affected by the levels of *Cassia tora* in the diets whereas no significant difference (P>0.05) was found on daily weight gain (30.81-43.26). This result differ with the values obtained by Augustine *et al*. (2017) and Isah *et al.* (2024b). At the overall phase, high significant difference (P<0.001) was obtained in feed conversion ratio with values ranging between 3.06-4.08 in diets 3 and 4 respectively. This also differ with the findings of Amaza *et al.* (2020) and Assam *et al.* (2017).

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Table 6: Cost-Benefit of Broiler Chickens Production Using Graded Levels of Sickle-Pod (*Cassia tora*) Seeds and Sunflower Seed Meals

Diets Parameters	A (0%)	B (20%)	C (30%)	D (40%)	E (50%)
Starter phase (2-4 weeks)					
Total feed intake (kg)	3.67	3.51	4.16	4.07	4.19
Feed cost kg (₦)	294.01	282.44	277.06	272.89	268.11
Total feed cost (₦)	1079.02	991.36	1152.57	1137.95	1123.38
Total weight gain (kg)	0.84	1.01	1.18	1.06	1.17
Feed cost kg gain (₦)	1285.55	981.54	976.75	1073.54	960.15
Cost saving (₦)	_ 303.01	307.80	211.01	324.40	
Finisher phase (5-7 weeks)					
Total feed intake (kg)	5.24	5.42	6.12	6.59	6.15
Feed cost/kg (₦)	294.01	282.44	277.06	272.89	268.11
Total feed cost (₦)	1540.61	1530.82	1695.61	1798.35	1648.88
Total weight gain (kg)	1.54	1.94	2.12	1.51	1.75
Feed cost/kg gain (₦)	998.45	789.08	799.82	1190.96	942.22
Cost saving (₦)	_ 209.37	198.63	-192.51	56.23	
Overall phase (2-7 weeks)					
Total feed intake (kg)	4.52	4.46	5.01	5.70	5.20
Feed cost/kg (₦)	294.01	282.44	277.06	272.89	268.11
Total feed cost (₦)	1328.93	1259.63	1388.07	1555.47	1394.17
Total weight gain (kg)	1.30	1.38	1.65	1.28	1.09
Feed cost/kg gain (₦)	1022.25	912.81	841.25	1215.21	1279.06
Cost saving (₦)	-	109.44	181.00	-192.96	-256.81

At the starter phase, total feed intake ranged from 3.51kg on diet B to 4.19kg on diet E, while feed cost ₦/Kg decrease progressively from ₦294.01 on diet A to ₦268.11 on diet E with the increasing *Cassia tora* levels. This observation agrees with Isah *et al* (2024a) who fed broiler chickens with *cassia tora* as replacement to full fat soya bean and Augustine *et al*. (2019) who fed broiler with raw, boiled soaked, sprouted and fermented *cassia tora* seeds as replacement for soya bean meal. This agree with the reported of Elgangy (2024) that unconventional protein sources reduce cost of production as they are obtained at lower costs compared to conventional ones. There was no consistency in the total feed cost, as the feed cost tend to fluctuate from a higher value in one diet and falls in another diet. The values ranged from ₦991.36 in diet B to ₦1152.57 in diet C. Total weight gain (₦/kg) also fluctuates from 0.84kg in diet A (control) to 1.18kg in birds fed diet C (30%). Feed cost ₦/kg gain varied between ₦960.15 on diet E and ₦1284.55 on diet A (control) diet. The cost saving (₦) ranged from ₦211.01 on diet D to ₦224.40 on diet E. This shows that the use of test ingredient to partial replace sunflower seed meal at the starter phase is more economical on diet E (₦324.40). At the finisher phase, the total feed intake (kg) varied between 5.24kg on the control diet to 6.59kg on diet D while feed cost per kg decreased from ₦294.01 on the control diet to ₦268.11 on diet E. Total feed cost fluctuate with increased level of inclusion, the values varied between ₦1530.82 on diet B to ₦1798.35 on diet D. Total weight gain equally fluctuates with increased level of inclusion. The value varied between 1.51kg on diet D to 2.12kg in diet C. Similarly total feed cost ₦/kg gain fluctuate with the increased level of inclusion. The values ranged from N789.08 on diet B to ₦1190.96 on diet D. Appreciable cost saving was observed on diet B (₦209.37) followed by diet C (₦198.63) then diet E (₦56.23). At the overall phase, total feed intake similarly fluctuates with increased level of inclusion, just as in the starter and finisher phase. The values varied between 4.46kg on diet B and 5.70kg on diet D. Feed cost decrease with increased in level of inclusion of *Cassia tora*. Diet A (₦294.01) indicated a higher cost, while diet E (₦268.11) indicated a lower cost. The total feed cost tend to fluctuate with increased level of *Cassia tora*, the values ranged from ₦1259.63on diet B to ₦1555.47 on diet D. The total weight gain followed the same trend, diet C (1.65kg) indicated the higher weight gain, while the least weight gain was observed on diet E (1.09kg). Feed

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cost ₦/kg gain was much lower on diet C (₦841.25) and highest on diet E (₦1279.06). Diets C (₦181.00) and B (₦109.44) indicated on appreciable cost saving. Whereas it is uneconomical in diets D (-₦192.96) and E (-₦256.81). This result agrees with that of Abdulazeez *et al.* (2019) who found reduction in feed cost per kg in using unconventional protein sources in broiler chicken diets.

CONCLUSION AND RECOMMENDATIONS

It was concluded that sickle pod (*Cassia tora*) seed meal is a viable alternative protein source in broiler chicken diets and can replace sunflower seed meal at 30% level with no detrimental effects on growth performance with economic advantage by reducing feed cost by 17.71%.

It was recommended that sickle pod (*Cassia tora)* seed meal be used in place of sunflower seed meal up to 30% in broiler chicken diets and further research is recommended for other monogastric species like layers, Japanese quails, turkeys, ducks and rabbits to evaluate the suitability of sickle pod (*Cassia tora)* in their diets.

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CARCASS AND ORGANS CHARACTERISTICS OF BROILER CHICKENS FED DIETARY LEVELS OF SICKLE POD (*CASSIA TORA)* SEED AND SUNFLOWER SEED MEALS

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ABSTRACT
An experiment was conducted to evaluate carcass and organs characteristics of broiler chicken fed dietary levels of sickle pod (*Cassia tora*) seed and sunflower seed meals. It was carried out at the poultry unit of Teaching and Research Farm, Federal College of Horticulture (FCH) Dadin kowa, Gombe State, Nigeria to evaluate carcass and organs characteristics of broiler chickens using sickle pod seed (*Cassia tora*) and sunflower seed meals based diets. Five experimental diets each for both starter (23% CP) and finisher (20% CP) were formulated in which *Cassia tora* meal replaced sunflower meal at 0, 20, 30, 40 and 50% designated as diets A, B, C, D and E respectively. Three hundred (300) day old broiler chicks were randomly allocated to the five diets in four replicates of fifteen birds each. The experimental feeds and water were supplied to the birds *ad libtum* and the feeding trial lasted for seven weeks. The results indicated that live (1.16-1.49kg) and carcass (0.81-1.10kg) weight as well as dressing percentage (68.56-73.87%) were significantly ($P<0.001$) influenced by the *Cassia tora* diets. Eviscerated weights (1.07-1.30kg) were not significantly affected by the dietary treatments. However, most organ parameters were not significantly affected except small and large intestine lengths with values of 169.25-216.67cm and 8.00-14,00cm respectively as well as gizzards (2.79-3.67%) at $P<0.001$. It was concluded that *Cassia tora* seed meal can be included into broiler chicken diets when properly processed. It can replace up to 50% sunflower seed meal in broiler chicken diets without affecting the carcass yield and other organs characteristics. It was recommended that 50% toasted *Cassia tora* seed meal can be used in broiler chicken diets to improve carcass yield.

Keywords: *Cassia tora,* Sun flower, Carcass, Organs, Broiler

INTRODUCTION
Domestic animals continue to make significant contributions to the global food supply and as a result, animal feeds have become an increasingly critical component of the integrated food chain. Not only is the demand for livestock products increasing markedly due to population growth, but feed suppliers also have to cope with increasing prices of feed ingredients, safety and welfare concerns. By 2050, the world's population is estimated to reach 9.1billion, 34% higher than what it is today. The Food and Agriculture Organization (FAO, 2018) projects that the total global consumption of meat and dairy products will increase by 102 and 82% respectively, between 2000 and 2050. Global demand for poultry meat will increase by up to 85% and there will be an estimated 30% increase in egg production by 2050. Livestock industry is currently pacing challenges in meeting demand. One of the limiting factor is the cost of feeding that takes 70-80% of broiler production (Jamaa *et al.,* 2022). Protein sources are usually the most expensive and scarce components of the diets. The over dependence of the feed industries on the conventional protein sources like soya bean worsen the situation. Protein intake among Nigerian is very low and continue to decline below the recommended level by united nation. Searching for alternative become necessary to save the industry and to meet up the challenges of animal product supply (Wiliams and Jama'a, 2024). Among the available alternative is the sickle pod seed (*Cassia tora*). It is abundantly found in the study area and has little or no demand for both human livestock. It contains up to 23.4% crude protein and little anti nutrients that can be removed easily by roasting, steaming and fermentation. Sickle pod seed can be a good substitute to the costly conventional soya bean in broiler chicken diets. A study by Kwari *et al.* (2023) found that chicken fed fermented sickle pod seed meal recorded superior final live weight, overall

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weight gain and daily feed intake. However, ensuring adequate nutrient levels, such as phosphorus and calcium is crucial when using sickle pod seed meal in broiler chicken diets (Isah *et al.,* 2024b).

METHODOLOGY

Experimental Site

The research was conducted at the poultry unit of Teaching and Research farm of the Federal College of Horticulture (FCH) Dadin kowa, Gombe State, Nigeria. Dadin kowa is in the North-Eastern Agro-ecological zone of Nigeria in the humid tropical area of West Africa and is situated at 10.3145°N 11.5308°E with altitude of 240 meters above sea level and has temperature of about 24^0C-40^0C with mean annual rainfall of about 960- 1110 millimeters, and relative humidity is about 38^0C - 50^0C all year round (FCH, 2022).

Experimental Diets

Five experimental diets each for both starter (23% CP) and finisher (20% CP) were formulated in which *cassia tora* meal replaced sunflower meal at 0, 20, 30, 40 and 50% in diets A, B, C, D and E respectively. Other ingredients used were maize, soyabean, fishmeal, wheat offal, bone meal, limestone, salt, vitamin/mineral premixes, methionine and lysine.

Table 1: Ingredients and Percentage Compositions of *Cassia tora* and Sunflower Seeds Fed to Starter Broilers (2-4 Weeks)

Diets					
Ingredients	**A (0%)**	**B (20%)**	**C(30%)**	**D (40%)**	**E (50%)**
Maize	47.00	47.00	47.00	47.00	47.00
Full fat soyabean	14.00	14.00	14.00	14.00	14.00
Sunflower seed	20.00	16.00	14.00	12.00	10.00
Cassia tora	0.00	4.00	6.00	8.00	10.00
Fish Meal	5.00	5.50	6.00	6.50	7.00
Wheat Offal	10.00	9.50	9.00	8.50	8.00
Bone Meal	2.00	2.00	2.00	2.00	2.00
Lime stone	1.30	1.30	1.30	1.30	1.30
Salt	0.25	0.25	0.25	0.25	0.25
Premix*(starter)	0.25	0.25	0.25	0.25	0.25
Methionine	0.10	0.10	0.10	0.10	0.10
Lysine	0.10	1.10	1.10	1.10	1.10
Total	**100**	**100**	**100**	**100**	**100**
Calculated Analyses (%)					
M. E. (Kcal/kg)	2818.30	2831.18	2844.07	2856.95	2869.84
Crude Protein	23	23	23	23	23
Crude Fibre	5.94	5.78	5.62	5.46	5.30
Ether Extract	3.38	3.40	3.42	3.45	3.47
Calcium	1.36	1.37	1.39	1.38	1.38
Phosphorus	1.05	1.08	1.12	1.15	1.19
Methionine	0.41	0.42	0.43	0.44	0.45
Lysine	0.72	0.80	0.88	0.96	1.04

*Vit/Mineral Premix Supplied/Kg of Diet: Vit A, 12500 IU, Vit D3 2500 IU; Vit E, 30IU; Vit K, 2.5 Mg, Riboflavin, 6mg, Pantothenic Acid, 10mg; Vit B2, 4mg; Niacin, 20mg; Vit B_{12}, 22mg; Biotin, 0.75mg; Folic Acid, 0.5mg; Vit B6, 1.5mg; Vit B, 1.6mg; Choline Chloride, 175mg; Cobalt,0.2mg; Copper 3mg; Iodine, 1mg; iron, 20mg; Manganese, 40mg; Selenium, 0.2mg; Zinc 20mg, Antioxidant 1.25mg

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Table 2: Ingredients and Percentage Compositions of *Cassia tora* and Sunflower Seeds Based Diets Fed to Finisher Broilers (5-7 Weeks)

	Diets				
Ingredients	**A (0%)**	**B (20%)**	**C(30%)**	**D(40%)**	**E(50%)**
Maize	52.70	52.70	52.70	52.70	52.70
Full fat soya bean meal	8.00	8.00	8.00	8.00	8.00
Sunflower Seed	20.00	16.00	14.00	12.00	10.00
Cassia tora	0.00	4.00	6.00	8.00	10.00
Fish Meal	2.00	2.00	2.00	2.00	2.00
Wheat Offal	13.00	13.00	13.00	13.00	13.00
Bone Meal	2.00	2.00	2.00	2.00	2.00
Limestone	1.30	1.30	1.30	1.30	1.30
Salt	0.25	0.25	0.25	0.25	0.25
Premix*(finisher)	0.25	0.25	0.25	0.25	0.25
Methionine	0.10	0.10	0.10	0.10	0.10
Lysine	0.10	0.10	0.10	0.10	0.10
Total	100	100	100	100	100
Calculated Analyses (%)					
M. E. (Kcal/kg)	2892.01	2904.86	2917.62	2930.47	2943.23
Crude protein	20	20	20	20	20
Crude fibre	5.44	5.34	5.18	5.05	4.92
Ether extract	3.28	3.27	3.34	3.37	3.40
Calcium	1.5	1.5	1.5	1.5	1.5
Phosphorus	0.88	0.88	0.89	0.89	0.89
Methionine	0.45	0.46	0.46	0.46	0.47
Lysine	0.71	0.77	0.83	0.88	0.94

Vit/Mineral Premix Supplied/Kg of Diet: Vit A, 12500 IU, Vit D3 2500 IU; Vit E, 30IU; Vit K, 2.5 Mg, Riboflavin, 6mg, Pantothenic Acid, 10mg; Vit B2, 4mg; Niacin, 20mg; Vit B_{12}, 22mg; Biotin, 0.75mg; Folic Acid, 0.5mg; Vit B6, 1.5mg; Vit B, 1.6mg; Choline Chloride, 175mg; Cobalt,0.2mg; Copper 3mg; Iodine, 1mg; Iron, 20mg; Manganese, 40mg; Selenium, 0.2mg; Zinc 20mg, Antioxidant 1.25mg.

Experimental Birds and their Management

A total of 300 unsexed day old broiler chicks were used for the study. Brooding and rearing houses were cleaned and disinfected before the arrival of the day old broiler chicks. Brooding was done for seven days during which electric bulbs were used to provide heat and light when needed. Feed and water were adequately given with no restriction. At the end of the brooding period, birds were randomly allotted to the five (5) diets in four replicates of 15 chicks each. The floor was covered with a wood shavings throughout the period of the research. Experimental feeds and water was served *ad libitum.* All necessary routine management practices were strictly adhered to. The experiment lasted for seven weeks (4 weeks starter and 3 weeks finisher phase.

Data Collection

At the end of seventh week, three broilers were randomly selected and prepared for carcass analysis. They were marked and starved over night to allow emptying of guts. Following morning, individual live weights of the selected birds were taken before slaughter. They were then dressed and data was collected on carcass and internal organs of each bird. Data generated was prepared and analyzed using version 17 MINITAB software.

The proximate composition and percentages of test ingredients is presented in Table 3 and 4.

Table 3:The Proximate Composition (%) and Mineral Content of the Test Ingredients on Dry Matter Basis.

Ingredients	**(%)**	**CP**	**CF**	**EE**	**Ca**	**P**
Soyabeans seed	44	3.5	7.5	1.5	0.81	
Sunflower seed	40	5.63	3.27	1.5	0.72	
Cassia tora seed	23.4	4.92	3.40	1.5	0.89	

CP = Crude Protein, EE = Ether Extract, CF = Crude Fibre.

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Table 4: Anti-nutritional Factors in the Test Ingredients Expressed in Percentage

	Antinutrients			
Ingredients (%)	**Saponin**	**Phytate**	**Tannin**	**Oxalate**
Soya bean seed	0.187	0.068	0.049	0.030
Sunflower seed	0.005	0.006	0.017	0.008
Cassia tora seed	0.257	0.041	0.155	0.062

RESULTS AND DISCUSSION

Table 5 shows the carcass and organs characteristics of broiler chickens fed sickle pod diets.

Table 5: Carcass and organ characteristics of broiler chickens fed diets containing graded levels of sickle-pod seed (*cassia tora*) seed and sunflower seed meals

	Diets					
Parameters	**A(0%)**	**B (20%)**	**C(30%)**	**D (40%)**	**E (50%)**	**SEM**
Live weight (kg)	1.16^{c}	1.31^{b}	1.49^{a}	1.26^{b}	1.49^{a}	0.01***
Eviscerated weight (kg)	0.99	1.13	1.30	1.07	1.07	0.01^{NS}
Carcass weight (kg)	0.81^{d}	0.95^{b}	1.10^{a}	0.87^{c}	0.87^{c}	0.009***
Dressing percentage	70.08^{b}	72.47^{a}	73.87^{a}	68.56^{b}	73.19^{a}	0.22***
Organs weight expressed as percent live weight						
Head (%)	2.51	2.77	2.62	2.69	2.44	0.03^{NS}
Legs (%)	4.59	3.80	3.84	3.83	3.52	2.75^{NS}
Small intestine (%)	3.74	3.86	5.31	4.07	5.00	0.10^{NS}
Small intestine (cm)	185.67^{b}	169.25^{b}	216.67^{a}	173.73^{b}	204.17^{a}	2.20***
Large intestine (%)	0.30	0.32	0.33	0.44	0.24	0.01^{NS}
Large intestine (cm)	8.00^{b}	9.17^{b}	14.00^{a}	13.55^{a}	9.17^{b}	0.22***
Caeca (%)	0.56	0.55	0.57	0.53	0.55	0.06^{NS}
Caeca (cm)	16.75	16.33	16.83	17.36	16.67	0.28^{NS}
Gizzard (%)	2.79^{b}	3.69^{a}	3.28^{a}	3.16^{b}	2.83^{b}	0.04***
Lungs (%)	0.44	0.43	0.40	0.43	0.39	0.009^{NS}
Liver	1.61	1.64	1.65	1.52	1.48	0.03^{NS}
Heart (%)	0.37	0.48	0.41	0.46	0.40	0.009^{NS}
Abdominal Fat (%)	0.58	1.31	0.99	1.10	1.02	0.05^{NS}
Kidney (%)	0.16	0.15	0.13	0.16	0.13	0.001^{NS}
Pancrease (%)	0.26	0.24	0.24	0.26	0.24	0.005^{NS}
Pancrease (cm)	11.42	12.00	12.08	12.00	11.67	0.12^{NS}

abc=Means bearing different superscripts within the same row differ *** = ($p<0.001$)
NS = Not significant, SEM = Standard Error of the means.

The results for carcass parameters indicated that live (1.16-1.49kg) and carcass (0.81-1.10kg) weight as well as dressing percentages (68.56-73.87%) were significantly ($P<0.001$) influenced by the *Cassia tora* diets. Eviscerated weights (1.07-1.30kg) were not significantly affected by the dietary treatment. This result agrees with the findings of Amaza *et al.* (2020) and Kwari *et al.* (2023) who fed fermented *Cassia tora seed meal* to broiler chicken at 10% inclusion level. However, all organs parameters were not significantly affected except small and large intestine lengths with 169.25-216.67cm and 8.00-14,00cm respectively as well as gizzard (2.79-3.67%) that were significantly ($P<0.001$) affected by the dietary levels of *Cassia tora*. This finding differ with that of Isah *et al.* (2024a) who found no significant difference in using fermented *Cassia tora* seed meal to replace soyabean meal in broiler chicken diets. The significant differences obtained on small and large intestine lengths and gizzard percentages may be due to the fibrous and some anti-nutrients contents of *cassia tora seed* (Isah *et al.,* 2024b)

CONLUSION AND RECOMENDATION

It was concluded that *Cassia tora* seed meal can be included into broiler chicken diets when properly processed. It can replace up to 50% sunflower seed meal without affecting the carcass yield and other organs characteristics.

Based on the findings of this study, 50% toasted *Cassia tora* seed meal is recommended for inclusion in broiler chicken diets for better carcass yield.

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ANALYSIS OF HOUSEHOLDS' SUGAR CONSUMPTION PATTERN IN BAUCHI STATE NIGERIA

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ABSTRACT
The study examined household sugar consumption patterns in Bauchi State, Nigeria. Cross-sectional data were collected from 412 households through a multi-stage sampling technique. The data were analyzed using descriptive statistics and a linear regression model. The result revealed that the mean age of the respondents was 46.71 in the northern zone, 46.75 in the central zone, and 49.7 in the western zone. Most (90.2%,94.2%, and 87.9%) of the household heads in the northern, central, and western zones respectively were male and married, with 87.4% in the north zone, 94.2% in the central zone and 89.7% in the western zone. The mean household size was 11 persons in the northern zone, 10 persons in the central zone, and 9 persons in the western zone. The study further reveals that the respondents (65.7%,45.2%, and 47.9%) in northern, central, and western zones consume sugar every day respectively. The socio-economic factors influencing sugar consumption were average monthly income ($P<0.01$), cost of a kilogram of sugar($P<0.05$), household size ($P<0.01$), age of the household head ($P<0.05$), community of the respondents ($P<0.05$), average monthly food expenditure ($P<0.05$) were all significant in influencing household sugar consumption, with an R^2 value of 0.505 and the F-value was (33.889) significant ($P<0.01$). The research concluded that socioeconomic factors have an influence on the sugar consumption pattern of households. The research, therefore, provides data for firms and individuals who wish to invest in the sugar market to develop suitable business strategies. The study, therefore, recommended implementing an adequate policy that will reduce the cost of sugar production and increase the supply. Household income should also be increased to enable the households to meet the demand for their food necessities like sugar and invariably enhance the living standard of the respondents.

Keywords: Households, Sugar Consumption, Pattern, Bauchi.

INTRODUCTION
Sugar is a very important commodity that contributes towards feeding mankind. It is also a very significant component of the global food market; on which it plays an irreplaceable role. The world market for sugar and sugar-containing products is constantly evolving (Ekott, 2021). Its present form is being very markedly shaped especially by the process of liberalization of the world market for agricultural commodities. Sugar in particular represents one of the most distorted markets in the world. This is due mainly to the protectionist policies of many governments. Production and trade in sugar are also very closely linked with the policies of sustainable development. It is common knowledge that sugar is used as a sweetener, spice, preservative, and for medicinal purposes (in limited quantity). The current domestic supply has not met the rising demand in the country despite the incentives offered by the federal government to boost local production (Adebayo, 2016). More than ninety percent 90% of Nigeria's sugar needs are met by importing raw sugar shipped mostly from Brazil, which is then refined by the local domestic sugar industry (GAIN, 2021). Population growth and lack of available substitutes increase the demand for sugar in the country. So long as Nigeria remains reliant on the world sugar market for the supply of the majority of its sugar requirements, it can have very little control over the domestic price of sugar. This is dependent upon short and long-term fluctuations in the world price. Generally, knowledge of any essential food item's demand in a country is useful in designing policies that benefit households' welfare. For instance, it helps to identify appropriate policy interventions to improve the nutritional status of individuals and households. It can also inform the designing of various food subsidies/palliative. Sugar firms who wish to invest in the

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sugar market in Nigeria have to understand sugar consumption patterns and sugar demand to develop suitable business strategies. Decisions about the consumption of goods and services are taken at the household level (the lowest level of societal organization); a reason why it is said that all national economies strive to satisfy the wants and needs of their households (Jibril,2018) The broad objective of the study was to analyze household sugar consumption patterns in Bauchi state, Nigeria. The specific objectives were to:

i) Describe the socio-economic characteristics of sugar consumers in the three agricultural zones of Bauchi state.

ii) Assess the households' sugar consumption pattern in the study area

iii) Determine the influence of socio-economic factors on sugar consumption in the study area

METHODOLOGY

The Study Area

The study was conducted in Bauchi State, North East, Nigeria. The State, located between Latitudes 9° 3′ and 12° 3′ north of the equator and Longitudes 85° and 11° east, covers an area of 49,119 km² 65% of which is cultivable. As of 2022, the population of the State which grows at a rate of 3.5% was estimated at 8308,800 million, making it the most populous State in the northeast of Nigeria where the average household size ranges between 4 to 9 persons (UNDP, 2018). The State span two distinctive vegetation zones, the Sudan savannah and the Sahel savannah. The Sudan savannah covers the southern part while the Sahel savannah manifests from the middle of the State as one moves to the north, comprising mainly of isolated stands of thorny shrubs. The southwestern part of the State is mountainous as a result of the continuation of the Jos Plateau, while the northern part is generally sandy (www.bauchistate.gov.ng). The mean daily temperatures range between 29.2°C to 37.6. Rainfall ranges between 700mm and 1300mm The economy of the State rests on agricultural output.

Sampling Procedure and Sample Size

A multistage sampling procedure was used for the selection of the households. In the first stage, Bauchi State was divided into three agricultural zones according to the Bauchi State Agricultural Development Programme (BSADP) classification for administrative convenience: the western zone, central zone, and northern zone, which were considered as strata. In the second stage from each stratum (Agricultural zones), two LGAs were randomly sampled through balloting, making six LGAs for the study. In the third stage, each of the LGAs selected, an urban ward and a rural ward, were randomly sampled, making a total of twelve wards. In the fourth stage, from each of the wards, two communities were randomly sampled, making four communities per local government. Hence the total number of communities for the study was twenty-four. In the fifth stage, from each of the selected communities, five percent of the households were randomly sampled by assigning numbers to the households in the communities followed by random sampling of the numbers. The numbers served as the households for the study. The total households were four hundred and fifty for the study. Although four hundred and twelve household questionnaires were retrieved, they were used for the research. The summary of the sampling procedure is shown in (Table 1).

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Table 1: Sampling Frame and Size

Zone	Local Government	Town	Ward	Community	Sampling Frame	Sample Size
Northern	Gamawa	Gamawa	Gamawa south	Fada	400	20
				Balele	300	15
		Gololo	Gololo north	Unguwar Makwalla	240	12
				Unguwar Yamma	260	13
	Katagum	Azare		Bakin Kasuwa Azare	960	48
			Tsakuwa/Kofar gabar	Kofar Gabar	860	43
		Chinade	Chinade	Unguwan Rimi	160	8
				Unguwar Fawari	140	7
Central	Ganjuwa	Kafin Madaki	Kafin Madaki A	Unguwar Waziri	700	35
				Unguwar Yayaji	180	9
		Rudiyausa	Yali	Dengili	120	6
				Taubasi	80	4
	Ningi	Ningi	Ningi west	Unguwar Tsamiya	500	25
				Daliya	400	20
		Burra	Burra/kyata	Kofar Fada	200	10
				Baduku	180	9
Western	*Bauchi	Bauchi	Makama A	Ganjuwa	800	40
				Dutsen Tanshi	1300	65
		Birshin Fulani	Birshi	Unguwar Sarki	100	5
				Wuro Gubi	80	4
	Bogoro	Bogoro	Bogoro B	Bamshi	300	15
				Bakin Kasuwa	200	10
		Dutsen Lawan	Bogoro A	Nasarawa	400	20
				Bazamshi	140	7
Total					9,000	450

Source: National Population Commission, 2006

Method of Data Collection

Cross-sectional data were used for the research using seven days' memory recall collected from four hundred and twelve households through the administration of structured questionnaires of Section B households consumption pattern.

Method of Data Analysis

The techniques for data analysis adopted included descriptive and inferential statistics. Descriptive was used to analyze objectives i, and ii, it is a mathematical technique that involves the use of means, frequency, and percentages. The most important is the arithmetic mean, usually denoted by $\bar{x}$, and is calculated using.

$$\bar{x} = \frac{\sum fx}{\sum f} \quad \text{----------(1)}$$

Where f = number of values in an internal
$\bar{x}$ = is the midpoint of the class internal.
Σ= Summation

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The frequency was used to group or arrange the raw data into a manageable form. It shows the variable`s values and the occurrence numbers of each value. The percentage was used to determine the population of respondents to a particular response and expressed mathematically as a percentage (%)= x/n x 100 ---------- (2)

Where % = percentage
x= Individual observation

The regression model was used to achieve objective iii of the study. The model is specified as: $Y= b_o+b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_5x_5+b_6x_6+ b_7x_7+b_8x_8+b_9x_9+b_{10}x_{10}+b_{11}x_{11}+ b_{12}x_{12}+e$----------(3)

Where:
Y=Total Monthly sugar expenditure (₦)
X_1=Monthly income of household head (₦)
X_2=Cost of kilogram of sugar (₦ /kg)
X_3 = Household size (Number)
X_4=Age of the household head (years)
X_5= level of education of the household head (1=Non formal education, 2= Adult education, 3=Quranic education, 4= Primary, 5= Secondary, 6= Tertiary)
X_6= Marital Status (1=married,2=Single, 3=Widow, 4=Divorcee)
X_7=Tribe (1=Hausa, 2= Fulani, 3= Sayawa, 4=Tera, 5= Kanuri, 6= Igbos, 7= Karekare, 8= Waja, 9=Gerawa, 10=Igala, 11= Angas)
X_8= Sex (1 =female, 2 =male)
X_9=Primary occupation of the household head (1=Civil servant, 2=Business, 3= Farming, 4= Artisan, 5= Pensioner, 6= Others)
X_{10}=Community of respondents (1= Nasarawa, 2= Bazamshi, 3= Bamshi, 4= Bakin kasuwa, 5= Bakin kasuwa Azare, 6= Kofar gabas, 7= Unguwar rimi, 8= Unguwar fawari, 9= Unguwar yamma, 10= Unguwar makwalla, 11= Fada, 12= Balele, 13= Kofar fada, 14= Baduku, 15= Unguwar tsamiya, 16= Daliya, 17= Ganjuwa, 18= Dutsen tanshi, 19= Unguwar sarki, 20= Wuro gubi, 21= Unguwar waziri, 22= Unguwar yayaji, 23= Dengili, 24= Taubasi)
X_{11}=Monthly food expenditure (₦)
X_{12}=Average monthly total household expenditure (₦)
b_1(i=1…12) are regression coefficients and direct measures of elasticity.
b_o =Constant term of intercept
e=Error term.

RESULTS AND DISCUSSION

Socio-economic Characteristics of Sugar Consumers

Learning about consumer behavior helps observers understand the real world in the agricultural economy. Socio-economic attributes influence consumption patterns to measure poverty level; thus, for welfare, one must measure what and how much individuals consume. Consumption is more representative of economic welfare (Adeyenju, 2014). The sugar consumers sampled for the study had diverse socio-economic characteristics that were expected to influence their sugar consumption patterns. The socioeconomic data on age, sex, marital status, and household size of sugar consumers in Bauchi State is presented in Table 2

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Table 2: Distribution of Respondents based on Age, Sex, Marital Status and Household Size (N= 412)

	Northern Zone		Central Zone		Western Zone		Pooled	
Age Group	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq**	**%**
21-30	20	14.0	3	2.9	10	6.1	33	8.01
31-40	27	18.8	34	32.7	30	18.2	91	22.09
41-50	49	34.3	37	35.6	47	28.5	133	32.28
51-60	25	17.5	21	20.2	53	32.0	99	24.03
61-70	22	15.4	9	8.7	25	15.2	56	13.59
Mean	46.71		46.75		49.7		47.90	
Min	25		22		25		22	
Max	65		70		69		70	
Std dev	12.54		10.3		11.73		11.75	
Sex								
Female	14	9.8	6	5.8	20	12.1	40	9.71
Male	129	90.2	98	94.2	145	87.9	372	90.29
Marital Status								
Married	125	87.4	98	94.2	148	89.7	371	90.05
Single	8	5.6	1	1.0	4	2.4	13	3.15
Widowed	6	4.2	5	4.8	11	6.7	22	5.33
Divorced	4	2.8	0	0.0	2	1.2	6	1.47
Household size								
1-5	32	22.4	16	15.4	42	25.5	90	21.85
6-10	37	25.8	51	49.0	74	44.8	162	39.32
11-15	46	32.2	18	17.3	26	15.8	90	21.85
16-20	12	8.4	13	12.5	13	7.9	38	9.22
21-25	16	12.2	6	5.8	10	6.0	32	7.76
Mean	11		10		9		10	
Min	1		1		2		1	
Max	29		33		26		33	
Std dev	6.46		5.50		5.39		5.86	

Source: Field survey, 2020

Age is an important demographic element that determines consumption level. Household consumption increases with age. An increase in age is strongly correlated to consumption per capita. This characteristic of the respondents is presented in Table 2. The results reveal a similarity in the respondent household head age across the zones. In the northern zone, 34.3% of the respondents were within the age bracket of 41 – 50 years, while in the central and western zones, they constituted 35.6% and 28.3%, respectively. This was followed by the respondents in the age bracket of 31-40 years, constituting 18.8% in the northern, 32.7%, in the central, and 18.2%, in the western zone. Similarly, 17.5 % of the respondents, 20.2% and 32.0%, belong to the age bracket of 51-60 years in northern, central, and western zones. The household heads that belong to the age bracket of 21-30 and 61-70 in the northern zone were 14.0% and 11.9%, respectively, while in the central zone and western zone, they were 2.9% and 7.7% and 6.1% and 9.7% respectively. An overwhelming majority of the respondents, 84.6% in the northern zone, 91.4% in the central zone, and 84.8% in the western zone were within the age bracket of 21-60 years, considered the economically active age bracket and consumed more sugar for daily activities. In the northern and western zones, the minimum age of the respondents is 25 years, while in the central zone, it is 22 years.

The mean age was 46 years for the northern and central zone and 49 years for the western zone while the maximum years for the household heads were 75 for the northern zone, 80 for the central zone, and 79 for the western zone. The implication of this, from the economic point of view, is that this age bracket (21-60) years will be spending more on sugar consumption, no matter the price of sugar. This affects the total food budget of households. The result is similar to the findings of Oyakhilomen (2014), in which the minimum, maximum, and mean age of the household heads that consume rice in Kaduna State were 24, 75, and 48 years, respectively. Sex refers to being male or

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female. The results from Table 2 show that 90.2%, 94.2%, and 87.9% of the households in the northern, central, and western zones, respectively, were headed by males. Female-headed households were only 9.8% in the northern zone, 5.8% in the central zone, and 12.1% in the western zone. The implication of this can be situated within the context of the traditional family system in northern Nigeria, which is the basis for the organization of production and consumption services. The family system is basically paternal, in which leadership rests on the men. This is similar to the finding of Ahmed *et al.* (2015) in the analysis of food security among farming households in Borno State, where 86.7% of the respondents were males, while only 13.3% were females. This was in contrast to the finding of (Fade *et al*.,2015) in household demand for sweeteners in Ogun State, where 51.2% of the households were headed by females and 48.8% by males.

Marital status refers to whether the respondent is married or not. Economic services provided by the husband and wife complement one another. Table 2 shows that 90.2% in the northern zone, 94.2% in the central zone, and 87.9% in the western zone were married. Only 5.6% and 4.2% of the respondents were single and widowed in the northern zone, 1% and 4.8% in the central zone, with only 2.4% and 6.7% in the western zone. This may be so because, in northern Nigeria, people get married early because of their culture and religion. The implication of this is that the respondent marital status influences the expenditure pattern of the household, especially on food and sugar-related products.

In economics, a household is defined as an economy's basic unit of consumption and production. It refers to a group of individuals, whether related by blood, marriage, or other forms of association, who live together and make joint decisions regarding the allocation of resources (NPC, 2006). Table 2 shows that in the northern zone, 22.4% had 1-5 persons in their household. Those who had 6-10 and 11-15 persons constituted 25.8% and 32.2%, respectively. The rest were those with 16-20, 21-25 and 26-30, constituting 8.4%, 7.7% and 3.5%, respectively. In the central zone, almost half 49.0% had 6-10 persons, followed by 17.3% with 11-15 persons. Those with 1-5 persons constituted 15.4%. The rest were 12.5% and 3.8% having 16-20 and 21-25 persons, respectively. In the western zone, 44.8% had 6-10 persons in their household, followed by 25.5%, 15.8%, and 7.9%, with 1-5,11-15 and 16-20 persons, respectively. Only 3.6% and 2.4% had 21-25 and 26-30 persons respectively. The mean household size was 11 in the northern zone, and 10 and 9 persons in the central and western zones, respectively. The implication of household size on consumption is enormous; as household size increases, the quantity of food and sugar consumed increases, thus leading to higher household expenditure. However, the composition of households with many children and adolescents is likely to consume more sugar than households with elderly members. Understanding households and their economic behaviors is crucial for analyzing consumption patterns, savings rates, labor market dynamics, and overall economic well-being. Economists study households to gain insights into consumer behavior, income distribution, poverty, inequality, and other aspects of the economy that are influenced by individual and household-level decisions. The result is similar to the finding of Ahmed *et al.* (2015) in the analysis of food security among farming households in Borno State, where about 36% of the sampled population had between 7–10 household members.

Households' Sugar Consumption Pattern

A household consists of a person or group of persons living together, usually under the same roof or in the same building or compound, who share the same source of food and recognize themselves as a social unit with a head of household. Table 3 reveals the monthly quantity of sugar consumed by households. Almost half 47.27% of the respondents in the western zone consume between 764-4940 grams of sugar monthly, while 37.76% and 23.08% consumed the same quantity in the northern and central zones, respectively. Slightly over half 55.77% of the respondents in the central zone,36.36% in the northern zone and 32.12% in the western zone consumed 4941—9117 grams of sugar respectively. A small percentage of the households 14.69% in the northern zone consumed 9118—13294g per month, while in the central and western zone, it was 20.19% and 18.19% respectively. As can be seen from Table 4, The respondents who consumed sugar in the range of 13,295g -25,825g constituted the lowest percentages across the zones. The implication of the quantity of sugar consumed depends on the size and composition of the household as size increases

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quantity consumed will also increase. Younger adults, children, and adolescents have more sugar to be consumed, thus higher sugar expenditure. This was similar to the finding of Fade *et al.* (2015) in the study of household demand for sweeteners in Ogun state where the maximum quantity of sugar consumed per month was 6670g while the minimum and mean were 250g and 1060g respectively. With an estimated population of 8.3 million in 2022, the estimated annual consumption in Bauchi State is 81 metric tonnes.

Table 3: Distribution of Respondents based on Monthly Sugar Consumption (n = 412)

Monthly consumption (grams)	Northern zone		Central zone		Western zone		Pooled	
	Freq	%	Freq	%	Freq	%	Freq	%
764— 4,940	54	37.76	24	23.08	78	47.27	156	37.86
4,941— 9,117	52	36.36	58	55.77	53	32.12	163	39.56
9,118—13,294	21	14.69	21	20.19	30	18.19	72	17.48
13,295—17,471	04	2.80	01	0.96	02	1.21	07	1.70
17,472—21,648	08	5.59	00	0.00	02	1.21	10	2.43
21,649—25,825	04	2.80	00	0.00	00	0.00	04	0.97
Total	**143**	**100**	**104**	**100**	**165**	**100**	**412**	**100**

Source: Field Survey, 2020.

Consumption patterns normally contribute greatly to the social and economic policy of the country. Measuring consumption over a week or month indicates a household's consumption habits over a year because it has a smooth flow. Table 4 shows that 65.7% of the respondents in the northern zone consume sugar every day. In the central and western zones, the percentages were 45.2% and 47.9%, respectively. This was followed by respondents who consume sugar three to four days a week, constituting 20.3%, 35.6%, and 30.9% in northern, central, and western zones, respectively. The lowest percentage of the consumption pattern was 4.2%, 1.9%, and 5.5%, consuming sugar one to two days a week in the northern, central, and western zones, respectively. The implication here is sugar become part and parcel of people's life, consuming it many days per week; it has become addictive and habitual. Lack of sugar will lead to lower consumption of food items and frustration by the household members, especially children and adolescents.

Table 4: Distribution of Respondents according to Frequency of Sugar Consumption

Variables	Northern zone		Central zone		Western zone		Pooled	
	Freq	%	Freq	%	Freq	%	Freq	%
Frequency of sugar consumption/week								
1-2	6	4.2	2	1.9	9	5.5	17	4.13
3-4	29	20.3	37	35.6	51	30.9	117	28.40
5-6	14	9.8	18	17.3	26	15.8	58	14.07
Daily	94	65.7	47	45.2	79	47.9	220	53.40

Source: Field Survey, 2020.

Influence of Socio-economic Characteristics on Sugar Consumption in Bauchi State

Multiple regression analysis is valuable for quantifying the impact of various simultaneous influences upon a single dependent variable as discussed in Table 5. The dependent variable here is monthly sugar expenditure. In the model for the three zones average monthly income, cost of a kilogram of sugar, household size, age of the household head, community, and average monthly food expenditure were all significant. These variables were found to be factors responsible for variation in household monthly sugar expenditure. The result revealed that R^2 was 0.505. This implies that the independent variables included in the model collectively explained about 51% of the variation in monthly sugar expenditure. Thus the hypothesis that none of the explanatory variables had a significant influence on sugar expenditure was rejected. In a study using cross-sectional data

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involving several observations, the generally low R^2 value is obtained because of the diversity of the cross-sectional unit. The F value (33.889) was significant ($p< 0.01$).

Average Monthly Income

The coefficient of average monthly income (390.523) was significant ($p< 0.01$) and positively related to monthly sugar expenditure. It revealed that as the income of the household head increases, the amount spent on sugar will also increase. This is in contrast to the findings of Lindblom (2017) that indicated that the higher-educated group consumes the same share of sugary foodstuffs, independent of their income level, whereas for the lower-educated group, income is a significant factor and the consumption share of sugar decreases as income increases. Konttinen *et al.* (2013) have found similar effects, far more energy-dense foods were consumed by people in the low-income or lower-education group, and high-income and high-education related to greater vegetable and fruit consumption. They also found evidence that those individuals with a low income or education place more importance on price and less importance on health in their food selection compared with the more educated or affluent counterparts. Thus the hypothesis that consumer's income has no significant influence on sugar expenditure was rejected.

The coefficient of cost of a kilogram of sugar was 2.349 significant ($p< 0.05$) and positive which indicates a direct relationship between cost of a kilogram of sugar and monthly sugar expenditure. The result shows that if the cost of a kilogram of sugar decreases, monthly sugar expenditure will also decrease.

The coefficient of household size is positive and significant ($p<0.01$) which implies that as the household size increases, monthly sugar expenditure will also increase. This agrees with a priori expectation that the higher the size of the household the higher the sugar expenditure. The coefficient of the age of the household head (11.716) is positive and significant ($p<0.05$). This indicates that the higher the age of the household head, the higher the monthly sugar expenditure. This agrees with a prior expectation, the older the household head, the more his children and dependents.

The coefficient of community 28.175 is positive and significant ($p<0.05$). The study revealed that the location of the respondents, which is the community they reside, has an influence on monthly sugar expenditure. Those living in urban areas are likely to spend more in purchasing sugar monthly because of the affordability and availability of the product. Also, the variety of food consumed in different communities will also increase the monthly expenditure on sugar.

The coefficient average monthly food expenditure (283.681) is positive and significant at ($p<0.05$). The result of the regression reveals that as average monthly food expenditure increases, monthly sugar expenditure will also increase. As sugar is a component of household food items. This is similar to previous studies on food consumption where an increase in income of the household leads to increase in food budget share. This is in consonant with Engels law. Babakhani and Suleimani (2012) estimated the demand for sugar in Iranian households using the ordinary least square (OLS) technique and linear regression model. With an income elasticity of 0.8, the study showed that like in many other countries, sugar is a necessary good in the Iranian household's basket. The results also gave a price elasticity of - 0.2 indicating that changes in price make a little change in demand for sugar in that country. The study concluded that sugar demand in Iran is associated with household expenditure, relative price of sugar, and family size.

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Table 5: Socio-economic Factors Influencing Sugar Consumption in Bauchi State

Variables	Coefficient	Std. Error	t-values
(Constant)	-1498.646	802.348	-1.868
Average monthly income	390.523***	64.371	6.067
Cost of a kilogram of sugar	2.349***	.697	3.372
Household size	77.854***	11.780	6.609
Age	11.716**	5.306	2.208
Education level	-50.079	36.321	-1.379
Marital Status	-68.356	132.156	-.517
Tribe	-12.119	24.212	-.501
Sex	-212.028	259.525	-.817
Primary occupation	-42.652	45.919	-.929
Community	28.175***	8.328	3.383
Average monthly total food expenditure	283.681**	99.519	2.851
Average monthly total household expenditure	-78.423	93.763	-.836
R-squared	0.505		
Adjust R-squared	0.490		
F-value	33.889		
Prob >F	0.000		

Source: Field survey,2020 Ns *p<1; **p< 05; *** p<01

CONCLUSION AND RECOMMENDATIONS

The research was designed to analyze household sugar consumption patterns in Bauchi state, Nigeria. The study revealed that Sugar is consumed daily by most households. Household size, age and income of the household head, community of the respondents, and monthly food expenditures significantly influenced household sugar expenditure in the study area. The study therefore recommended;

I. The per capita income of household heads should be improved, by paying living wages to workers, economic empowerment programs to the citizens, and introducing job opportunities by state and federal governments and wealthy individuals. This will increase the households purchasing power and thereby help meet the sugar requirement of the households.

II. Education related to eating habits is a crucial agenda for development and health. Therefore, it is necessary for the government and individuals to advocate healthy eating habits to citizens, for example adhering to the World Health Organization's sugar intake per day.

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PERCEPTION OF CLIMATE CHANGE EFFECTS AMONG MAIZE AND POTATO BASED FARMERS IN CENTRAL ZONE OF PLATEAU STATE, NIGERIA

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ABSTRACT
The study examined the factors influencing awareness of climate change effect on maize and potato production in Kanam and Mangu LGAs of Plateau State, Nigeria. Multistage sampling technique was employed in selecting 220 respondents. Primary data were obtained through the administration of structured questionnaire and analyzed using both descriptive and inferential statistics. The result revealed that majority (70.0) of the respondents were in their active age group with a mean of 37 years. Majority (75.5%) of the respondents were male, engaged in multiple occupations, including farming (27.3%), civil servant (41.8%), and trading (14.1%). The results also showed that majority (76.4%) of the respondents were married with small household sizes as indicated by the mean household size of 8 persons. The results further revealed that 30% and 47.3% had attended secondary and tertiary as level of education. Inheritance (45.9%) was the primary mode of land acquisition. In addition, the result also showed that sex, occupation, membership of association, access to extension, agrochemical usage and type of labour were significant ($P<0.01$) factors influencing farmers awareness of climate change effects on maize and potato production. Drought (92.3%), low literacy levels (89.5%), and poverty (67.3%) were identified as the major constraints to climate change mitigation strategies and were ranked 1st, 2nd and 3rd respectively. The study concluded that age, sex, membership of association, access to extension, agrochemical usage and type of labour were the factors influencing respondents' awareness to climate change effect on maize and potato production. Based on the findings of the study the following recommendations were made; enhance the capacity of extension agents to provide timely and relevant information on climate-smart agriculture practices, encourage the adoption of climate-resilient agricultural technologies, such as drought-tolerant crop varieties, efficient irrigation systems.

Keywords: Awareness, Climate, Change, Effect, Maize, Potato

INTRODUCTION
Climate change, according to the Intergovernmental Panel on Climate Change (IPCC), is a change in the state of the climate that can be defined by changes in the mean and/or weather variability that lasts for a protracted period of time, generally decades. Changes in global warming could also be caused by human-induced variables (Ebele and Emodi, 2016). Globally, it is regarded as the most important environmental issue confronting the world, wreaking havoc on agriculture and changing life patterns and general living circumstances (FAO, 2022). It has ramifications like disrupting seasonal cycles, hurting ecosystems and water supplies, impacting agricultural farming systems and food production, raising sea levels, and so on (Elia, 2017). However, agriculture's survival is dependent on climate, and the two are intertwined since they both occur globally.

In Nigeria, climate change is having a severe influence on agricultural activity (Haider, 2019). Sweet potato production in the country has come under serious threat; as a result, both yearly and domestic output have decreased, impoverishing farmers and limiting their financial returns (Esan and Omilani, 2018). Available data shows that the last decade has been the warmest ever recorded with 2016 being the warmest year during the period (National Aeronautics and Space Administration, 2020). Furthermore, the data indicates that since the late 19th century, the average temperature of the earth's surface increased by over 1.62°Fahrenheit (0°C). Consequently, increasing concentration of greenhouse gases in the atmosphere is changing precipitation patterns, raising temperature, spurring

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frequent extreme weather events, and shifting growing seasons (Egbetokun *et al*., 2020; IPCC, 2014; MFA, 2010). Meanwhile, Nigeria's agriculture and agro-allied industries could potentially drive the economy's growth and diversification from crude oil (Gershon *et al*., 2019). However, it is largely climate fed - depends mainly on rainfall and temperature. Moreover, infrequent fluctuations in rainfall and temperature patterns have distorted the standard April-October rainfall period and October-March harmattan weather or dry season. On the one hand, untimely rainfall and climatic extremes could threaten potential agricultural investment (Gershon and Patricia, 2019).

Climate change has, in fact, been extensively observed to have an impact on crop productivity in Africa and Nigeria, particularly sweet potato cultivation (Asrat and Simane, 2018). Despite advances in agricultural technology such as the use of inorganic fertilizers, modern land preparation, planting of early season crops, farm mechanization, the use of agrochemicals, improved seed varieties, irrigation system expansion, and genetically modified crops, among others, weather and climate continue to be major challenges to agricultural production (Diriba *et al*., 2019). Nigeria is identified as a climate change hotspot, with an expected increase in unpredictable rainfall patterns, flooding, and drought. Nigeria is committed to doing everything possible to minimize climate change impacts on a regional scale (Madaki *et al*., 2023). Nigeria is identified as a climate change hotspot, with an expected increase in unpredictable rainfall patterns, flooding, and drought. Nigeria is committed to doing everything possible to minimize climate change impacts on a regional scale (Madaki *et al*., 2023). Despite efforts by the Government to improve the farming of maize and irish potato in Plateau, decreasing level of production indicated that there are constraints associated with the small and medium enterprises farmers of maize and irish potato in Central Zones of Plateau State. Major factors contributing to the low level of maize and irish potato farming in these areas includes: climate change, poor quality of maize and irish potato farming, low level of technology, inadequate capital, poor economic infrastructure, lack of adequate incentives and the likes.

The broad objective of the study is to examine climate change knowledge, effect and coping strategies among maize and potato farmers in Kanam and Mangu LGAs of Plateau State. While specific objectives were to:

i. describe the socioeconomic characteristics of the respondents;
ii. determine the factors influencing respondents' awareness of effect climate change effect on maize and potato;
iii. identify the constraints associated with climate change strategies in the study area.

MATERIALS AND METHODS

The Study Area

The study was conducted in Plateau State, Nigeria. The State has 17 Local Government Areas and is divided into 3 Zones Northern, Central and Southern Zone. It is located between Latitudes 8^0 24' N to 10^0 30'N and Longitudes 8^0 32' and 10^0 38' East (NBS, 2022). Plateau State is primarily an agrarian community having a land mass of 26,026km^2 with a projected population of 4,717,300 (PLSG, 2021; NBS, 2022) people at 3.2% growth rate per annum with land area of 8385Km^2. The major food crops produced in the State are cereals like maize, sorghum, millet, acha, root and tubers like yam, cassava, sweet potato, irish potato etc, while tree crops like apple, avocado, olives among others. The major economic activities of the people are production and marketing of potato (Adamu, *et al.,* 2022).

The State is bounded to the North by Bauchi State, North-West by Kaduna State, West by Nassarawa State and South-East by Taraba State. The tribes found in the area are Ngas, Fer, Chakfem, Kadung, Bijim, Tambes, Miship, Mwagavul, Mupun, Ron, Kulere, Mushere, Berom, Afizere, Anaguta, Ganawuri, Atakar, Kwaghlah, Tarok, Hausa, Fulani, Igbo and Yoruba to mention a few. About two third of the land area is arable. The main commercial activities of the people are farming mining and trading (McKenna, 2023). The main livestock kept by the farmers are sheep, goats, pigs, rabbits, and poultry. The study area has a cold climatic condition due to its high altitude, with its highest point around the shere hills, situated about 10km east of the Jos metropolis, reaching a height of about 1,829m or 6,001ft above sea level (Zitta and Madaki 2020). The coldest period is from

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December to January, while the hottest is from March to April which ushers in the rains. The rainy season which is between the months of May and October, has its peak during the month of August. The mean annual rainfall stands at 1200 mm, with a mean temperature of about 22^0C (Binbol *et al*., 2020).

Sampling Procedure and Sampling Technique

A multi-stage sampling technique was used for the selection of respondents for the study. In the first stage, three (3) Local Government Areas (LGAs) were purposively selected from Central Zone of Plateau State. Purposive sampling was used to capture LGAs with concentration of both maize and potato production in the Zone. The selected LGAs includes Bokkos, Kanam and Mangu. Second stage involved the use of simple random sampling technique in the selection of two (2) districts from each LGA making a total of six (6). In Kanam; Garga and Dengi Districts were selected, in Mangu LGA; Mangu and Kombun Districts were chosen and in Bokkos LGA; Horop and Butura were selected for the study. In the third stage two (2) villages were systematically selected from each of the selected Districts to make a total of 12 communities. The selected villages were Lugur and Kyaram (Garga District); Kafil and Namaran (Dengi District); Mangu halle and Dutse lamba (Mangu District); Nting and Millet (Kombun Ditrict); Kaban and Mijing (Horop District) and Mandar and Kuba (Butura District). Fourth stage involved random and proportional (9% and 7%) selection of maize and potato farmers from a total population of 1,248 and 1,562, respectively. Thus, a sample size of 111 maize farmers and 109 potato farmers were drawn from the study area. Hence a total of 220 respondents were used for the study.

Table 1: Sampling Technique and Sampling Size

LGA	District	Villages	Maize farmers	Potato farmers	Sample maize (9%)	Sample potato (7%)
Bokkos	Horop	Kaban	102	210	9	15
		Mijing	61	156	5	11
	Butura	Mandar	116	98	10	7
		Kuba	132	75	12	5
Kanam	Garga	Lugur	66	132	6	9
		Kyaram	94	106	9	7
	Dengi	Kafil	115	101	10	7
		Namaran	102	85	9	6
Mangu	Mangu	Mangu Halle	132	153	12	11
		Dutse Lamba	60	245	5	17
	Kombun	Nting	154	89	14	6
		Millet	114	112	10	8
Total			1,248	1,562	111	109

Source: Authors' computations

Method of Data Collection

The study used primary data only and questionnaire was employed as a data collection instrument. Data were obtained by administering the questionnaire to the respondents and supplemented with interviews.

Method of Data Analysis

Data will be analyzed using both descriptive and inferential statistics to achieve the stated objectives of the study.

Descriptive statistics

Descriptive statistics such as frequency tables, percentage and mean were used to achieve objectives i, ii, iii, v and vi of the study.

Inferential Statistics

Logit regression statistics was employed to analyse objective iv of the study area. Logit regression model will be use to estimate regression function statistics which is given as:

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$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + U \quad \ldots(1)$$

Where:
Y= Awareness on effect of climate change (1= Yes, 0=No)
X_1 = Age (Years)
X_2= Marital status (1=Single, 2= Married 3=Divorced =, 4=Widowed)
X_3= Education (1=Quranic, 2=Primary, 3=Secondary, 4=Tertiary)
X_4= Household size (Number of persons)
X_5= Farming experience (Years)
X_6 = Membership of association (Yes = 1, 2=No)
X_7 = Extension Contact (Number of times)
X_8 = Farm size (Hectares)
X_9 = Access to credit (Access = 1, 2=Non-access)
X_{10} = Quantity of harvest (Kg)
X_{11} = Land acquisition
X_{12} = Use of agro-chemicals (1=Yes, 2=No)
X_{13} = Type of labour (1=Family, 2=Hired)
β_0= Constant
$\beta_1 - \beta_8$ = Regression coefficients
U = Error term

RESULTS AND DISSCUSSION

Socioeconomic Characteristics of the Respondents

The result from Table 2 describes the socioeconomic characteristics of the respondents. The finding indicated that 41.8% and 28.2% of the respondents were within the ages of 29-36 years. The result also showed that 28.2%, 12.7%, 10.5% and 6.8% of the respondents were within the age brackets of 37-44, 21-28, 45-52 and 52 years and above, respectively, with a mean age of 37 years. This finding implies that most of the respondents were within their active and youthful age of production in the study area. This finding is in line with that of Jatbong *et al.* (2018) who found that potato farmers in Plateau State were within the age of 47 years. Similarly, Adamu *et al.* (2022) reported that majority of potato farmers within the study area fell within age range of 30-39 years representing active ages of the farmers. The result further showed that majority (75.5%) of the respondents were male and 24.5% of the respondents were female. This finding implies that most of the respondents were male which is not unconnected to the male dominance in agricultural activities due to the tedious nature of activities involved in maize and potato production which is mostly practiced by men in the study area. This affirmed the findings of Gebru *et al* (2017) also reported 88.8% were male among surveyed potato farmers in Ethiopia. Adamu *et al.* (2022) also reported that majority of potato farmers were male and married in the study area. The result also reveals that 41.8% of the respondents were civil servants while 27.3%, 14.1%, 12.7% and 4.1% of were crop farmers, traders, artisans and livestock farmers, respectively. This finding implies that most of the respondents were engaged in other forms of occupation which serves as additional sources of income among the respondents in the study area.

The result also showed that majority (76.4%) of the respondents were married while 18.2% and 5.5% were single and widowed. This finding implies that most of the respondents were married and have certain level of responsibilities in the study area. The result also revealed that more than half (52.7%) of the respondents had a household size of 1-6 persons while 25.5%, 11.8%, 6.4% and 3.6% had 7-12, 13-18, 19-24 and 25 persons and above, respectively with a mean household size of 8 persons. This finding implies that most of the respondents had small household size which indicate low or inadequate family labour among the respondents in the study area. This is similar to the finding of Ntat *et al.* (2021) who revealed that household size, age and sex of the potato farmers in Plateau State, Nigeria was 6- 10 household size had, 36-50 years range and majority were male.

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Table 2: Distribution of Respondents According to their Socioeconomic Characteristics of the Respondents (n=220)

Variables	Frequency	Percentage	Mean
Age			
21-28	28	12.7	
29-36	92	41.8	
37-44	62	28.2	**37**
45-52	23	10.5	
52 and Above	15	6.8	
Sex			
Male	166	75.5	
Female	54	24.5	
Occupation			
Civil servant	92	41.8	
Artisans	28	12.7	
Crop farmer	60	27.3	
Livestock farmer	9	4.1	
Trader	31	14.1	
Marital status			
Single	40	18.2	
Married	168	76.4	
Widowed	12	5.5	
Household size			
1-6	116	52.7	
7-12	56	25.5	**8**
13-18	26	11.8	
19-24	14	6.4	
25 and Above	8	3.6	
Educational level			
Primary	4	1.8	
Secondary	66	30.0	
Certificate	36	16.4	
Tertiary	104	47.3	
Qur'anic	10	4.5	
Land acquisition			
Inheritance	101	45.9	
Purchase	57	25.9	
Rent	42	19.1	
Leasehold	4	1.8	
Government	16	7.3	

Source: Field Survey, 2024

The result further reveals that 47.3% and 30% of the respondents had tertiary and secondary levels of education. The result also shows that 16.4%, 4.5% and 1.8% of the respondents had certificates, qur'anic and primary levels of education, respectively. This finding implies that most of the respondents had attended one form of formal education or another in the study area. Adamu *et al.* (2022) reported that majority of potato farmers had tertiary levels of education in the study area. The result further showed that 45.9% of the respondents acquired their land through inheritance while 25.9%, 19.1%, 7.3% and 1.8% acquired their land through purchase, rent, government and leasehold, respectively. This finding implies that most of the respondents had access to land though the inheritance which is the cheapest form of acquiring land for agricultural production as it is transferred from one generation to another in succession.

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Factors Influencing Respondents' Awareness of Climate Change Effect on Maize and Potato Production

The result from Table 3 reveals the factors influencing respondents' awareness of climate change effect on maize and potato production. The finding revealed that sex was positive (r=3.65) and significant (P<0.01) in influencing respondents awareness of the effect of climate change. This implies that increase in male respondents will lead to increase of the awareness of effects of climate change on maize and potato production in the study area, which is not unconnected to the fact that male respondents have freedom and access to extension services workshop, seminars and filed days within and outside the study area as oppose to their female Counterparts whose husbands, children or parent hinders their movement in the study area. The result further showed that occupation was positive (r=2.62) and significant (P<0.01) in influencing respondents' awareness of climate change effects on maize and potato production, this implies that increase in other forms of occupation will lead to increase in the level of awareness of climate change in the study.

Table 3: Factors Influencing Respondents Awareness of Climate Change Effect on Maize and Potato Production

Variables	Coef.	Std. Err.	Z	P|z|
Age	.140254	.1818715	0.77	0.441
Sex	6.367026	1.746709	3.65	0.000***
Occupation	1.215888	.4636592	2.62	0.009***
Marital status	2.719382	1.568682	1.73	0.083
Household size	-.0253893	.1264385	-0.20	0.841
Educational level	-1.21828	1.09593	-1.11	0.266
Land acquisition	-.441175	.4940457	-0.89	0.372
Farm size	.0026697	.4324499	0.01	0.995
Farming experience	.0697497	.1472521	0.47	0.636
Membership of association	2.813364	1.063986	2.64	0.008***
Access to extension	-4.915578	1.817446	-2.70	0.007***
Access to credit	.9088234	2.759794	0.33	0.742
Quantity of bags harvested	-.0933032	.0700186	-1.33	0.183
Agrochemical usage	-9.407777	2.255869	-4.17	0.000***
Type of labour	2.512938	.797803	3.15	0.002***
Annual income	-8.22e-08	1.83e-07	-0.45	0.654
_cons	-3.037295	3.963688	-0.77	0.444
LR $chi^2(16)$	61.94			
Log likelihood	-68.689204			
Pseudo R^2	0.3108			

Source: Field Survey, 2024 ***Significant at 1%

The result further showed that membership of association was positive (r=2.64) and significant (P<0.01) in influencing respondents awareness of the effect of climate change on maize and potato production, this implies that increase in participation or membership of association will lead to increase in awareness climate change effect on maize and potato production in the study area. In addition, the result also showed that type of labour was positive (r=3.15) and significant (P<0.01) in influencing respondents awareness of climate change effect on maize and potato production, this implies that increase in hired labour will lead to increase awareness of climate change effect on maize and potato production which could not be unconnected to the fact that most hired workers had worked on several other farms within and outside the study area.

Similarly the results showed that access to extension and agro-chemical usage were negative (-2.70 and -4.17) and significant (P<0.01) in influencing respondents awareness of climate change effects on maize and potato production in the study area. This implies that increase in access to extension and use of agro-chemical will lead to decrease awareness of climate change effects on maize and potato production among the respondents.

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Constraints to Climate Change Coping Strategies

The result from Table 4 revealed that the constraints to climate change coping strategies. The finding showed that the major constraints to climate change coping strategies among the respondents were drought (92.3%), high illiteracy level (89.5%) and poverty (67.3%) which were ranked 1st, 2nd and 3rd respectively.

Table 4: Distribution of Respondents According to their Constraints to Adaptation of Climate Change Mitigation Strategies

Variables	Percentage	Rank
Drought	92.3	1st
High illiteracy level	89.5	2nd
Poverty	67.3	3rd
Inadequate capital	60.9	4th
Flooding	59.5	5th
Inadequate information on climate change	58.6	6th
Lack of government support	58.6	6th
Fluctuation of rainfall pattern	55.5	8th
Inadequate policy support	50.9	9th
Inadequate extension agents	31.4	10th

Source: Field Survey, 2024 *Multiple response

The findings further revealed that inadequate capital (60.9%), flooding (59.5%), inadequate information on climate change (58.6%) and lack of government support (58.6%) which were ranked 4th. 5th and 6th respectively. Other constraints highlighted by the respondents includes fluctuation of rainfall pattern (55.5%), inadequate policy support (50.9%) and inadequate extension agents (31.4%) which were ranked 8th, 9th and 10th respectively. This finding implies that respondents were faced with various constraints coping with climate change on effect on maize and potato production in the study area.

CONCLUSION AND RECOMMENDATIONS

The study concluded that age, sex, membership of association, access to extension, agrochemical usage and type of labour were the factors influencing respondents' awareness to climate change effect on maize and potato production.

Based on the findings of the study the following recommendations were made;

i. Enhance the capacity of extension agents to provide timely and relevant information on climate-smart agriculture practices.
ii. Encourage the adoption of climate-resilient agricultural technologies, such as drought-tolerant crop varieties, efficient irrigation systems, and conservation agriculture practices.
iii. Provide farmers with access to affordable credit to invest in climate-smart technologies and inputs.

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AWARENESS OF CLIMATE CHANGE ADAPTATION STRATEGIES AMONG POULTRY FARMERS IN WESTERN ZONE OF BAUCHI STATE, NIGERIA

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ABSTRACT
The study examined the awareness of climate change adaptation strategies among poultry farmers in Western Zone of Bauchi State, Nigeria. A multi-stage sampling technique was used in selecting 120 respondents. Data were collected using structured questionnaire and analyzed using descriptive statistics and linear regression. The findings show that a substantial proportion (46.7%) of the respondents were within the ages of 28-40 years with a mean age of 36 years. Half (50.8%) of the respondents had tertiary level of education and majority (76.7%, 76.7%) rear chicken and had a flock size of 200 birds respectively. Majority (83.3%) of the respondents were aware of climate change and the major adaptation strategies used to mitigate climate change were trees planting ($\overline{X}$=4.4), access to information on climate and weather ($\overline{X}$=4.3), provision of ventilated houses ($\overline{X}$=4.2), provision of better hygiene ($\overline{X}$=4.2), and creating space ($\overline{X}$=4.1). The result from linear regression revealed that age and sex were negative and significant (P<0.05) factors influencing respondents' awareness on climate change effect on poultry birds. It can be concluded that majority of poultry farmers were aware of climate change. In addition, Age and flock size were the major factors influencing the adoption of climate change mitigation strategies. It is recommended that there is need to intensify awareness campaigns to poultry farmers on how to mitigate the effects of climate change on poultry production.

Keywords: Awareness, Adaptation, Strategies, Poultry, Farmers

INTRODUCTION
Climate change is the effect of long-term changing climatic conditions which is caused, among other human activities, by carbon dioxide and carbon monoxides released from incomplete burning of fossil fuels; deforestation and methane emission from animal dungs, rice fields, landfill sites, agricultural chemicals and pesticides (Eneji *et al*., 2020). Climate change is intimately linked with agriculture, its impacts on livelihoods and economies depend on agriculture which have been recorded in many places (Ullah *et al*., 2018). By implication, the poor are the most vulnerable to climate change because of their dependence on agriculture as mainstay of livelihood. Though a global issue, climate change impacts are felt differently across the world (Matemilola *et al.,* 2019). Farmers may adapt to the altering conditions of climate change with the aid of climate-smart agricultural practices including conservation agriculture and agroforestry while also lowering greenhouse gas emissions and boosting production (Akande & Ajayi, 2019). Awareness is the first step toward effective adaptation, influencing the likelihood that farmers will take preemptive or reactive measures to mitigate climate change (Adeyemo, *et al.,* 2022). Farmers who are well-informed are more likely to take proactive measures such as modifying housing structures, adjusting feeding schedules, using resilient poultry breeds, and adopting climate-smart practices (Eze *et al.,* 2023). Farmers who are aware of climate change and its impacts are more likely to adopt coping strategies such as improved housing for poultry, use of resilient breeds, changes in feeding and watering schedules, and adoption of biosecurity measures (Umeh & Okonkwo, 2022). Conversely, low awareness is linked to passive attitudes, maladaptation, or dependence on emergency relief (Adeyemo *et al.,* 2022). Moreover, awareness enhances the effectiveness of extension services, encourages community-level planning, and facilitates the uptake of climate-smart innovations. According to the IPCC (2022), increasing climate literacy among smallholder farmers is essential to achieving long-term adaptation and resilience. Nigeria's economy heavily depends on agriculture, which is being negatively impacted by climate change in ways, including altered rainfall patterns and an increase in extreme weather events

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(Akande & Ajayi, 2019). Nigeria is experiencing several environmental problems because of climate change, including altered weather patterns, increasing sea levels, and a decline in biodiversity (Ogunwale *et al.,* 2018). Natural catastrophes like floods and droughts are becoming more frequent and severe because of climate change, which is having catastrophic effects on infrastructure and communities (Ibe *et al.,* 2018).

The Western Agricultural zone of Bauchi State, Nigeria is a significant hub for poultry farming contributing to the local economy and food security. However, climate change poses a substantial threat to poultry production, with rising temperature, changing precipitation pattern, and increased frequency of extreme weather events affecting farm productivity and livelihood (Akande & Ajayi, 2019). Adaptation strategies are practical measures taken by poultry farmers to mitigate the adverse effects of climate change. These strategies can be categorized into technological, managerial, and structural adaptations (Adelekan, 2022; Eze *et al.,* 2024). Technological adaptations might include improved poultry breeds and climate-resilient housing systems (Adelekan, 2022). Managerial adaptations could involve changes in feeding practices and health management, while structural adaptations might encompass alterations in farm infrastructure and water management systems. Socio-economic factors play a crucial role in shaping farmers' perceptions and their capacity to adopt adaptation strategies. These factors include income levels, access to resources, education, and extension services. For example, higher income levels and better access to agricultural extension services have been shown to enhance the adoption of climate-smart practices (Abdulkareem *et al.,* 2023). Conversely, limited resources and low education levels may constrain the ability to adapt effectively (Akinola *et al.,* 2023). Therefore, the study examined the awareness of climate change among poultry farmers in Western Zone of Bauchi State, Nigeria.

METHODOLOGY

STUDY AREA

THE STUDY WAS CONDUCTED IN WESTERN AGRICULTURAL ZONE OF BAUCHI STATE, NIGERIA. THE ZONE HAS SEVEN (7) LOCAL GOVERNMENT AREAS (LGAS) THAT INCLUDE ALKALERI, BAUCHI, BOGORO, DASS, KIRFI, TAFAWA BALEWA AND TORO. THE ZONE IS LOCATED BETWEEN LATITUDE 9° 3' AND 12° 3' NORTH AND LONGITUDE 8° 50' AND 11° EAST. (NATIONAL BUREAU OF STATISTICS [NBS], 2021). THE AREA COVERS A LAND AREA OF 23,247 SQUARE KILOMETERS WITH A PROJECTED POPULATION OF 2, 797, 566 BY 2024 (JAAFAR *ET AL.,* 2023). MAJOR ECONOMIC ACTIVITIES INCLUDE FARMING, LIVESTOCK REARING, AND TRADING. THE CROPS PRODUCED INCLUDE MAIZE, RICE, MILLET, SORGHUM, GROUNDNUT AND SOYABEANS, WHILE CATTLE AND POULTRY FARMING ARE MORE SIGNIFICANT IN RURAL HOUSEHOLDS (FOOD AND AGRICULTURE ORGANIZATION [FAO], 2022). THE VEGETATION SUPPORTS BOTH CROP PRODUCTION AND PASTORALISM (FOOD AND AGRICULTURE ORGANIZATION [FAO], 2022). THE REGION EXPERIENCES AN AVERAGE ANNUAL TEMPERATURE OF 27°C TO 32°C, WITH THE HOTTEST MONTHS OCCURRING BETWEEN MARCH AND MAY (NIGERIAN METROLOGICAL AGENCY [NIMET], 2022). ANNUAL RAINFALL RANGES FROM 900 MM TO 1,200 MM, MOSTLY CONCENTRATED BETWEEN MAY AND OCTOBER DURING THE RAINY SEASON (NIGERIAN METROLOGICAL AGENCY [NIMET], 2022).

Sampling Technique

A multi- stage sampling technique was used to select the respondents for this study. The first stage, involved the purposive selection of two (2) Local Government Areas (LGAs) (Bauchi and Toro) from the zone. This was because of the presence of high number of poultry farmers. The second stage involved purposive selection of three (3) communities from each of the selected LGAs making a total of six (6). In the final stage, 120 respondents were randomly and proportionately (65%) chosen from the selected communities as shown in Table 1.

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Table 1: Sample Size Selection Plan

LGAs	Communities	Sampling frame	Sample size (65%)
Bauchi	Yelwa	46	30
	Dawaki	40	26
	Dan'iya	37	24
Toro	Tilden Fulani	16	10
	Magama	15	10
	Rimin Zayam	30	20
Total			**120**

SOURCE: AUTHOR'S COMPUTATION, 2024

METHOD OF DATA COLLECTION

THE PRIMARY DATA FOR THE STUDY WAS COLLECTED THROUGH A STRUCTURED QUESTIONNAIRE WHICH WAS USED TO ELICIT INFORMATION FROM THE RESPONDENTS. DATA WERE COLLECTED ON SOCIO-ECONOMIC CHARACTERISTICS OF THE RESPONDENTS, AWARENESS OF CLIMATE CHANGE AMONG THE RESPONDENTS, AND RESPONDENTS' ADAPTIVE MEASURES TO MITIGATE CLIMATE CHANGE.

METHOD OF DATA ANALYSIS

Data for the study were analyzed using descriptive and inferential statistics to achieve the research objectives. Descriptive statistics such as; frequency, percentages and mean were used to achieve objectives i, ii, and iii. Inferential statistics such as linear regression model was employed to achieve objective iv.

Descriptive Statistics

Descriptive statistics such as; frequency, distribution, percentages, and mean were used to achieve objectives i, ii, and iii.

Mean score

Mean score was also used to achieve objectives ii and iii. Five points mean score was used and coded as follows; Strongly agreed = 5, agreed = 4, undecided = 3, disagreed =2, and strongly disagreed 1 with mean score threshold of > 3.0 and above showed that adaptive measures were effective, while a threshold of < 3.0 indicates adaptive measures were not effective.

$$M = \frac{\Sigma X}{N}$$

Where;
M = Mean
∑ = Sum
X = Raw Score
N = Number of Cases

Inferential statistics

The linear regression model was used to determine the relationship between climate change awareness and socio-economic characteristics of poultry farmers. The model is expressed as:

Y = _0 + _1 X1 + _2 X2 + _3 X3 + _4X4 + _5X5 + _6X6 + _7X7 + _8X8 + _9X9 + _10X10 …….. + e …(1)

The model is mathematically expressed as:

Y = 0+ 1X + e …(2)

Where:
Y = Awareness of climate change among poultry farmers (yes = 1, no = 0)
X_1 =Age (Years)
X_2= Sex (1 = Male, 2= Female)
X_3=Marital status (1= Married, 2 = Single, 3 = Divorced, 4 = Widowed)
X_4= household size (1 = 1-5, 2 = 6-10, 3 = 11-15, 4 = 15-20, 5 = 20 above)
X_5= Source of income (1 = Personal savings, 2 = Loan, 3 = Salary, 4 = Relatives, 5 = others)
X_6= Education level (1 = None, 2 = Qur'anic Education, 3 = Adult Education, 4 = Primary Education, 5 = Secondary Education, 6 = Tertiary Education)

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X_7=Types of poultry reared (1 = Turkey, 2 = Chicken, 3 = Ostrich, 4 = Guinea Fowl)
X_8= Flock size (Number of birds)
X_9= Sources of capital (1 = Personal saving, 2 = Loan, 3 = Salary, 4 = Relatives)
X_{10}= Sources of information (1 = Farmers, 2 = Friends, 3 = BSADP, 4 = Mass media, 5 = Extension agents, 6 = Cooperative societies, 7 = Agro dealers)
0 = Intercept
1 = Slope
e = Error term

RESULTS AND DISCUSSION

Quantitative Socio-economic Characteristics of the Respondents

The result in table 2 described the socio-economic characteristics of the respondents which is an important component of the study. The finding shows that 46.7% of the respondents were within the ages of 30-39 years. In addition, 26.7% and 19.2% were found to be within the ages of 20-29 years and 40-49 years respectively, with a mean age of 36 years in the study area. This finding implies that most of the respondents were within their active ages of production, this is a good indicator that youth are venturing into poultry production and this translate that agricultural production will improve as farmers are believed to be educated and willing to adopt modern farming techniques especially in coping the effects of climate change in poultry production. This age group is particularly significant in agricultural practice and climate action, as they are more likely to be open to innovation and adaptive strategies (Ajaero & Anorue, 2022).

Majority (86.7%) of the respondents had a household size of 1-12 persons and a good number representing 36.7% had a household size of 7-12 persons with a mean household size of 8 members. in the study area. This finding implies that most of the respondents had a relatively small household size which could be connected to the fact that most of them were young farmers. This agrees with Ojo and Baiyegunhi (2020) who noted that moderate household sizes tend to adopt more sustainable practices, as they have manageable consumption needs and labor for poultry-related tasks.

Majority (76.7%) of the respondents had a flock size of 200 birds and 10.8% had a flock size of 200-399 birds in the study area. A small proportion (8.3%, 4.2%) of the respondents had a flock size of 400-599, 600 and above with mean flock size of 170 birds. This finding implies that most of the respondents had relatively large number of birds which could be a motivating factor to adoption of climate change mitigation strategies since no farmer will risk losing many birds due to heat or extreme cold, hence most of the respondents will be vigilant especially with the weather condition which is key to bird survival production in the study area. This small to medium-scale categorization is in line with findings by Okorie and Umeh (2024), who highlighted that limited capital, poor infrastructure, and inadequate veterinary services are barriers to scaling up poultry operations in rural Nigeria.

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Table 2: Distribution of Respondents According to their Quantitative Socioeconomic Characteristics (n=120)

Socio-economic characteristics	Frequency	Percentage	Mean
Age			
20-29	32	26.7	
30-39	56	46.7	36
40-49	23	19.2	
50 and above	9	7.5	
Household size			
1-6	60	50.0	
7-12	44	36.7	8
13-18	7	5.8	
19 and Above	9	8.5	
Flock size			
200	92	76.7	
200-399	13	10.8	170
400-599	10	8.3	
600 and Above	3	2.5	

Source: Field Survey, 2024

Qualitative Socio-economic Characteristics of the Respondents

As shown in Table 3, 65% of the respondents were male, and 35% were female. This finding implies that most of the poultry farmers were male which implies that male dominate most of the agricultural production aspects in the study area. This male dominance is consistent with the findings by Adewumi and Adebayo (2022), who reported that men typically dominate poultry farming in northern Nigeria due to socio-cultural roles, land access, and household decision-making norms. However, the growing participation of women (35%) is an echoing trend identified by FAO (2023) that women's involvement in livestock and poultry farming is increasing, despite being in smaller-scale or subsistence operations. The finding further shows that more than half (54.2%) of the respondents were married and a good proportion, constituting 40.8% were single. This implies that a substantial proportion of the respondents had certain level of responsibilities. This agrees with the findings of Ojo and Ibrahim (2023), who observed that married individuals in agricultural households tend to have more stability and support networks, which can influence their level of involvement in climate-related decision-making.

The findings further reveal that half (50.8%) of the respondents had tertiary level of education, 35% had secondary education, a few number 7.5%, 5% and 0.8% had Qur'anic, adult, primary and non-formal education, respectively. This finding implies that most of the respondents had attended certain level of education in the study area. Eze *et al.* (2023) emphasized that education level significantly influences awareness and adoption of climate-smart agricultural practices. This also implies a strong potential for leveraging formal education in designing extension and climate communication strategies. The result also shows that majority (76.7%) of the respondent rear chicken and 17.5% rear turkey. A few numbers 4.2% and 1.7% of the respondent rear ostrich and guinea fowl. This finding implies that rearing chicken is more efficient, profitable and is high in demand especially during festive periods in the study area. This finding is in support with Okorie and Umeh (2024) who confirmed that broiler and layer poultry dominate the Nigerian poultry sector, reflecting both economic viability and cultural preferences and the presence of exotic birds like ostriches suggests a small but growing interest in diversified poultry systems.

The finding further shows that more than half (55.8%) of the respondents had personal savings s their major source of capital, 25% and 15.8% had salary and loan as their major source of capital for poultry production, small proportion 3.3% had relatives as their major source of capital for poultry production in the study area. This finding implies that most of the respondents had their

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capital from a non-interest source which is preferable in agricultural venture which is mostly associated with high risk and long incubation periods. According to Ogunbode *et al.* (2023), the inability of rural poultry farmers to access formal loans restricts investment in climate-resilient infrastructure and modern production techniques.

More so, half (50%) of the respondents had fellow farmers as their major source of information on poultry production, 15%, 11.7% and 10% had extension agents, mass media and friends as their major source of information on poultry production, respectively. A few proportion 6.7%, 4.2% and 2.5% of the respondents had BSADP, cooperatives and agro-dealers as their major sources of information on poultry production, respectively. This finding implies that most of the respondents had different sources of information on poultry production which expose respondent to new techniques and methods of poultry production and climate change mitigation strategies in the study area. This finding agrees with Nnadi and Chukwu *(*2023) who noted that rural farmers rely heavily on peer networks due to limited extension coverage. Similarly, Ayanlade, and Morton (2017) emphasized the role of interpersonal communication in shaping adaptation responses, particularly in rural areas with limited access to formal sources like media or extension services. The finding further shows that 29.2%, 28.3% and 24.2% of the respondents were civil servants, livestock producers and farmers with 15% and 3.3% been traders and students, respectively. This finding implies that most of the respondents were engaged in agricultural production value chain which shows that a good number of the respondents could be familiar with poultry bird requirement in production especially regarding climate and weather requirement in the study area. Also, the significant proportion of civil servants and livestock farmers shows that poultry farming is often pursued alongside other income-generating activities, possibly as a coping strategy against economic volatility. This is in line with Ajaero and Anorue (2022), who found that diversified livelihoods enhance household resilience to climate change shocks.

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Table 3: Distribution of Respondents According to their Qualitative Socioeconomic Characteristics (n=120)

Socio-economic characteristics	Frequency	Percentage
Sex		
Male	78	65.0
Female	42	35.0
Marital status		
Married	65	54.2
Single	49	40.8
Divorce	3	2.5
Widowed	3	2.5
Educational level		
Non-formal	1	0.8
Qur'anic	9	7.5
Adult education	6	5.0
Primary	1	0.8
Secondary	42	35.0
Tertiary	61	50.8
Types of poultry reared		
Turkey	21	17.5
Chicken	92	76.7
Ostrich	5	4.2
Guinea fowl	2	1.7
Sources of capital		
Personal savings	67	55.8
Loan	19	15.8
Salary	30	25.0
Relatives	4	3.3
Sources of information		
Fellow farmers	60	50.0
Friends	12	10.0
BSADP	8	6.7
Mass media	14	11.7
Extension agent	18	15.0
Cooperatives	5	4.2
Agro-dealers	3	2.5
Major occupation		
Farming	29	24.2
Livestock rearing	34	28.3
Civil servant	35	29.2
Trading	18	15.0
Student	4	3.3

Source: Field Survey, 2024

Awareness of Climate Change Among the Respondents

The result from Table 4 describes the awareness of respondents on climate change and its effects on the environment in the study area. Among the surveyed farmers, 83.3% reported to have had on climate change. This high awareness rate aligns with global trends indicating increased public recognition of climate change particularly in regions vulnerable to climate impacts such as sub-Saharan Africa (Okoli *et al.,* 2023). Similarly, Nwobodo *et al.* (2022) found that over 80% of Nigerian rural farmers were aware of climate change and attributed it to observable environmental alterations such as prolonged dry seasons and flooding. The finding also shows that 46.7% of the respondents indicated that climate change awareness was very important on poultry production. This indicates that about 76.7% of respondents see climate change as significantly important, though a

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small percentage remain different. This observation is consistent with research by Onyeneke *et al.* (2020), who noted that farmers with direct experience of erratic weather patterns were more likely to perceive climate change as a major concern.

Table 4: Distribution of Respondents According to Awareness on Climate Change (n=120)

Variables	Frequency	Percentage
Climate change awareness		
Yes	100	83.3
No	20	16.7
Level of importance on climate change		
Very important	56	46.7
Quite important	36	30.0
Not very important	17	14.2
Not important	11	9.2
Climate change affect environment		
Yes	102	85.0
No	18	15.0
Awareness on climate change prevention		
Yes	107	89.2
No	13	10.8

Source: Field Survey, 2024

The finding also reveals that majority (85%) of the respondents indicated that climate change had effect on the environment in the study area. This finding implies that respondent had good knowledge of the devastating effect of climate change on the society and poultry production as most of them were indicating that climate change had effect on the environment most affect poultry production in which the animals are highly sensitive to climate change especially increase in temperature. According to IPCC (2023), climate change has led to more frequent and intense environmental disturbances, and these changes are increasingly visible even to lay observers. More so, 89.2% of the respondents were aware of climate change prevention which implies that most of the respondents were aware of climate change prevention strategies especially on poultry production in the study area. This is in line with Ayanlade (2021) who reported that awareness of prevention measures is critical for behavioral change and policy support.

Respondents' Adaptive Measures to Mitigate Climate Change

The result from Table 5 shows the adaptive measures use to mitigate climate change in the study area by the respondents. The finding reveals that respondents agreed on planting of trees ($\overline{X}$=4.4), access to information on climate/weather ($\overline{X}$=4.3), and provision of better hygiene ($\overline{X}$=4.2), and construction of ventilated houses ($\overline{X}$=4.2), creating space ($\overline{X}$=4.1), and change in feed formulation were adopted mitigation strategies on climate change as indicated by mean score values above the threshold value of ($\overline{X}$=3.0) in the study area. This finding implies that most of the respondents had adopted several strategies which help in mitigating climate change effects especially on poultry bird in the study area. These findings are consistent with Ojo *et al.* (2021), who assessed adaptive strategies among poultry farmers in South-Western Nigeria and reported high adoption rates of ventilated housing and tree planting as climate-resilient methods. Furthermore, Sadiq and Bello (2020) studied adaptation among livestock farmers in Kaduna State and found that access to climate information and better hygiene practices were rated highly (mean scores above 4.0). additionally, Olaniyi *et al.* (2019) highlighted the significance of decongested housing systems to reduce heat stress in poultry during dry spells in Northern Nigeria.

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Table 5: Distribution of Respondents According to their Adaptive Measures to Mitigate Climate Change

Variable	Mean	Remark
Planting of trees	4.4	Agree
Accessing information on climate and weather	4.3	Agree
Provision of better hygiene	4.2	Agree
Construction of ventilated houses	4.2	Agree
Creating spaces	4.1	Agree
Change in feed formulation	4.0	Agree

Source: Field Survey, 2024 $\bar{X} \geq 3.0$; Agree. $\bar{X} < 3.0$; Disagree

The Relationship between Climate Change Awareness and Socioeconomic Characteristics of the Respondents

The result from Table 10 reveals that age (-.010) and sex (-.239) were negative and significant ($P<0.05$) factors influencing respondents' awareness on climate change effect on poultry birds. This finding implies that increase in age of the respondents will lead to decrease in climate change awareness on poultry which could be as a result old age leading to reduction in participation into agricultural activities, likewise increase in female participation in poultry production will lead to decrease in climate change awareness as a result of limited access to information by female farmers who might be restricted to seminars, workshop and field days organized on climate change awareness in the study area. This finding aligns with (Maguza *et al.,* 2023) who observed that older farmers tend to be less likely to adopt innovations compared to younger farmers.

On the other hand, the finding shows that marital status, household size, major occupation educational level, types of poultry reared, flock size, sources of capital and sources of information have no significant influence on climate change effect awareness among poultry farmers. This finding implies that increase or decrease on these variables will not affect climate change effect awareness in the study area. Other variables in the model, such as marital status, household size, educational level, and major occupation, show no significant influence ($p < 0.05$). While education shows a positive but non-significant relationship, this aligns with Abegunde *et al.* (2022) who observed that education sometimes increases awareness but doesn't always translate into action, particularly when structural barriers persist. The type of poultry reared and flock size also show no significant effect. This implies that regardless of poultry type or size, the driving factors are more socio-demographic than production-related. Furthermore, sources of capital and information were expected to play a larger role but are not statistically significant, hinting at potential inefficiencies or low-quality dissemination of resources and knowledge (Yila *et al.,* 2023).

Table 6: Relationship between Climate Change Awareness and Socio-economic Characteristics of the Poultry Farmers

Variables	B	Std. Error	Beta	T	Sig.
(Constant)	2.070	.416	_	4.981	.000
Age	-.010**	.004	-.251	-2.219	.029
Sex	-.239**	.108	-.233	-2.220	.029
Marital status	.028	.080	.038	.351	.727
Household size	.004	.009	.041	.425	.671
Major occupation	-.049	.043	-.112	-1.145	.255
Educational level	.037	.038	.094	.990	.324
Types of poultry reared	-.057	.090	-.061	-.627	.532
Flock size	-7.190E-5	.000	-.024	-.245	.807
Sources of capital	.023	.046	.048	.505	.615
Sources of information	-.027	.025	-.101	-1.063	.290

Source: Field Survey, 2024 Note: Significant ** $p<0.05$

CONCLUSION AND RECOMMENDATIONS

It can be concluded that majority of poultry farmers are aware of climate change. In addition, Age and flock size were the major factors influencing the adoption of climate change mitigation strategies. Based on the findings of this study, it was therefore recommended that, there is need to intensify awareness campaigns to poultry farmers on how to mitigate the effects of climate change on poultry production. Regular capacity-building workshops should be organized on adaptive management practices and sustainable poultry farming under changing climate conditions.

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GENDER AND AGRICULTURAL DEVELOPMENT IN DELTA STATE, NIGERIA: AN ANALYSIS OF RURAL WOMEN`S CONTRIBUTIONS AND CHALLENGES

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ABSTRACT
The study examined Gender and Agricultural Development In Delta State, Nigeria: An Analysis of Rural Women`s Contributions and Challenges. Multi-stage sampling procedure was used in selecting 128 respondents. Data were collected using structured questionnaire and analyzed using descriptive statistics such as mean, percentages and likert scale. The results revealed that the mean age of the respondents was 28years with mean household size of 7persons. Majority of the respondents were married with many of them having primary school level of education as their highest level of education and with mean years of farming experience being 6.2years. Agricultural activities performed by the respondents that helped in agricultural development included sourcing for seeds from ADP, use of family labor on the farm, practicing soil conservation tillage. The respondents perception about agricultural development showed that it was a profitable enterprise for women farmers to venture in, they also believed that women farmers participating in agriculture positively impacted their productivity and output and women farmers have the potential to significantly contribute to the sustainable development of the agricultural sector in the study area. Women farmers faced constraints like lack of safety in rural areas, lack of capital, lack of training, and no gender based programs. It is recommended to increase the awareness of the important role that women farmers play in agricultural development and to lessen constraints by enacting laws providing safety, credit, trainings and gender based programs, cheap labor and protecting land rights so women can function better in the study area.

Keywords: Women, Farmers, Agricultural, Development, Constraints

INTRODUCTION
In Nigeria, traditionally, women are regarded as homemakers, who oversee and coordinate the affairs and activities of the home while their husbands and children go out to do farm work, but at home however, they are not idle as they engage in manual processing of food crops, and other farm produce in addition to their housekeeping (Lawanson, 2008). Women are also saddled with most of the tasks in agricultural production but the benefit gained by them are not commensurate with their man-hours, they are hardly given attention in the area of training and visiting by extension agents with improved technologies. Banks hardly grant them loans and they are hardly reached with improved seeds, fertilizer and other inputs (Damisa, 2007). Lawanson (2008) stated that Nigerian women have worked side by side with men in agricultural production with some marked division of labor between them. The men perform the tedious tasks of felling trees, gathering and burning of bushes and making ridges while women are involved in planting of seeds particularly food crops, harvesting, transportation, processing and selling of farm products. Damisa (2007) pointed out that various researchers have conducted studies on the contribution of women to agricultural production in the country; he suggested that women's contribution to farm work is as high as between 60 and 90 percent of the total farm tasks performed. The contribution of the women ranges from such tasks as land cleaning, land-tilling, planting, weeding, fertilizer/manure application to harvesting, food processing, threshing, winnowing, milling, transportation and marketing as well as the management of livestock. Sharon (2008) viewed that both women and men plays critical roles in agricultural production throughout the world, producing, processing and providing the food we eat. Women make up half the rural population and they constitute more than half of the agricultural labor force. Rural women in particular are responsible for half of the world's food production and produce between 60 –

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80 percent of the food in most developing countries, yet despite their contributions to global food security, women farmers are frequently underestimated and overlooked in developing countries (World Bank, 2008).

METHODOLOGY

The Study Area

The study was conducted in Delta State, Nigeria, which is largely an agricultural based State. The State is located at longitude 5°00 and 6°00 East of the Greenwich Meridian and latitude 5° 00' and 6°30` North of the Equator. Delta State has twenty-five (25) LGAs, with a population of 7.8million people as at 2024. It is bordered on the North by Edo State, the East by Anambra and Rivers States and the South by Bayelsa State while to the West by bright of Benin which covers about 160 kilometers of the State`s coastline. Crops grown in the State are oil palm, yams, and cassava, while fishing and heliciculture are also practiced in the State.

Sampling Technique and Sampling Size

Multi-stage sampling procedure was employed for this research with four Local Government Areas being purposively selected namely; Ukwuani, Bomadi, Aniocha South and Isoko North LGAs due to the high prevalence of women farmers. In each LGA, four communities were randomly selected, in each community eight (8) respondents were also randomly selected to make a sample size of a hundred and twenty eight (128) respondents for the study.

Method of Data Collection

To accomplish the stated objectives of this study, a well-structured questionnaire was administered to the rural women in the study area to fill with an interview schedule which was used to extract both primary and secondary data from the respondents. Rural women were questioned pertinently about their involvement in agriculture and economic growth in order to gather data.

Method of Data Analysis

Descriptive statistics such as mean, frequency distribution, percentages and likert scale were used to analyze the objectives of this study; to describe the socio-economic characteristics of the respondents and identify the constraints encountered by the respondents on agricultural development, frequency distribution and percentages were employed, to determine the agricultural activities performed by the respondents and examine the perception of the respondents on agricultural development likert scale was employed. A five point likert scale was used to determine the agricultural activities performed by the respondents, and to examine the perception of the respondents on agricultural development. To obtain the mean cut off point, the scored responses were multiplied by each weight and divided by the responses pooled together with the decision being (5+4+3+2+1 =15/5 =3). Implying that any agricultural activity and perception of the respondents with mean score of 3.0 and above was a major agricultural activity and perception of the respondents on agricultural development while any mean score of less than 3.0 was not a major agricultural activity and perception on agricultural development in the study area.

RESULTS AND DISCUSSION

Socio-economic Characteristics of the Respondents

According to the findings in Table 1, about 29.7% of respondents in the study area were between the ages of 31 and 40 years, closely followed by those between the ages of 21 and 30 years with 28.1%. Those between the ages of 41 and 50 years were just 17.2%, while those over 51 years made up just 15.6% of the respondents. According to this result, women farmers in the study area are still comparatively active, gaining more production and management experiences and skills, and so being able to adjust to more demanding production tasks. This result is in line with Anugwo and Egwue, (2024) who asserted that younger women participate in more tedious farm operations than older ones in the rural areas.

According to Table 1 results, 25.0% of respondents in the study area were unmarried, 40.6% were married, 16.4 % were divorced the remaining 18.0% were made up of widows and the separated. This implies that since most of the respondents were married, they would contribute more labor to all

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of their farming activities. This result is inline with findings by Yokying and Lambrecht (2020) who posited that farmers being married creates room for fairly enough hands on labour. Table 1 also reveals that 25.8% of respondents had a household of 1 to 5 people, 39.1% had a family size of 6 to 10 people, and 19.5% had a household size of 11 to 15 persons while just 15.7% had household size of 16 persons and above. Given that most of them had a good number of persons in their households, the result implies that the farmers might not need to hire additional workers in order to function efficiently and the finding conforms to the work of Ankrah *et al*, (2020) and Abdisa *et al*, (2024).The result in Table 1 further revealed that 12.5% of respondents had no formal education, about 39.8% had only completed primary school, with another 25.8% having completed secondary school, while 21.9% had tertiary level of education. These findings suggest that the respondents' high literacy levels made them more capable managers. The result is consistent with the findings of Amusa *et al*. (2022), who claimed that education is essential for growth management. Additionally, Table 1 revealed that 25.0% of the respondents had 1–5 years of experience in their agricultural fields, 39.1% had 6–10 years of farming experience, and 19.5% of the women farmers had 11–15 years level of experience on the farm, and just 16.4% had been on the farm for above 16 years in the study area.

Table 1: Distribution of the Respondents based on the Socio-economic Characteristics in the Study Area

Socioeconomic characteristics	Frequency	Percentage %	Mean
Age			
<20	12	9.4	
21-30	36	28.1	
31-40	38	29.7	
41-50	22	17.2	
>51	20	15.6	28years
Marital status			
Single	32	25.0	
Married	52	40.6	
Divorced	21	16.4	
Others	23	18.0	
Household Size			
1-5	33	25.8	
6-10	50	39.1	
11-15	25	19.5	
>16	20	15.6	7persons
Level of Education			
No Formal Education	16	12.5	
Primary	51	39.8	
Secondary	33	25.8	
Tertiary	28	21.9	
Farming experience			
1-5	32	25.0	
6-10	50	39.1	
11-15	25	19.5	
>16	21	16.4	6.2years
Total	128	100	

Source: Field Survey, 2025

Agricultural Activities Performed by the Respondents

From Table 2, the majority of the respondents strongly agreed that they obtained seeds from the ADP as agricultural inputs in the study area and was ranked first-place with a mean score of (3.695). The results also indicated that respondents also used family labor on their farms and was

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ranked second-place with a mean score of (3.484). With a mean score of (3.414) and ranked third-place, respondents indicated that they practiced soil conservation tillage on their farms. Control of pests and diseases on the farm using chemical method was ranked fourth-place with a mean score of (3.320), indicating that it was a good farm activity adopted by the respondents. With a mean score of (3.304) and ranked fifth-place, the respondents also showed they used irrigation systems on the farm. Similarly, with a mean score of (3.281) and ranked sixth-place, crop rotation was practiced by the respondents as an agricultural activity and with a mean score of (3.140), the respondents made more use of organic fertilizers more than inorganic fertilizers in the study area and ranked seventh-place in the study area. Implying that all the agricultural activities performed by the respondents were major activities as they all had a mean score of above 3.0 in the study area, this result is consistent with the findings of Ankrah *et al*, (2020) who worked on Gender Access to Productive Resources, Evidence from Smallholder Farmers in Awutu Senya West District of Ghana.

Table 2: Agricultural Practices Performed by the Respondents

Agricultural practices by respondents	SA	A	N	D	SD	Mean	Ranking
Practice of crop rotation on the farm as farm technique	30	32	25	26	15	3.281	6th
Practice of soil conservation tillage on the farm as agricultural technique	35	31	28	20	14	3.414	3rd
Usage of organic fertilizer more than inorganic fertilizer	29	27	26	25	21	3.140	7th
Use of irrigation systems on the farm	37	28	16	31	16	3.304	5th
Use of chemical methods to control pest and diseases on the farm	40	21	28	18	21	3.320	4th
Use of family labor on the farm	49	14	30	20	15	3.484	2nd
Sourcing seeds from ADP	50	31	21	10	16	3.695	1st

Source: Field Survey, 2025. *SA-Strongly Agreed, A-Agreed, N-Neutral, D-Disagree, SD-Strongly Disagree

Perception of the Respondents about Agricultural Development

With a mean score of (3.420) and ranked first-place, Table 3 shows that the majority of respondents indicated that agriculture was profitable and as such viewed as a venture, women can participate in. Furthermore, as indicated in the second-place rank and with mean score of (3.390), respondents strongly believed that women farmers participating in agriculture positively impacts their productivity and output in the study area. Additionally, with a mean score of (3.359) and ranked third-place, rural women had the potential to contribute to sustainable agricultural development in the study area. The respondents believed the government should provide targeted support and incentives to encourage the participation of rural women farmers in agriculture and it had a mean score of (3.289) and was ranked fourth-place. With a mean score of (3.234) and ranked fifth-place, the respondents recommended that the government should offer the necessary incentives and support to promote rural women's involvement in agriculture so as to overcome the challenges and barriers in accessing resources and opportunities in agriculture. With a mean score of (2.945) and ranked eleventh-place, the results suggested the society should recognize and appreciate the valuable contributions of rural women in agriculture. Furthermore, with a mean score of (2.875) and with the lowest ranking of twelfth-place, efforts should be made to involve rural women farmers in decision making processes related to agricultural development in the study area, this result is consistent with the findings of Bello *et al*, (2021), who worked on Gender Decomposition in Smallholder Agricultural Performance in Rural Nigeria.

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Table 3: Perception of the Respondents on Agricultural Development

Perception questions on agricultural development	SA	A	N	D	SD	Mean	Ranking
Do you think agriculture is profitable for women farmers	34	32	33	13	16	3.420	1st
Do you think agriculture has a place for women farmers	31	30	27	14	26	3.203	6th
Do rural women farmers play a crucial role in the agricultural development	25	35	25	18	25	3.132	9th
Does the involvement of rural women farmers in agricultural activities positively impact the overall productivity of the agricultural sector in the study area	35	30	30	16	17	3.390	2nd
Do rural women farmers face significant challenges and barriers in accessing resources and opportunities in agriculture	30	30	28	20	20	3.234	5th
Does providing education and training opportunities specifically tailored for rural women farmers enhance their contribution to agricultural development	30	20	29	19	30	3.007	10th
Should the society recognize and appreciate the valuable contributions of rural women in agriculture	25	28	20	25	30	2.945	11th
Is access to financial resources and credit a key factor in empowering rural women to engage in agricultural activities	30	38	16	16	28	3.203	6th
Should the government provide targeted support and incentives to encourage the participation of rural women farmers in agriculture	34	31	17	30	16	3.289	4th
Is policies and programs that promote gender equality in agriculture essential for the development of rural women	30	28	20	31	19	3.148	8th
Should efforts be made to involve rural women farmers in decision making processes related to agricultural development	28	16	16	48	20	2.875	12th
Do rural women farmers have the potential to significantly contribute to the sustainable development of the agricultural sector	40	20	30	22	16	3.359	3rd

Source: Field Survey, 2025. *SA-Strongly Agreed, A-Agreed, N-Neutral, D-Disagree, SD-Strongly Disagree

Constraints Rural Women Faced in Agricultural Development

Findings in Table 4 illustrate the overall issue that rural women in the study area face when working in the field of agriculture. Given the current status of the economy in the study area, it was not surprising that one of the main restraints was capital, 54.7% of the respondents believed capital was a major constraint. Every development program needs funding, but because commercial or even agricultural specialized banks charge exorbitant interest rates and require substantial collateral, it has become more and more difficult for farmers to obtain credits from these institutions, also 45.3% of the respondents didn't believe capital was a barrier.

Safety in rural areas is another major concern with 59.4% affirming to this as a barrier in agricultural development. The atmosphere is unsafe for people, particularly farmers, because of the murders committed by gunmen and herdsmen while 40.6% didn't affirm it as a major constraint. The research found out that 56.3% of the respondents affirmed, that there are currently no gender based programs about agricultural development in the study area, and there is the need for more of these programs to be held on a regular basis, also 43.7% of the respondents didn't agree there should be regular gender based programs in the study area. Lack of training, lack of access to agricultural inputs, lack of access to land, no access to agricultural inputs and lack of available labor were all viewed as major constraints to agricultural development in the study area and if women farmers could in one way or the other overcome all of them their roles in agricultural development in the study area will be of very high impact. This result conforms to the findings of Tufa *et al*, (2022), who worked on Gender Differences in Technology Adoption and Agricultural Productivity: Evidence from Malawi

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Table 4: Constraints Encountered by the Respondents in the Study Area

Constraints		Frequency	Percentage %
Lack of capital	Yes	70	54.7
	No	58	45.3
Lack of safety of rural areas	Yes	76	59.4
	No	52	40.6
Lack of good roads	Yes	69	54.0
	No	59	46.0
No Gender based programs	Yes	72	56.3
	No	56	43.7
Lack of training	Yes	73	57.0
	No	55	43.0
Access to agricultural inputs	Yes	65	50.8
	No	63	49.2
Access to land	Yes	67	52.3
	No	61	47.7
No Access to agricultural information	Yes	68	53.1
	No	60	46.9
Lack of available labor	Yes	78	61.0
	No	50	39.0
Total		128	100

Source: Field Survey, 2025.

CONCLUSION AND RECOMMENDATIONS

Educated and married with a family size of 1 to 5 persons and a very good level of agricultural experience predominate among the rural women involved in agricultural development in the study area. Just a few women lacked formal schooling. Rural women were essential to the production, processing, winnowing, milling, storage, marketing, and distribution of food, but they confront a number of obstacles, including lack of funds that forces them to borrow from relatives and cooperatives. Insecurity-related safety issues were a major issue, especially on the farms. Urbanization also made it more difficult to access agricultural land, which reduced the amount of land available for cultivation. If provided sufficient incentives and gender equality, women generally will have considerable capacity to sustain agricultural productivity and family income despite all the constraints and according to the women respondents, agriculture is seen as a profitable enterprise in the study area. It is advised to host seminars for women farmers to engage with researchers and subject matter experts while discussing their unique technical difficulties. It is crucial to encourage women to pursue large-scale farming beyond subsistence, as this will help them generate a lot of capital after every harvesting season. It is crucial to increase awareness of the important role that women farmers play in the production of food and to lessen constraints by enacting laws protecting land rights, acknowledging unpaid work, and improving access to credit. Women can manage their finances for their entrepreneurial endeavors more efficiently if training programs and initiatives are carried out in rural areas. It would be advantageous to provide easily accessible venues, such as drop-in sessions, for women to get guidance on farming methods and company administration. It is recommended that rural women form cooperative groups, pool resources for mutual support, and provide marketing services, loans, agricultural inputs and build rural storage facilities together which would successfully stop their agricultural produce from spoiling and wasting in the study area.

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IMPACT OF CLIMATE CHANGE ON RURAL GOAT FARMING IN EBONYI STATE, NIGERIA: IDENTIFYING EFFECTIVE ADAPTATION STRATEGIES

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ABSTRACT
The study examined the Impact of Climate Change on Rural Goat Farming in Ebonyi State, Nigeria: Identifying Effective Adaptation Strategies. Based on the level of climate variability and large number of goat farmers, three local government areas namely, (Ohaozara, Ohaukwu and Ezza South LGAs) were randomly selected for this research. Multi-stage sampling technique was adopted for this research, with a total number of 84 respondents interviewed. Descriptive statistics and regression analysis were employed to analyze the objectives of the study. The results revealed that the mean age of the respondents was 27years implying that the farmers were still young and active. Goat farming was dominated by males (63.0%) and a smaller proportion of females (37.0%). Majority of the respondents were married (53.6%). The results showed that many of the farmers with mean of (12 years) were relatively educated and (39.3%) had 6 to 10 years of experience mitigating the effects of climate change on goat production in the study area. Regression result revealed the R^2 value was 0.832, implying that the regression analysis explained 83.2% of the total variation in the model. Regression variables of age, household size, marital status, access to extension agents, ownership of goats and land ownership were all positive and statistically significant. Goat farmers should form cooperative associations so as to receive aid from the government in providing high resistant breeds of goats, portable water and drugs which will help in mitigating the effects of climate change on goat production in the study area.

Keywords: Climate, change, mitigation, coping, strategies, information.

INTRODUCTION
Climate change, characterized by fluctuations in temperature, precipitation patterns, and the increased frequency of extreme weather events, poses a significant threat to goat production systems worldwide. These variations disrupt the delicate balance between goats, their environment, and the resources they rely upon. One of the most immediate impacts of climate variability is a decrease in fodder availability. Prolonged droughts and erratic rainfall patterns lead to dry pastures, directly impacting the quantity and quality of feed accessible to goats (Muruganandam *et al*. 2023). This scarcity of essential nutrients results in slower growth rates, reduced milk production, and a decline in the overall nutritional health of goat herds. For instance, limited access to fresh forage can lead to deficiencies in essential vitamins and minerals, compromising their immune function and overall well-being (Sebata, 2018).

The rising temperatures associated with climate change pose another major challenge for goat production. Goats struggle to regulate their body temperature during extreme heat events, leading to heat stress (Kumalo and Manyani, 2023). This stress manifests in several ways, including reduced feed intake, decreased fertility, and increased health problems. Heat stress further compromises their nutritional intake as goats lose their appetite and disrupt hormonal cycles, leading to lower conception rates and reproductive problems (Kumalo and Manyani, 2023). Additionally, a weakened immune system due to heat stress increases the susceptibility of goats to various health issues. Recent studies by Sejian *et al*, 2021) have shown that prolonged exposure to high temperatures increases the risk of infectious diseases such as mastitis and respiratory infections in goats. Moreover, heat stress can exacerbate existing health conditions, leading to increased mortality rates and decreased productivity

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among goat herds (Machado 2018). These detrimental effects highlight the urgent need for adaptive measures to mitigate the impacts of climate variability on goat production.

Water scarcity, often exacerbated by climate variability, poses another significant threat. Goats require consistent access to clean water for proper digestion, thermoregulation, and overall health (Kumalo and Manyani, 2023). When water becomes scarce, dehydration can lead to a range of health problems, including kidney failure, digestive issues, and reduced milk production in lactating does (Kumalo and Manyani, 2023). Climate change can also alter the dynamics of diseases that affect goats. Rising temperatures and erratic weather patterns can create favourable conditions for disease vectors, increasing the risk of outbreaks (Yadav *et al*. 2023). Additionally, erratic rainfall and temperature fluctuations can disrupt the breeding cycles of goats, leading to lower conception rates and greater infant mortality due to stress-induced weakening of offspring (Yadav *et al*. 2023).

METHODOLOGY

The Study Area

This research was carried out in Ebonyi State, Nigeria. The State covers a total of 6,488square kilometers of land mass and it is bounded in the South-East by Cross River State, the South-West by Abia State and to the North and North-East by Benue State while to the East it is bounded by Enugu State. Ebonyi State is found on latitude 6.2649^0N and longitude 8.0137^0E of the Greenwich Meridian. The State is made up of thirteen (13) Local Governments Areas (LGAs). According to the (NBS 2022), Ebonyi State`s population stood at 3,242,500 people thus making it rank the 29th most populous states in the country. The major occupations of the people living in the State are farming and trading while a few work as civil servants. Both cash crops and food crops including fruits and vegetables are produced in Ebonyi State. Cash crops like cashew, palm produce and food crops like yam, cassava, cocoyam, maize and rice are also produced in the state. Banana and other fruits and vegetables are also produced in Ebonyi State. There are two distinct seasons namely wet and dry seasons. The primary language of the state is Igbo, and its citizens are of Igbo descent.

Sampling Technique and Sampling Size

The study employed the use of multi-stage sampling technique. In the first stage, three Local Government Areas (Ohaozara, Ohaukwu and Ezza South LGAs) were chosen at random from among the thirteen local governments in Ebonyi State due to the large number of goat farmers in the State. In the second stage, four communities were chosen at random from each of the selected L.G.As making a total of 12 communities. In the third stage, Seven (7) goat farmers were chosen from each community using a simple random sampling technique bringing the total number of respondents in the study area to eighty-four (84).

Method of Data Collection

Primary data were used for this research; primary data was sourced using personal interviews and the administration of a well-structured questionnaire on goat farmers in the study area. The questionnaire was used to obtain primary data based on the objectives of the study.

Methods of Data Analysis

Descriptive statistics, such as frequency distributions and percentages, were used to analyze the data collected for the study. Using frequency distribution and percentages, descriptive statistics were used to analyze objectives i, ii, and iv, which were to describe the socioeconomic characteristics of the respondents in the study area, identify sources of information on climate change, and identify the coping strategies of goat farmers in the study area in order to adapt to climate change. Regression analysis was used to analyze objective iii, which aimed to determine the factors influencing climate change adaptation techniques.

To determine the variables influencing climate change adaptation strategies in goat farming, the regression model was employed. A dependent dichotomous variable, which assumes just two values (zero or one), was used to estimate the likelihood of events using the probit model. The model that needs to be estimated is as follows;

$$P\ Yt = 1 = \exp(xi\beta) \quad (1)$$

$$xi\ 1 + \exp(xi\beta) \quad (2)$$

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The explicit function was estimated as:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + Ui \quad (3)$$

Where:

Y is a binary response variable defined as; Y = 1 if the goat farmer participates in adaptation strategies to climate change and Y = 0 if otherwise.

X_1= Age (years)
X_2 = Household size (number of persons)
X_3= Marital Status (1 = Yes, 0 = No)
X_4= Access to extension agents (1 = Yes, 0 = No)
X_5= Climate change awareness (1 = Yes, 0 = No)
X_6= Ownership of goats produced (1=Owned, 2=No)
X_7= Land Ownership (1=Owned, 2=Leased)
$b_1 \ldots b_7$= parameter estimates
b_0= Intercept
Ui = error term

RESULTS AND DISCUSSION

Socio-economic Characteristics of the Respondents

According to results from Table 1, about 32.1% of the respondents were between the ages of 41 and 50 years, followed by those between the ages of 31 and 40 years (28.6%), those over 51 years were just (13%), and those under 30 years were (26.3%). These findings suggest that those in the 31–50 age range were likely to be more resilient to fatigue from the arduous work and effort required to raise goats and adapt to climate change in the study area. According to the study by Anugwo *et al*. (2024) titled High Feed Costs in Poultry Farming; An Analysis of Effective Coping Strategies in Enugu State, Nigeria, the majority of the poultry farmers were middle-aged and these findings are consistent with that study. Table 1 revealed that males (63.0%) were rearing more goats than females (37.0%) in the study area, indicating that the male goat farmers have the strength to engage all coping strategies on goat rearing in the study area, this finding conforms to the study by (Lantokpode *et al*, 2022). Results from Table 1, also revealed that 41.7% of respondents had household size of 6–10 people, (27.3%) had household size of 1-5 people, (14.3%) had household size of 11–15 people, 16.7% had household size above 16 people in the study area. Implying that the respondents' goat farms have a sufficient amount of labor to address the causes of climate change. Additionally, the result further revealed that (17.8%) of the respondents were divorced, single, (28.6%) and married (53.6%). This suggests that the majority of respondents were married and would have enough family workers to complete some of the labor-intensive jobs associated with raising goats and adjusting to the changing climate in the study area and this finding is in line with the study by (Alemayehu, 2022). Table 1 revealed that, about 14.3% of respondents lacked formal education, 40.5% had completed primary school, 32.1% had completed secondary school, and only 13.1% had completed tertiary education. According to this, the majority of the respondents were educated, and a high level of literacy is anticipated to improve comprehension of concepts and innovations utilized to lessen the consequences of climate change on goat husbandry in the study area. Additionally, Table 1 indicates that the mean number of years of farming experience was 6.7 years, while (20.2%) of the respondents had between one and five years of experience with climate change mitigating strategies for goat rearing, 39.3% had between six and ten years, and significant proportion (23.8%) of respondents, had between eleven and fifteen years of experience with climate change mitigating strategies for goat rearing, and only 16.7% had more than sixteen years of experience with climate change coping strategies for goat rearing in the study area. This suggests that many of the study participants have a significant amount of expertise with coping mechanisms, which will assist to mitigate the impact of climate change on goat husbandry on their farms, this finding conforms to the study by (Lantokpode *et al*, 2022).

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Table 1: Distribution of the Respondents based on Socio-economic Characteristics (n=?)

Age	Frequency	Percentages	Mean
<20	10	12.0	
21-30	12	14.3	
31-40	24	28.6	
41-50	27	32.1	
>51	11	13.0	27 years
Sex			
Male	53	63.0	
Female	31	37.0	
Household Size			
1-5	23	27.3	
6-10	35	41.7	
11-15	12	14.3	
>16	14	16.7	7 persons
Marital status			
Single	24	28.6	
Married	45	53.6	
Divorced	15	17.8	
Educational level			
No formal education	12	14.3	
Primary school	34	40.5	
Secondary school	27	32.1	
Tertiary level	11	13.1	12 years
Farming experience			
1-5	17	20.2	
6-10	33	39.3	
11-15	20	23.8	
>16	14	16.7	6.7 years
Total	84	100	

Source: Field Survey, 2025.

Sources of Information on Climate Change

According to results from Table 2, about 17.9% of respondents indicated that extension agents were the source of their information about climate change, 11.9% said that they learned about it from their family and friends, and television (19.0%) . The results also revealed that 11.9% of respondents derived their own information from radio in the study area, while only 10.7% of respondents obtained their information about climate change from newspapers and magazine, cooperative societies (13.1%),and social media (15.5%). Given that few of the goat farmers in the study area had constant access to electricity to power their radios, televisions, and phones, and that even the current high price of fuel is not helping, it is evident that the primary source of information about climate change for these farmers came from their extension agents. This outcome is consistent with the study by Dhakal *et al.* (2021), which found that farmers viewed the interpersonal and group methods as the most common ways to obtain climate change information.

Table 2: Distribution of Respondents based on the Sources of Information on Climate Change

Sources of Information	Frequency	Percentages
Extension Agents	19	22.6
Family and Friends	15	17.8
Television	17	20.2
Radio	13	15.4
Newspaper/Magazine	9	10.7
Cooperative Societies	18	21.4
Social Media	16	19.0

Source: Field Survey, 2025 *Multiple responses allowed.

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Factors affecting Adaptation Strategies to Climate Change.

The regression model analysis of the link between climate change adaptation and the predictive variables in rural goat production in the study area is shown in the results of Table 3. According to the results, the regression model was able to explain about 83.2% of the link between climate change adaptation and the predictive factors, with the error term accounting for the remaining 16.8%. The R^2 value was 0.832. From Table 3 results, it showed that household size and access to extension agents were all positive and significant at the 10% level. This suggests that increasing all of these factors will increase the adaptation strategies used to mitigate climate change and boost goat production in the study area. Age and marital status were positive and significant at the 5% level, and ownership of goat production and land ownership was positive at the 1% level as well. This suggests that as these variables rise, new ideas and innovations for climate change adaptation are adopted, making goat production in the study area profitable this finding conforms to the works by (Lantokpode *et al*, 2022), (Hristov, *et al*, 2022).

Table 3: Factors Affecting Adaptation Strategies on Climate Change.

Variables	Coefficients	Std errors	T-values
Constant	3.8028*	1.7782	2.1385
Age	1.621**	0.658	2.463
Household size	0.978***	0.349	2.802
Marital status	1.286**	0.516	2.492
Access to Extension Agent	0.882***	0.260	3.392
Climate Change awareness	0.526	0.376	1.398
Ownership of goats production	2.602*	1.269	2.050
Land ownership	2.476*	1.170	2.116
Model	R^2=0.832	Adjusted R^2= 0.643	

Source: Field Survey, 2025 *=1%, **=5%, ***=10%

Coping Strategies to Climate Change Employed by Goat Farmers.

According to the results in Table 4, the majority (65.5%) of goat farmers in the study area used high-resistant goat breeds to raise their livestock, while 34.5% did not. This suggests that the majority of these farmers used goat breeds that are resistant to the whims of climate change as a major coping strategy in the study area, meaning they won't lose many livestock. Additionally, Table 4 revealed that majority (71.4%) of respondents provided portable water for their goats in their farms, whereas 28.6% did not provide any kind of water. This suggests that goat farmers were conscious of the effects of water scarcity on their farms, and as a result, the majority of them provided water for their goats rather than depending on natural resources that may dry up due to climate change. Table 4 also revealed that morethan half (52.4%) of respondents re-grassed their paddock, while 47.6% did not. This suggests that many farmers can continue to feed their livestock comfortably during harsh dry seasons brought on by climate change, without having to move around looking for grasses to graze. Additionally, 53.6% of goat farmers established rangelands for goat rearing in order to avoid the whims of climate change, while 46.4% did not have rangeland for goat rearing in the study area. From Table 4 results, majority (66.7%) of respondents in the study area gave their goats medication on a regular basis, while 33.3% did not. This suggests that most respondents made sure to vaccinate their goats to prevent disease and pest outbreaks on their farms. The result further revealed that majority (75%) of respondents in the study area sold some of their livestock to cover daily farm expenses, while 25% did not. This suggests that the majority of goat farmers used the money they raised from the sale of their goats to pay for some coping mechanisms they employed on the farm to lessen the effects of climate change. This outcome demonstrates that the goat farmers in the study area possess extensive knowledge of the coping mechanisms employed to lessen the impact of climate change on goat rearing, this finding conforms to the study by (Ifeanyichukwu *et al*, 2018), (Kabore *et al,* 2019), (Quedrago *et al*, 2021).

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Table 4: Coping Strategies to Climate Change Employed by Goat Farmers

Coping Strategies	Frequency/ (%)		Total
Use of high resistant breeds	Yes	55(65.5)	84
	No	29(34.5)	
Provision of portable water	Yes	60(71.4)	84
	No	24(28.6)	
Re-grassing of paddock	Yes	44(52.4)	84
	No	40(47.6)	
Rangeland establishment	Yes	45(53.6)	84
	No	39(46.4)	
Fencing of camp	Yes	47(56.0)	84
	No	37(44.0)	
Drug administration periodically	Yes	56(66.7)	84
	No	28(33.3)	
Sale of livestock to meet needs	Yes	63(75.0)	84
	No	21(25.0)	
Use of high quality grass	Yes	43(51.2)	84
	No	41(48.8)	

Source: Field Survey, 2025

CONCLUSION AND RECOMMENDATIONS

The study examined climate change and its mitigation strategies on goat production in the study area. The findings showed that majority of the respondents were within the economic active age and were married. Majority of the respondents have attended formal education at various levels and had reasonable years of climate change mitigating experience on goat production in the study area. The findings further revealed that extension agents were the major sources of climate change in the study area and most of them used high resistant goat breeds in their goat farms. Findings from the study further showed that household size and access to extension agents, were all positive and significant at 10%level. Age, marital status, ownership of goat production and land ownership were all positive and significant in influencing adaptation strategies among goat farmers in the study area.

This study therefore recommends that goat farmers should form cooperative associations which will help procure high resistant goat breeds tolerant to the vagaries of climate change, also the cooperative associations should provide portable water during drought for the goat farmers to enable ease of proper digestion, thermoregulation and to avoid health problems for their goats. Government at all levels should employ more well trained agricultural extension agents to disseminate new ideas and innovations on climate change mitigation strategies on goat production in the study area so as to make the respondents be abreast of mitigating strategies on climate change. More so, policy makers, governments at all levels should take into consideration all these problems faced by goat farmers on climate change when enacting policies in the agricultural sector so as to help provide solutions that will enhance the respondents' adaptation strategies to climate change on goat farming in the study area.

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PERCEIVED EFFECTS OF CLIMATE CHANGE ON RICE PRODUCTION IN JAMAARE AND ITAS GADAU LGAs OF BAUCHI STATE, NIGERIA

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ABSTRACT
The study examined the effect of climate change on rice production in Jama'are and Itas/Gadau LGAs of Bauchi State, Nigeria. Multistage sampling techniques was used to select 216 respondents from the study area. Data were collected using structured questionnaire and analyzed using both descriptive and inferential statistics. The result revealed that almost all (97%) of the respondents were male and 62.9% married with a mean age of 35years. The result also showed that the respondents had a mean household size and farm size of 6 persons and 1.6ha. The most severe perceived effects of climate change on rice production were loss of soil water, low yields, increased weed growth and low soil fertility with a mean score ($\bar{X}$=3.7), ($\bar{X}$=2.8), ($\bar{X}$=2.7) and ($\bar{X}$=2.7), respectively. The results of regression analysis revealed that farm size and farming experience were positive and significant (P< 0.01) influencing rice yield while access to credit was positive and significant (P<0.05). The major constraints faced by rice farmers were low capital, low yield of early maturing varieties (100%), frequent floods (100%), and high cost of fertilizer (100%). The study concluded that loss of soil water, low yield, increased weed growth and loss of soil fertility were some of the perceived effects of climate change in the study area. Based on the findings the respondents should promote and strengthen cooperative membership, Adequate and timely information on climate change should be provided by extension agents to enable rice farmers take adequate adaptation and mitigation measures.

Keywords: Climate, Change, Effect, Rice and Production

INTRODUCTION
Agriculture plays a vital role in the economy of most countries, contributing significantly to their Gross Domestic Product (GDP) and economic development, According to the Food and Agriculture Organization (FAO) of the United Nations, the global agriculture sector contributes around 10-12% to GDP, African countries, contributing around 20-30% to GDP, while Nigeria accounts for around 22-25% to GDP. Globally, climate change is a threat to humanity. These have triggered a wide variety of physical and biological changes across the world (Torres, 2024). Vulnerability is exacerbated by the continents with low adaptive capacity and dependence on rain-fed agriculture (Apraku *et al.,* 2021; Azadi *et al.,* 2021). Despite the damaging effects of climate change to Nigeria's agriculture, options aimed at responding (adapting) to climate change are few and therefore makes the poor who depend on farming, fishing and forestry as their main livelihood become more vulnerable to the changes in climatic condition (Bello, *et al.,* 2023). The impact of climate change on rice farmers in Jama'are and Itas Gadau local government areas, Bauchi State, Nigeria is a of great concern. Climate change has been projected to alter temperature and precipitation patterns, leading to increased frequency and severity of droughts, floods, and heatwaves, which can result in reduced crop yields, lower food quality, and increased food waste. Despite the importance of rice as a staple food in Nigeria, the country's rice production is vulnerable to climate change. Therefore, it is essential to investigate and address the impacts of climate change on rice production and the livelihood of rice farmers, and to identify strategies for building resilience and promoting sustainable agriculture practices.

Climate change is a global phenomenon that has significant impacts on agriculture, food security, and livelihoods. Nigeria, like many other countries, is experiencing the effects of climate change, including changes in temperature and precipitation patterns. The study focused on the perceptions of rice farmers from the immediate effect of climate change, resulting to disruption of agricultural activities in the study area. The study is very important because, as observed, there was

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limited in-depth study on the effects of climate change on rice production in Jama'are and Itas Gadau LGAs of Bauchi State. The change in rice production due to effect of climate change will remain important research focus as well as measures needed to improve the resilience of the farmers to enable them adapt to climate change. Recent research has shown that rice can be used to offset the major impacts of climate change because of its potentials and unique properties as a food crop for urban and rural rice-growing populations (Manneh *et al.,* 2020). The authors added that rice is a major cereal in Nigeria in terms of its output and land area. The crop is currently grown in more than 70% of the States in Nigeria.

The broad objective of the study is to analyse the effect of climate change on rice production in Jama'are and Itas Gadau Local Government Areas of Bauchi State. While the specific objectives of the study are to:

i. describe the socio-economic characteristics of rice farmers in the study area;
ii. examine the perceived effects of climate change on rice production;
iii. determine the factors influencing climate change effect on rice yield; and
iv. identify the constraints affecting rice production due to climate change in the study area.

METHODOLOGY

The Study Area

The study was conducted in Jama'are and Itas Gadau local government areas of Bauchi State, Nigeria. Jama'are headquarters is in the town of Jama'are. Its geographical coordinates are 11° 40' 0" longitude to North and 9° 55' 53" latitude to East. It has an area of 493 km^2 and a population of 176,883 as of 2006 census, and approximately 209,800 as of 2023 projection density of 3.7% annual population changes NPC (2024), in 2025, the population is expected to reach around 250,800 driven largely by high birth rates and a youthful population. It is populated by a Fulani tribe that migrated from Dulare in the Lake Chad basin in the Republic of Chad. It has an average temperature of 31 °C. The popular Jama'are river flows through the LGA with average humidity level of the area put at 41%. The rainy season is hot, oppressive, and mostly cloudy and the dry season is sweltering and partly cloudy. Over the course of the year, the temperature typically varies from 56 °F (13.3 °C) to 104 °F (40.0 °C) and is rarely below 50 °F (10.0 °C) or above 108 °F (42.2 °C). The average wind speed in Jama'are LGA is estimated at 12 km/h.

Itas/Gadau headquarters is in the town of Itas, at Longitude 10° 10' 1.20" E and Latitude 11°50 4.79"N, It consists of two districts, namely Itas district and Gadau district. Gadau District holds Baauchi State University main campus. Itas Gadau has an area of 1,398 km^2 and had a Population of 229,996 during 2006 census, and approximately 408,100 as of 2024, Projection density of 3.7% Annual Population Change [2006 → 2023], in 2025, the population is expected to reach around 450,800 driven largely by high birth rates. The predominant ethnic group in the area are the Hausa and Fulani. Itas Gadau has two seasons (dry and rainy), the dry season is oppressively hot and partially cloudy, while the wet season is oppressively hot and predominantly cloudy. The average annual temperature ranges from 56 to 104 degrees Fahrenheit, rarely falling below 50 or rising over 108.

Farming is the major economic activity of the people of Jama'are and Itas Gadau LGAs crops such as rice, cotton, cowpea, peanuts (groundnuts), cotton, sorghum, millet, and onions, and vegetables are being cultivated in the area. They also rear domestic animals like sheep and goats, cattle, sheep, donkeys, and horses. Other important economic enterprises undertaken by the people of Jama'are and Itas Gadau LGAs are trades, fishing, hunting, weaving and dyeing of cotton.

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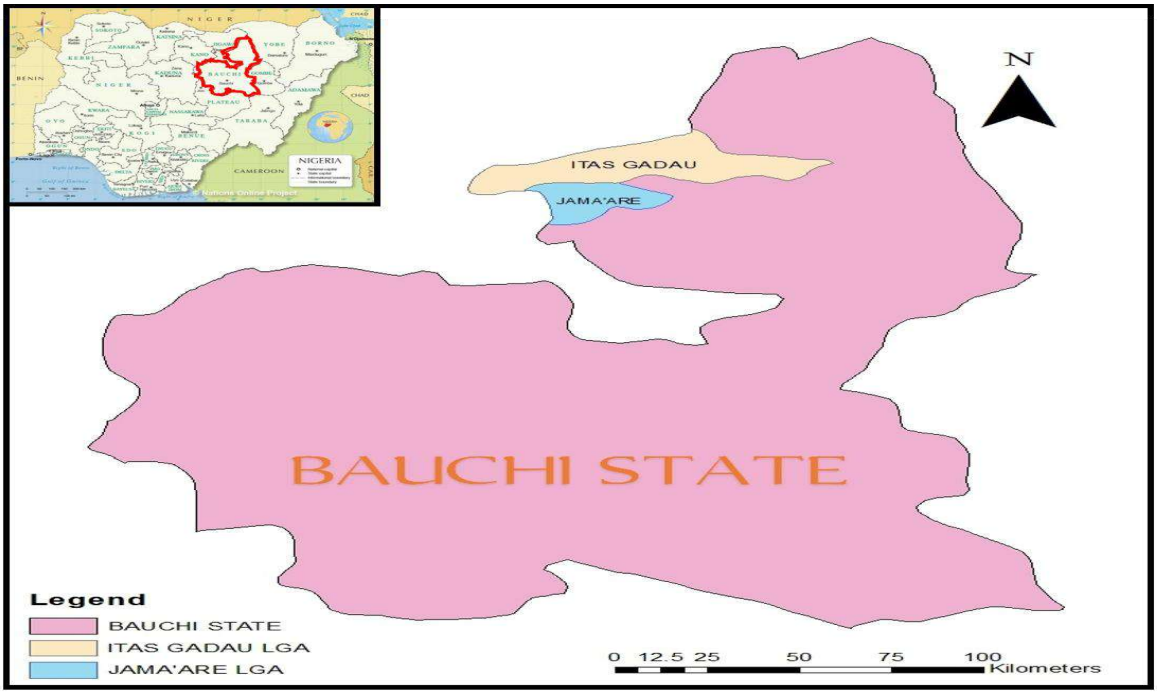

Figure 1: ***Map of the Study Area.***

Sampling Techniques and Sample Size

A multi stage sampling procedure was employed. In the first stage, two Local Government Areas (Jama'are and Itas Gadau LGAs) were selected using purposive sampling techniques based on their high climate change-related hazards which seem to reduce rice availability. In the second stage, two districts were purposively selected from each LGA because they are predominantly known for rice production making a sample of four (4) Districts. In the third stage, three (3) villages that are predominantly known in Rice production were purposively selected from each district making a sample of 12 villages. In the final stage, 10% of rice farmers were selected using proportionate sampling from the sampling frame giving a sample size of 216 rice farmers.

Data Collection

The study employed structured questionnaire to collect information from the selected rice farmers in the study area. The questionnaire was divided into sections; section "A" contained items on socio – economic characteristics of the respondents; section "B" causes of climate change, section "C" consists of questions on factors influencing climate change on rice production in the study area; "D" covered factors influencing the effect of climate change on rice production and livelihood; section "E" covered of question on the rice production constraints in the study areas. The questions in the questionnaire are both open and close ended and was distributed to rice farmers in the study area. It is important to note that out of 216 questionnares distributed to the respondents, only 197 were retrieved and analysed.

Data Analysis

The study employed both descriptive and inferential statistics in achieving its objectives. The data were analysed using SPSS version 23 in achieving the specific objectives of the study.

Descriptive statistics

Descriptive statistics such as frequency, distribution, percentages and mean were used to achieve objectives (i), (ii) and (iv).

Inferential statistics

Linear regression was used to achieve objective (iii) that is to determine the factors influencing the effect of climate change on rice yield in the study area**.**

The regression model is specified as:

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$$Y=b_0+ b_1x_1+b_2x_2+b_3x_3+b_4x_4+b_5x_5+b_6x_6+b_7x_7+b_8x_8+b_9x_9+b_{10}x_{10}+b_{11}x_{11}+ b_{12}x_{12}+b_{13}x_{13}+b_{14}x_{14}++b_{15}x_{15}++b_{16}x_{16}+e \quad \text{.....ii}$$

Where;

Y = Rice yield (Kg/ha)
b_0 = Intercept
b_1- b_{16} = Regression coefficients
X_1 = Age (Years)
X_2 = Sex (Male = 1, Female = 2)
X_3 = Marital status (1= Single, 2= Married, 3= Divorced, 4= Widowed)
X_4 = Household size (Number of persons)
X_5 = Education level (1= Non formal, 2= Primary, 3=Secondary, 4=Adult Education, 5= Tertiary)
X_6 = Farm size (ha)
X_7 = Farming experience (Years)
X_8 = Rice production (sole cropping (Yes = 1, No =2)
X_9 = Livestock production (Yes = 1, No =2)
X_{10} = Civil servant (Yes = 1, No =2)
X_{11} = Artisan (Yes = 1, No =2)
X_{12} = Cooperative membership (Number of Cooperative membership)
X_{13} = Access to credit (Yes = 1, No =2)
X_{14} = Amount of credit received (₦)
X_{15} = Access to inputs (Yes = 1, No =2)
X_{16} = Annual Income (₦)
e = Error term

RESULTS AND DISCUSSION

Socioeconomic Characteristics of the Respondents

The result in Table 2 depicts the socioeconomic characteristics of the respondents. The finding revealed that 39.1% and 34.5% of the respondents were within the ages bracket of 35 – 42 and 27-34 years with and average age of 35 years. According to Nwalieji and Uzuegbunam (2018) most of the rice farmers were between the age ranges of 40 to 49 years. This finding implies that most of the respondents were within their active ages of production. The finding further showed that almost all (97%) of the respondents were male. This finding implies that most of the respondents were male which could be attributed to the cultural and religious belief of the respondents which limits women participation in on–farm activities. Bello *et al.* (2023) reported that majority (76.4%) of the farmers were male. The finding also showed that majority (62.9%) of the respondents were married and 31.5% of the respondents were single. This finding implies that most of the respondents were married which indicates that respondents will be willing to take responsibilities of their dependents. This result is in agreement with the finding of Enete (2018) in Gombe State, where he observed about 50% of the farmers were married.

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Table 1: Distribution of Respondents according to Socio-economic Characteristics (n=197)

Variables	Frequency	Percentage	Mean
Age			
19-26	25	12.7	
27-34	68	34.5	
35-42	77	39.1	35
43-50	25	12.7	
51 and Above	2	1.0	
Sex			
Male	191	97.0	
Female	6	3.0	
Marital status			
Single	62	31.5	
Married	124	62.9	
Divorce	4	2.0	
Widowed	7	3.6	
Household size			
1-5	109	55.3	
6-10	51	25.9	6
11-15	27	13.7	
16-20	8	4.1	
21 and Above	2	1.0	
Educational level			
Non-formal	19	9.6	
Primary	35	17.8	
Secondary	51	25.9	
Adult education	13	6.6	
Tertiary	79	40.1	
Farm size			
0.5-1.5	130	66.0	
1.6-2.5	45	22.8	
2.6-3.5	12	6.2	1.6
3.6-4.5	6	3.0	
4.6 Above	4	2.0	
Farming experience			
1-4	49	24.9	
5-8	94	47.7	7
9-12	34	17.3	
13-16	13	6.5	
17 and Above	7	3.6	

Source: Field Survey, 2024

The result further showed that more than half (55.3%) of the respondents had a household size of 1-5 persons with a mean household size of 6 persons. This finding implies that most of the respondents had relatively moderate household size which indicates that respondents had chances of cheap family labor for rice production activities in the study area. Yakubu *et al.* (2021) reported that majority of the respondents in Kebbi and Sokoto States had a family size of 10 - 14 individuals. The results further showed that 40.1% and 25.9% of the respondents had tertiary and secondary levels of education. This finding implies that most of the respondents had attended one form of education or another which in turn help to increase respondents' level of knowledge and awareness on the effects of climate change in the study area. Yakubu *et al.* (2021) reported that majority had primary, secondary and tertiary education. The result further revealed that majority (66%) of the respondents had a farm size ranging 0.5 - 1.5ha with an average farm size of 1.6hecters. This implies that most of the respondents were relatively small-scale rice farmers in the study area. This is in contrast with Obioha (2018) who reported that 30.8% of the rice farmers had farm sizes of 2-4 hecters. The finding

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also revealed that 47.7% and 24.9% of the respondents had 5 - 8 years and 1-4 years of farming experience. The finding also showed that the mean years of farming experience was 7 years in the study area. This finding implies that implies that most of the respondents had relatively good number of years in farming which plays a good role in increasing respondents' knowledge and skills in climate change adaptation techniques in the study area. The result also corroborates with the finding of Lansigan, (2020) who reported that long farming experience is an advantage for increase in farm productivity since it encourages rapid adoption of farm innovations.

The finding further showed that majority (59.9%) of the respondents had a yield of 10 - 82 bags of rice, with a mean yield of 101 bags this implies that most of the respondents had relatively good harvest from rice production and were small scale rice farmers in the study area. The finding also showed that 57.4% had not received any amount as credit While 22.8% and 16.8% received ₦344,000-₦507,000 and ₦180,000-₦343,000 as credit from their respective sources of credit with a mean credit of ₦170,015. This finding implies that most of the respondents who had access to credit and were able to obtain a reasonable amount to improve their rice production in the study area. The finding further showed that majority (65%) of the respondents had an annual income of ₦220,000 - ₦1,175,000, while 16.8% and 12.2% of the respondent had an annual income of ₦1,176,000 - ₦2,132,000 and ₦2,133,000-₦3,088,000. Only 5.1% and 1% of the respondents had an annual income of ₦3,089,000 - ₦4,044,000 and ₦4,045,000 and above in the study area. The result showed that respondents had a mean annual income of ₦1,202,487, which implies that most of the respondents had relatively high annual income from rice production in the study area.

Table 2: Distribution of Respondents according to Yield in Bags, Amount of Credit Received and Annual Income (n=197)

Variables	Frequency	Percentage	Mean
Yield in bags			
10-82	118	59.9	
83-155	46	23.4	101
156-228	24	12.2	
229-301	6	3.0	
302 and Above	3	1.5	
Amount of credit received			
Non	113	57.4	
₦180,000-₦343,000	33	16.8	170,015.00
₦344,000-₦507,000	45	22.8	
₦508,000-₦671,000	2	1.0	
₦672,000 and Above	4	2.0	
Annual income			
₦220,000-₦1,175,000	128	65.0	
₦1,176,000-₦2,132,000	33	16.8	1,202,487.00
₦2,133,000-₦3,088,000	24	12.2	
₦3,089,000-₦4,044,000	10	5.0	
₦4,045,000 and Above	2	1.0	

Source: Field Survey, 2024

Effect of Climate Change on Rice Production

The result in Table 4 showed the perceived effects of climate change on rice production in the study area. The finding revealed that loss of water from the soil with a mean score of ($\overline{X}$=3.7), low yield ($\overline{X}$=2.8), increase weed growth ($\overline{X}$=2.7) and low soil fertility ($\overline{X}$=2.7) were considered severe effects of climate change by the respondents on rice production as indicated by the mean score above the threshold value of 2.5 in the study area.

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***Table 3*: Effect of Climate Change on Rice Production**

Variables	VS	S	MS	NS	Mean	Decision
Easy loss of water from the soil	179(90.9)	-	-	18(9.1)	3.7	Severe
Low yield	8(4.1)	149(75.6)	40(20.3)	-	2.8	Severe
Increase in growth of weeds	36(18.3	69(35.0)	92(46.7)	-	2.7	Severe
Reduction in soil fertility	-	157(79.7)	40(20.3)	-	2.7	Severe
Reduction in farm income	12(6.1)	55(27.9)	130(66.0)	-	2.4	Not severe
Increases hunger/famine	-	18(9.1	179(90.9)	-	2.4	Not severe
Food insecurity	-	8(4.1)	103(52.3)	86(43.7)	1.6	Not severe
Desertification	-	28(14.2)	118(59.9)	51(25.9)	1.8	Not severe
Increases soil erosion	-	68(34.5)	129(65.5	-	2.3	Not severe
Pest and disease infestation	18(9.1)	-	177(89.8)	2(1.0)	2.1	Not severe
Unemployment	-	22(11.2)	173(87.8)	2(1.0)	2.1	Not severe
Stunted growth in crops	-	32(16.2)	147(74.6)	18(9.1)	2.0	Not severe
Increase in prices of rice	-	79(40.1)	118(59.9)	-	2.4	Not severe
Loss of farmland	-	10(5.1)	187(94.9)	-	2.0	Not severe
Reduction in supply of raw materials	-	54(27.4)	143(72.6)	-	2.2	Not severe

Source: Field Survey, 2024, Very Severe, Severe, Moderately Severe, Not Severe.

The finding further revealed that reduced farm income ($\overline{X}$=2.4), increase in hunger/famine ($\overline{X}$=2.4), food insecurity ($\overline{X}$=1.6), desertification ($\overline{X}$=1.8) and increase in soil erosion ($\overline{X}$=2.3) were found to be not severe effects of climate change on rice production by the respondents as indicated by the mean score values less than the threshold value of 2.5 in the study area. Other factors includes pest/disease infestation ($\overline{X}$=2.1), unemployment ($\overline{X}$=2.1), stunted growth in crops ($\overline{X}$=2.0), increase price of rice ($\overline{X}$=2.4), loss of farm land ($\overline{X}$=2.0) and reduction in supply of raw materials ($\overline{X}$=2.2) were also not severe effects of climate change on rice production as indicated by the mean score values less than the threshold mean value of 2.5 in the study area. This finding implies that most of the respondents were aware of the various effects of climate change on rice production and were able to measure the effects on rating scale to determine the level of severity of the effects on rice production in the study area. This is in line with Yakubu *et al.* (2021) indicated that farmers' experienced negative effects of climate change on rice production and rice yield.

Factors Influencing Rice Yield among the Respondents

The result in Table 5 shows an R-square value of 0.8832. This indicates that approximately 88.32% of the variation in rice yield explained by the independent variables included in the model, suggesting a strong explanatory power. The finding shows that Farm size has a highly significant and positive ($P<0.01$) effect on rice yield. This implies that a unit increase in farm size leads to a substantial increase in rice yield, holding other factors constant. The finding also showed that farming experience significantly and positive ($P<0.05$) influenced rice yield. A one year increace in farming experience leads to 1.38 increase in rice yield. Experienced farmers tend to have accumulated practical knowledge about local weather patterns, soil conditions, pest management, and optimal timing for farm operations. Also, civil servant as a secondary occupation significantly and positively ($P<0.01$) influences rice yield. This suggests that farmers who also hold civil service jobs achieve higher rice yields. Which indicates that civil servants have access to stable off-farm income, enabled them to invest more in quality inputs (improved seeds, fertilizers, irrigation) or hire labor, thereby overcoming financial constraints faced by full-time farmers. Similar to civil servants, having an artisan secondary occupation significantly and positively ($P<0.01$) influences rice yield. This reinforces the idea that diversified livelihoods with stable income enable farmers to inject capital into

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their farming operations, leading to higher yields. Access to credit significantly and positively (P<0.05) influences rice yield. This implies that farmers who have access to credit tend to achieve higher yields. This finding highlights the critical role of financial resources in boosting agricultural productivity. Credit enables farmers to purchase necessary inputs (seeds, fertilizers, pesticides), invest in small-scale irrigation, or adopt modern farming technologies that are often capital-intensive.

***Table 4*: Factors Influencing Rice Yield among Respondents**

Variables	Coef.	Std. Err.	t	P>|t|
Age(x_1)	-.1339195	.3995554	-0.34	0.738
Sex(x_2)	-1.618251	11.27433	-0.14	0.886
Marital status(x_3)	.785291	3.856674	0.20	0.839
Household size(x_4)	.4930857	.5872961	0.84	0.402
Educational level(x_5)	1.531702	1.897429	0.81	0.421
Farm size(x_6)	55.1525	3.701869	14.90	0.000***
Farming experience(x_7)	1.389039	.6070122	2.29	0.023**
Rice production(x_8)	-2.68637	11.89584	-0.23	0.822
Livestock production(x_9)	10.51668	10.51668	1.79	0.076
Civil servant(x_{10})	17.9337	6.511892	2.75	0.006***
Artisan(x_{11})	14.10358	5.166943	2.73	0.007***
Membership of cooperatives(x_{12})	-8.782454	5.54338	-1.58	0.115
Access to credit(x_{13})	16.60879	7.706664	2.16	0.032**
Amount of credit received(x_{14})	.0000124	.0000166	0.74	0.458
Access to inputs(x_{15})	-8.708007	4.755335	-1.83	0.069
Annual income(x_{16})	2.98e-06	3.24e-06	0.92	0.359
_cons	-71.68734	35.68452	-2.01	0.046
R-squared	**0.8832**			
Adj R-squared	**0.8729**			

Source: Field Survey, 2024 ***, **Significant at (P<0.01 and 0.05)

Constraints to Rice Production in the Study Area

The result in Table 6 depicts the constraints affecting rice production in the study area. The finding showed that the major constraints to rice production were low capital base, low yield of early maturing varieties, frequent flood, high cost of fertilizer and labour were 100.0% and were ranked 1st respectively. This finding is in accordance with Malabe *et al.* (2019) who identified financial constraints as a major barrier to climate change adaptation among farmers in Nigeria. These were followed by inadequate knowledge on climate change, poor road network 74.1%, 56.9%, and were ranked 6th and 7th. This finding is in conformity with Akeem (2022) who reported that the use of climate change adaptation strategies is constraints by poor knowledge of climate change and its effects.

***Table 5*: Constraints Affecting Rice Production due to Climate Change**

Variables	Frequency	Percentage	Rank
Low capital base	197	100.0	1st
Low yield of early maturing varieties	197	100.0	1st
Frequent flood	197	100.0	1st
High cost of fertilizer	197	100.0	1st
High cost of labor	197	100.0	1st
Inadequate knowledge on climate change	146	74.1	6th
Poor road network	112	56.9	7th

Source: Field Survey, 2024

CONCLUSION AND RECOMMENDATION

Based on the findings, it was concluded that loss of soil water, low yield, increased weed growth and loss of soil fertility were some of the perceived effects of climate change in the study area.

Also farm size, farming experience and other occupations were found to be the significant factors influencing rice yield.

Based on the findings, the following recommendations were made;

i. Farmers should promote and strengthen cooperative membership in the study area, Cooperatives should support research and development of climate-resilient rice varieties and improved farming techniques.
ii. NGO should provide support to small-scale rice farmers, considering their limited resources and vulnerability to climate change.
iii. Extension agents should intensify climate change education and awareness programs, focusing on practical adaptation strategies and the importance of sustainable farming practices.
iv. Improving farmers' access to affordable and timely credit is essential for commercializing rice farming and enhancing food security in the study area.

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GENETIC DIVERSITY STUDY OF SOME SEED AND MORPHOLOGICAL TRAITS OF *LABLAB PURPUREUS* USING CLUSTER, HEIRARCHICAL, AND PRINCIPAL COMPONENT ANALYSES

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ABSTRACTS
The study evaluated genetic diversity of some Lablab purpureus accessions using multivariate analyses [Cluster, Hierarchical, and Principal Component Analyses (PCA)]. The plant materials were sourced from farmers' farms in Ogun State, Nigeria, and the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 12 traits (6 seed and 6 morphological traits) were studied. The field plots were established at the Plant Biology Field of the Department of Biological Sciences, Tai Solarin University of Education, Ijagun, Nigeria, using a randomized complete block design (RCBD) with three replicates and a block size of 21m × 50m. Each plot was 1m × 2.5 m. Inter- and intra-row spacing was 1m and 0.25m, respectively, with ten (10) plants per plot. The principal component analysis explains a cumulative variance of 81.014% with four components (PC1 = 35.046%, PC2 = 22.359%, PC3 = 13.060%, and PC4 = 10.549%). The hierarchical analysis, presented with a dendogram, grouped the 28 accessions into seven linkage groups (clusters) with TSU-2 and TSU-44 being distinct and grouped into cluster 1 and cluster 7, respectively. In conclusion, a significant genetic diversity was observed among the understudied genotypes. Cluster and PCA effectively grouped the genotypes into 7 linkage groups based on the understudied traits, and the selected genotypes show great promise for future breeding of Lablab purpureus. Therefore, the use of genotypes from distinct clusters in this study can be used as parents in the hybridization of this crop. Replication of this study is recommended using molecular markers to complement morphological data.

Keywords: Lablab purpureus, Cluster, PCA, Hierarchical, Hybridization

INTRODUCTION
Lablab purpureus (L.) Sweet, belonging to the family Fabaceae, is a legume native to tropical Africa and widely cultivated in Asia and other parts of the world. It exhibits remarkable adaptability to diverse environments and is recognized for its versatility. All parts of the plant—leaves, pods, seeds, and roots—have economic importance (Islam *et al.,* 2020). Traditionally cultivated in Asia and Africa, it is used for food, fodder, green manure, and soil conservation. In recent years, lablab has gained global attention due to its high protein content, capacity to fix atmospheric nitrogen, and potential to thrive under low-input agricultural systems (Maass *et al.,* 2010). The legume, *Lablab purpureus* (L.) Sweet, commonly known as lablab bean, is an underutilized crop with multifaceted agronomic potential. It is recognized for its drought tolerance, ability to improve soil fertility through nitrogen fixation, and its multipurpose uses—ranging from food and fodder to green manure and cover cropping (Maass *et al.,* 2010). Despite its vast potential, lablab remains genetically underexplored compared to other legumes such as soybean (*Glycine max*) or cowpea (*Vigna unguiculata*), limiting its breeding and improvement. Genetic diversity provides the essential raw material for crop improvement through selection and breeding. It ensures resilience against biotic and abiotic stresses and enhances adaptability to changing climates. Loss of genetic diversity reduces the evolutionary potential of species and poses a significant risk to food security (Dwivedi *et al.,* 2008). In underutilized legumes like lablab, exploring existing genetic variation is crucial for improving traits such as yield, maturity, seed quality, and stress resistance.

Morphological traits are the simplest and most direct tools for assessing genetic variability. Several studies have highlighted the effectiveness of seed and morphological traits in evaluating the diversity of lablab accessions. Traits such as seed size, seed color, pod length, and flowering time

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have shown substantial variability among lablab genotypes (Adebisi *et al.,* 2011; Kassa *et al.,* 2021). Although morphological traits may be influenced by the environment, they remain fundamental in initial diversity assessments, especially in resource-limited contexts.For example, Adebisi *et al.,* (2011) reported significant variation in 25 lablab accessions from Nigeria using traits such as days to flowering, plant height, number of pods, and seed weight. Similarly, a study by Kassa *et al.,* (2021) on Ethiopian lablab accessions found considerable diversity in pod length, number of seeds per pod, and hundred seed weight. The morphological and seed traits of *Lablab purpureus*—such as seed size, seed coat color, pod length, plant height, days to flowering, and number of branches—are essential for evaluating genetic variability and selecting promising genotypes for breeding. Phenotypic diversity provides critical insights into the adaptive capacity of a species, particularly when molecular tools are limited or unavailable. Morphological characterization is also the first step in genetic resource management and plays a vital role in developing elite cultivars (Upadhyaya *et al.,* 2011).

Multivariate statistical methods such as cluster analysis, hierarchical cluster analysis (HCA), and principal component analysis (PCA) have emerged as powerful tools for assessing genetic diversity in crop plants. These techniques allow the grouping of accessions with similar traits and help in the identification of the most discriminating traits contributing to diversity (Mohammadi & Prasanna, 2003). PCA reduces dimensionality and highlights the main axes of variation, while cluster and hierarchical analyses visualize relationships among accessions. Collectively, these analyses enhance the efficiency of breeding programs by guiding parental selection and genetic resource management. Cluster analysis groups genotypes based on trait similarity, facilitating identification of distinct clusters that may harbor novel or superior alleles. It provides insights into the genetic structure of populations and aids in germplasm management. Cluster analysis has been successfully applied in legume crops, including lablab (Jaiswal *et al.,* 2022). For instance, Anandan *et al.,* (2018) applied cluster analysis on 40 lablab genotypes and grouped them into distinct clusters based on agronomic and seed characteristics. Hierarchical Cluster Analysis (HCA) is a form of cluster analysis that provides a dendrogram or tree-like structure indicating the relationships among genotypes. The most widely used algorithms in HCA include UPGMA (Unweighted Pair Group Method with Arithmetic Mean) and Ward's method. These methods have been widely applied in crop genetic diversity studies to delineate population structure (Bhandari *et al.,* 2020). In *Lablab purpureus*, hierarchical clustering helps identify distant genotypes suitable for hybridization. Principal Component Analysis (PCA) reduces the dimensionality of trait data and identifies key traits that contribute most to genetic variation. It is particularly useful for simplifying large datasets while retaining most of the original information. In legumes like lablab, PCA has revealed that traits such as seed weight, pod length, and days to flowering are major contributors to genetic divergence (Shivakumar *et al.,* 2022). PCA not only helps in visualizing the distribution of accessions but also guides trait prioritization in breeding.

Recent studies continue to reveal significant diversity among lablab accessions. Kassa *et al.,* (2021) evaluated 100 lablab accessions and found that seed size, flower color, and pod traits were highly variable. PCA revealed that the first three components explained over 70% of the total variance. Similarly, Shivakumar *et al.,* (2022) assessed 50 genotypes using morphological traits and grouped them into five distinct clusters using UPGMA, indicating rich genetic diversity. Furthermore, Jaiswal *et al.,* (2022) studied 60 lablab genotypes and applied PCA, HCA, and cluster analysis, revealing strong differentiation among accessions collected from different eco-geographical regions. Their studies emphasized that genotypes from diverse clusters should be prioritized in hybridization to maximize heterosis. The identification of genetically divergent genotypes provides a foundation for hybrid development and germplasm conservation. When diverse genotypes are crossed, the likelihood of obtaining heterotic F1 hybrids increases, which can lead to improved yield, disease resistance, or climate adaptability (Kumar *et al.,* 2019). Therefore, integrating multivariate analyses into diversity studies enhances the strategic utilization of plant genetic resources. The use of multivariate statistical tools such as cluster analysis, hierarchical clustering, and principal component analysis (PCA) provides a robust approach to classify genotypes based on complex trait information. These methods help in revealing hidden patterns of genetic diversity, grouping genotypes with similar or

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complementary traits, identifying key traits contributing to genetic divergence, and reducing data dimensionality for better visualization and interpretation. In the context of *Lablab purpureus*, employing these analyses will offer critical insights into morphological and agronomic trait variability. This is especially valuable for crop improvement strategies aimed at stress resilience, yield enhancement, and adaptation to diverse agro-ecological zones. Furthermore, characterizing genetic diversity ensures the preservation of unique genotypes that may possess valuable genes for disease resistance, early flowering, or seed quality traits. Thus, this study is timely and essential for revitalizing the breeding potential of *Lablab purpureus*, strengthening its genetic base, and enhancing its role in sustainable agriculture and food systems.

This study aimed to determine the genetic divergence of some accessions of *Lablab purpureus* with the following objectives;

- To assess the genetic diversity of selected lablab genotypes.
- To classify genotypes using cluster and hierarchical cluster analysis.
- To identify the major components contributing to phenotypic variability using Principal Component Analysis (PCA).
- To recommend elite genotypes for breeding purposes.

METHODOLOGY

Study Area

The field work was conducted at the research farm of the Department of Biological Science, College of Science and Information Technology, Tai Solarin University of Education, Ogun State, Nigeria. Seeds were sown on March 14th, 2025.

Seed Materials

The seeds were sourced from the Genetic Resources Centre (GRC), International Institute of Tropical Agriculture, Ibadan and some local farmers.

Experimental Design

The field experiments and seed multiplication were laid out in a Randomized Complete Block Design (RCBD) with three replications and a block size of 21m × 50m. Each plot was 1m × 2.5 m. Inter- and intra-row spacing was 1m and 0.25m, respectively, with ten (10) plants per plot.

Data Collection

Data were taken on 6 seed traits and 6 morphological traits as follows;

Traits studied are as follows;

(1.) Petiole length [Length of petiole from the stem to leaf base using meter rule (mm)].
(2.) Stem Girth [Measured at the base of the stem with vernier caliper]
(3.) Number of branches per plant [Counting of the number of branches on each selected plant (Visual assessment)].
(4.) Plant height [Distance from the ground level to the longest terminal leaf using meter rule (cm)].
(5.) Terminal leaflet length [Measured as the distance from the leaf tip to the leaf stalk using a meter rule (mm)].
(6.) Terminal leaflet width [Widest ends across the leaf blade using meter rule (mm).
(7.) Seed length [Length of pod in perpendicular position using Digital Vernier Caliper (mm)].
(8.) Seed width [Length of pod across ends traverse position using Digital Vernier Caliper (mm)].
(9.) Seed thickness [Measurement of shell thickness using Digital Vernier Caliper (mm)].
(10.) 100-seed weight [Weight of 100 seeds using weighing balance (g)].
(11.) Seed coat colour intensity- [scaling of the seed colour visually on a scale of 1 – 8]
(12.) Seed width/Seed length ratio- [measured as seed width divided by seed length]

Statistical Analyses

- Descriptive statistics: Means and standard deviation.
- Cluster analysis: Euclidean distance method.
- Hierarchical clustering: Using dendrograms to show similarity.
- PCA: Eigenvalues, scree plots, and loading scores interpreted using SPSS (vesion 25)

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RESULTS

Table 1: Descriptive Statistics for Linkage Groups (Clusters)

Traits	Cluster 1 **N = 1**	Cluster 2 **N = 3**	Cluster 3 **N = 8**	Cluster4 **N = 8**	Cluster 5 **N = 2**	Cluster 6 **N = 3**	Cluster 7 **N = 1**
Plant Height (cm)	**212.60 ± 0.00**	102.36 ± 5.32	142.63 ± 3.53	118.88 ± 6.99	85.20 ± 1.13	160.60 ± 1.64	134.60 ± 0.00
Stem Girth (mm)	7.04 ± 0.00	7.50 ± 1.55	11.09 ± 1.70	10.23 ± 3.85	6.33 ± 0.71	9.37 ± 2.11	**12..58 ± 0.00**
Petiole Length	9.20 ± 0.00	7.87 ± 2.13	10.98 ± 8.99	10.73 ± 1.25	8.68 ± 2.74	9.65 ± 3.60	**12.04 ± 0.00**
Terminal Leaf Width (cm)	**8.42 ± 0.00**	7.11 ± 1.19	9.11 ± 1.18	8.09 ± 1.05	7.69 ± 1.15	8.87 ± 2.22	**10.01 ± 0.00**
Number of Branches	**8.20 ± 0.00**	2.36 ± 0.65	4.20 ± 1.11	3.35 ± 1.30	2.50 ± 0.42	3.00 ± 1.11	4.40 ± 0.00
Terminal Leaf Length (cm)	8.28 ± 0.00	7.45 ± 1.29	9.06 ± 1.18	8.21 ± 0.62	7.50 ± 0.51	8.67 ± 1.58	**9.26 ± 0.00**
100-seed weight (g)	**27.20 ± 0.00**	24.29 ± 6.75	24.86 ± 3.79	22.72 ± 1.87	21.97 ± 9.63	26.75 ± 2.26	24.82 ± 0.00
Seed Width (mm)	6.28 ± 0.00	5.44 ± 0.74	5.60 ± 0.21	5.21 ± 0.22	5.53 ± 1.88	5.81 ± 0.59	**8.28 ± 0.00**
Seed Length (mm)	**8.96 ± 0.00**	8.29 ± 1.04	8.48 ± 0.62	8.21 ± 0.55	7.65 ± 2.35	8.10 ± 0.14	8.94 ± 0.00
Seed Thickness (mm)	**4.14 ± 0.00**	1.91 ± 1.14	2.64 ± 0.51	2.45 ± 0.34	2.35 ± 1.06	3.26 ± 0.85	2.86 ± 0.00
Seed Colour Intensity	5.10 ± 0.00	3.54 ± 1.60	4.35 ± 2.47	4.29 ± 2.66	**6.85 ± 1.85**	5.77 ± 1.85	3.90 ± 0.00
Seed Width/Seed length Ratio (%)	70.00 ± 0.00	65.60 ± 3.78	66.50 ± 4.57	63.63 ± 3.46	59.50 ± 3.54	61.67 ± 6.81	**93.00 ± 0.00**

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In this study, seven clusters were identified using agglomerative hierarchical clustering, with group sizes ranging from one to eight accessions (see table 1). Each cluster is evaluated below based on the average trait values, standard deviations, and their biological implications.

Cluster 1 (N = 1)**: Elite Vigorous Type**

This cluster contains only one genotype, indicating it is phenotypically unique. It has the highest values for plant height (212.60 cm), terminal leaf width (8.42 cm), number of branches (8.20), and 100-seed weight (27.20 g). Its seed traits, including seed width (6.28 mm), seed length (8.96 mm), and seed width-to-length ratio (70%), are above average. It also records a relatively high seed colour intensity (5.10). This accession appears to be a highly vigorous genotype with both superior vegetative growth and seed yield potential. Its isolation into a single cluster reflects a distinct genetic profile. Such an accession would be valuable for breeding programs targeting biomass production and dual-purpose (forage and seed) uses of *Lablab*.

Cluster 2 (N = 3)**: Low Yield, Low Biomass Group**

Cluster 2 has the lowest values for most traits, including plant height (102.36 cm), stem girth (7.50 mm), number of branches (2.36), 100-seed weight (24.29 g), and seed thickness (1.91 mm). This cluster may represent accessions that are less productive, potentially adapted to marginal environments or subject to past selection for early maturity or drought escape traits. The low biomass and reproductive potential of this cluster suggest its limited utility in yield-driven breeding unless specific stress-tolerant genes are being introgressed.

Cluster 3 (N = 8)**: Intermediate Seed Size, Balanced Growth**

Cluster 3, the largest group, shows moderate values across most traits. With plant height (142.63 cm), seed width (5.60 mm), 100-seed weight (24.86 g), and petiole length (10.98 cm), this group appears well-balanced. It combines moderate vigour and seed yield traits, suggesting stability and adaptability.

Cluster 4 (N = 8)**: Compact Architecture, Modest Yield**

This cluster has relatively lower values for seed traits such as seed width (5.21 mm), seed thickness (2.45 mm), and 100-seed weight (22.72 g), while the vegetative traits like plant height (118.88 cm) and terminal leaf width (8.09 cm) are moderate. The seed width-to-length ratio is lower (63.63%), suggesting more elongated seeds.

Cluster 5 (N = 2)**: Short-Statured, High Colour Intensity**

Accessions in Cluster 5 exhibit the lowest values for plant height (85.20 cm) and stem girth (6.33 mm), along with a high seed colour intensity (6.85) and a low seed width-to-length ratio (59.50%). This indicates smaller, narrower seeds with intense pigmentation.

These traits suggest that this group may contain genotypes selected for visual appeal, processing quality, or traditional uses, possibly with bioactive compounds tied to seed pigmentation (e.g., anthocyanins).

Cluster 6 (N = 3)**: High Biomass and Broad Adaptation**

Cluster 6 has above-average values for plant height (160.60 cm), stem girth (9.37 mm), petiole length (9.65 cm), and 100-seed weight (26.75 g). Seed width (5.81 mm) and terminal leaf width (8.87 cm) also suggest strong vegetative development. Moderate seed colour intensity (5.77) and seed shape (61.67%) further indicate broad utility. These genotypes combine good agronomic potential with adaptability, making them strong candidates for inclusion in breeding programs targeting yield, forage value, and adaptation. This agrees with Aliyu *et al.,* (2021) who emphasized selecting high biomass *Lablab* lines for dual-purpose forage and grain production.

Cluster 7 (N = 1)**: Unique Round-Seeded Type**

This cluster is also a singleton (N = 1), and is notable for its very high seed width (8.28 mm) and exceptionally high seed width-to-length ratio (93%), suggesting a very round seed type. The seed thickness (2.86 mm) and other vegetative traits are moderate. This unique profile may represent a distinct morphological variant or a locally selected cultivar. Round seeds are preferred in certain markets for ease of handling and fast cooking. This genotype may serve in quality-focused breeding for culinary traits. According to Chukwu *et al.,* (2023), seed shape is an important consumer

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preference trait in local legume markets and can be an indicator of geographic or cultural differentiation.

Table 2: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.547
Approximate Chi-Square	322.613
Bartlett's Test of Sphericity (df)	66
Significance	0.000

Bartlett's test evaluates whether the correlation matrix is an identity matrix (i.e., whether there is or no correlations between variables). A significant result ($p<0.05$) means that the variables are significantly correlated enough to apply Principal Component Analysis (PCA) or any other factor analysis. Since the significance of the data collected is 0.000 (as shown in the table 2 above), which is highly significant, this means that the data is suitable for dimensional reduction (Principal Component Analysis or any other factor analysis. The dataset passes both tests for PCA.

Table 3: Total Variance Explained

	Initaial Eigen values			**Extraction Sums of Squared Loadings**		
Component	**Total**	**% of Variance**	**Cummulative %**	**Total**	**% of Variance**	**Cummulative %**
1.	4.206	35.046	35.046	4.200	35.046	35.046
2.	2.683	22.359	57.405	2.683	22.357	57.405
3.	1.567	13.060	70.405	1.567	13.060	70.465
4.	1.266	10.549	81.014	1.266	10.549	81.014
5.	0.967	8.059	89.073			
6.	0.449	3.744	92.816			
7.	0.295	2.461	95.278			
8.	0.275	2.296	97.574			
9.	0.126	1.054	98.627			
10.	0.108	0.898	99.525			
11.	0.056	0.468	99.993			
12.	0.001	0.007	100.000			

Extraction Method: Principal Component Analysis

This PCA result in the table 3 shows how much variance (information) each principal component (PC) explains in the dataset.
The table is divided into:

- **Initial Eigenvalues** – the total variance explained by each component before extraction.
- **Extraction Sums of Squared Loadings** – the variance retained after applying the PCA (for components with eigenvalues ≥ 1).

Using Kaiser's Criterion (eigenvalues ≥ 1), only 4 components are retained. These components explain a cumulative variance of 81.014%, which is quite high and indicates strong data reduction with minimal loss of information. Component 1 explains 35.046% of the total variance, the most among all components, indicating it's the most informative dimension. Component 2 explains 22.359%, also significant. Component 3 adds 13.060%. Component 4 adds 10.549%. Each of these contributes meaningfully to explaining variability in the data. The first 2 components explain 57.405% of the total variance. Adding component 3 brings it to 70.465%. Component 4 brings it to 81.014%, which is acceptable for this study. The rest (components 5 to 12) have eigenvalues <1 and contribute very little individually (< 8.1% each), and cumulatively add just ~19% more variance. They are considered noise or minor sources of variation and are not retained. Conclusively, the original data with 12 variables was effectively reduced to 4 principal components, retaining over 81% of the information.

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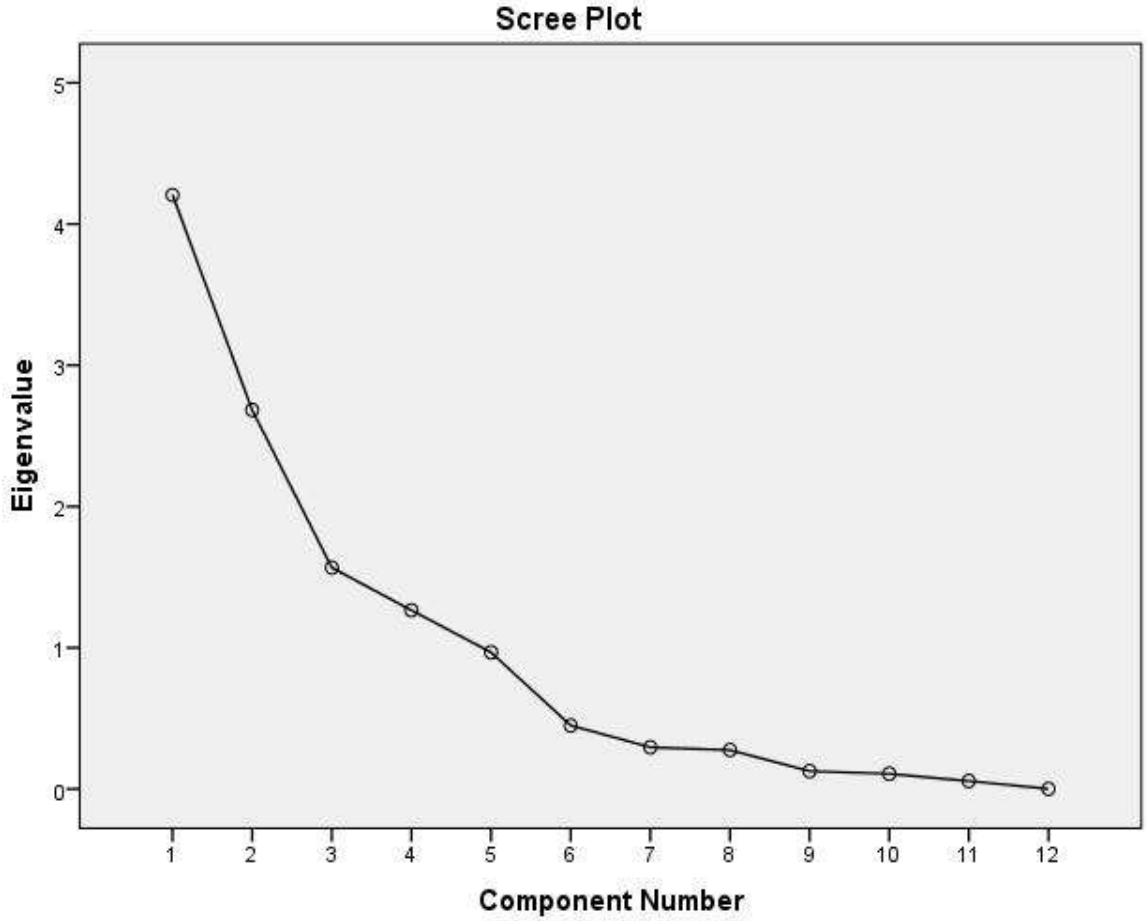

Figure 1: *The Scree Plot Showing the Eigen Values and the Component Numbers*

Table 4: Principal Component Analysis

	COMPONENT 1	COMPONENT 2	COMPONENT 3	COMPONENT 4
Plant Height	0.623	0.278	-0.190	-0.366
Stem Girth	0.596	-0.492	0.051	-0.338
Petiole Length	0.623	-0.610	-0.084	0.062
Term.Leaf Width	0.858	-0.407	-0.075	0.115
No. of Branches	0.711	-0.090	-0.121	-0.357
Terminal Length	0.806	-0.423	-0.102	0.266
100-Seed Weigth	0.546	0.686	-0.057	0.093
Seed Width	0.551	0.413	0.714	0.060
Seeed Length	0.596	0.673	-0.006	0.023
Seed Thickness	0.338	0.728	-0.288	-0.090
Seed Colour	0.287	0.077	-0.197	0.882
Length Ratio (%)	0.182	-0.093	0.925	0.061

Extraction Method: Principal Component Analysis (4 components extracted)

Table 4 above presents the loading coefficients of twelve traits on four principal components. These components cumulatively explain a significant portion of the total variance and reveal the structure of variation among the genotypes.

Component 1: ***Morphological Vigour and Plant Architecture***

The first principal component (PC1) exhibits high positive loadings from terminal leaf width (0.858), terminal length (0.806), number of branches (0.711), petiole length (0.623), and plant height

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(0.623). These traits are related to vegetative growth and canopy architecture. The heavy loadings on PC1 suggest that this component primarily represents the general vigour and plant stature of the *Lablab* genotypes.

This agrees with the findings of Ajayi *et al.,* (2023), who noted that plant architectural traits such as plant height and branching pattern are major contributors to genetic variability in legumes under field conditions. Traits like terminal leaf width and petiole length are highly correlated with photosynthetic capacity and biomass production, as supported by Yusuf *et al.,* (2022), who emphasized their role in early seedling vigour and competitive ability.

The prominence of vegetative traits in PC1 indicates their substantial contribution to genetic divergence. This implies that selection for these traits could lead to improved genotypes with enhanced biomass, branching, and potential for better light interception, which are important for both forage and seed productivity.

Component 2: *Seed Morphometric Traits*

Component 2 (PC2) is dominated by seed thickness (0.728), 100-seed weight (0.686), seed length (0.673), and seed width (0.413). These traits are tightly associated with seed morphology and size. Their strong positive loadings suggest that PC2 represents variation related to seed development and yield potential. Seed traits are key components in domestication and breeding programs due to their direct influence on marketability and seedling establishment. According to Wamalwa *et al.,* (2021), seed weight and size are heritable and stable traits that significantly affect the economic value of legumes. In *Lablab purpureus*, heavier seeds are often associated with higher protein content and better germination rates (Agbo *et al.,* 2020).

Interestingly, stem girth shows a negative loading (-0.492) on PC2, suggesting a trade-off between seed size and stem robustness in some genotypes. This inverse relationship may reflect different adaptive strategies among accessions, possibly indicating genetic divergence due to selective pressures in different agro-ecological zones.

Component 3: *Seed Shape and Dimensional Ratios*

Component 3 (PC3) exhibits high loading from length ratio (0.925), followed by seed width (0.714). These two traits are related to seed shape, which influences seed handling, packaging, and cooking quality. The length ratio, in particular, is a derived trait representing the ratio of seed length to width, offering a composite index of seed elongation. A study by Ndhlovu *et al.,* (2022) on *Phaseolus vulgaris* emphasized the role of seed shape in market preference and adaptability. Likewise, in *Lablab*, elongated or round seeds may reflect genetic variability tied to domestication or natural selection, especially under traditional farming systems where farmers select based on visual seed traits. The high loading of these derived traits in PC3 underscores their contribution to total variation and their potential as indirect selection criteria for breeding programs aiming at seed uniformity and processing efficiency.

Component 4: *Seed Coat Colour and Aesthetic Traits*

Component 4 is characterized predominantly by seed colour (0.882), which stands out as a uniquely influential trait in this axis. Seed colour is often associated with consumer preference, market acceptance, and seed coat composition, including tannin and anthocyanin levels, which affect nutritional quality and storability. Recent studies, such as Zhang *et al.,* (2023) on *Vigna unguiculata*, confirm that seed coat pigmentation is controlled by a few major loci and is a critical trait in legume improvement. In *Lablab*, variation in seed colour also reflects underlying genetic differentiation and possible linkage to other biochemical traits such as anti-nutritional factors or seed dormancy (Oladele *et al.,* 2022). Interestingly, this component shows minimal contributions from other variables, emphasizing the uniqueness of seed colour in explaining variability among accessions. It highlights the potential of using seed colour as a marker trait in participatory breeding and conservation efforts, particularly in regions where visual attributes determine adoption.

GENERAL INTERPRETATION OF PCA

The four principal components together explain a substantial proportion of the total phenotypic variance among *Lablab purpureus* genotypes. PC1 and PC2 primarily capture vegetative

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and seed yield attributes, while PC3 and PC4 deal with seed dimensional ratios and qualitative traits like colour.

This partitioning of variance aligns with earlier work by Raghuvanshi and Tripathi (2021), who emphasized that PCA is efficient in reducing dimensionality without losing critical information in multivariate trait evaluation. In practical breeding, such reduction allows breeders to focus on key components that explain the most variation, thereby improving selection efficiency.

Moreover, the high loadings on specific PCs suggest that these traits can be used to distinguish accessions in cluster analysis and hierarchical classification. The genetic variability observed among the genotypes indicates significant scope for selection and improvement, a conclusion also reached by Akintayo *et al.,* (2021) in their study of cowpea diversity using similar multivariate tools.

The PCA pattern further reveals that several traits are inter-correlated and should not be treated independently in breeding programs. For instance, the strong correlation of plant height with branching and leaf traits in PC1 suggests that selection for one may simultaneously influence others. Similarly, seed dimensional traits appear to be grouped in PC2 and PC3, indicating shared genetic control or developmental pathways.

This Principal Component Analysis (PCA) result in the table 4 presents the loadings (correlation coefficients) of each trait on the first four principal components (PCs). Each loading indicates how strongly a trait contributes to a particular component. Principal component 1 (PC1) represents the "vegetative growth component". Traits with high positive loadings are the terminal leaf width (0.806), terminal leaf length (0.806), number of branches (0.711), petiole length (0.623), plant height (0.623), and stem girth (0.596). PC1 represents general vegetative vigour/plant size. Genotypes with high PC1 scores indicate taller plants, thicker stems, more branches, and broader leaves.

Principal component 2 (PC2 represents seed morphology and weight. Traits with high positive loadings are seed thickness (0.728), 100-seed weight (0.686), seed length (0.673), and seed width (0.413), while those with high negative loadings are petiole length (-0.610), stem girth (-0.492) and terminal leaf width (-0.407). PC2 contrasts seed size and weight with some vegetative traits. Accessions scoring high on PC2 indicate larger, heavier seeds but thinner stems and shorter petioles.
In Principal component 3 (PC3) seed width/seed length ratio (0.925) and seed width (0.714) have high positive loading, which reflects seed shape, especially the seed width/seed length ratio. High scores indicate seeds that are more elongated or with a higher seed width/seed length ratio.
High loading trait in principal component 4 (PC4), for seed colour component, is the seed colour intensity, which captures variation mostly in seed coat colour intensity that is independent of other traits.

In summary of the Principal Component Analysis of this study, the PC1 (vegetative and PC2 (seed size/weight) explain different types of variation-ideal for identifying accessions that balance growth and yield. More so, PC3 (seed shape) and PC4 (seed colour) represent more specific traits useful for breeding or classification.

Table 5: Cluster Membership

Clusters	N	Accessions
Cluster 1	1	TSU-2
Cluster 2	5	TSU-5, TSU-6, TSU-8, TSU-17, TSU-39
Cluster 3	8	TSU-7, TSU-11, TSU-50, TSU-55, TSU-57, TSU-59, TSU-64, TSU-66
Cluster 4	8	TSU-12, TSU-13, TSU-28, TSU-31, TSU-37, TSU-43, TSU-49, TSU-60
Cluster 5	2	TSU-29, TSU-51
Cluster 6	3	TSU-36, TSU-46, TSU-70
Cluster 7	1	TSU-44

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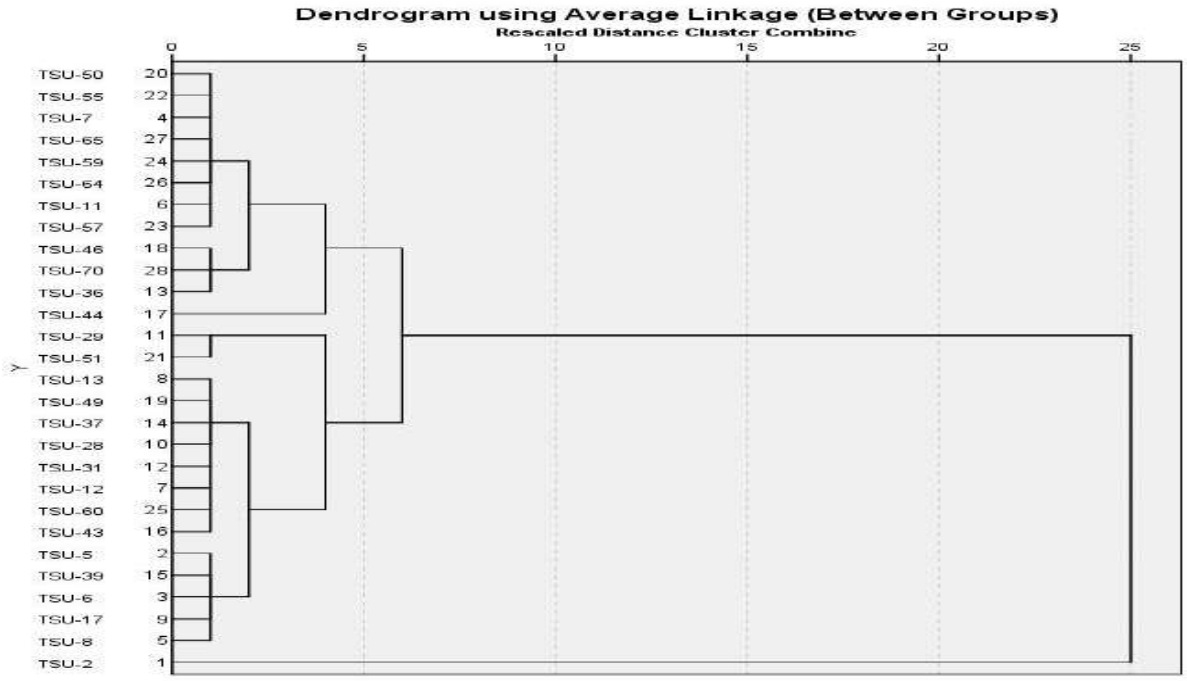

Figure 2: *Dendogram showing the Clusters using Average linkage (between groups)*

DISCUSSION

The vigorous traits observed in cluster 1 align with findings by Adebisi *et al.,* (2023), who reported that accessions with high vegetative vigour and seed size often possess superior allelic combinations and stress resilience.

Similar classifications, as found in cluster 2, were reported by Mahama *et al.,* (2021) in *Vigna unguiculata*, where low-performing clusters were identified as potential reservoirs of adaptive traits, though not ideal for direct cultivation.

The role of groups like cluster 3 in conserving genetic diversity and broad adaptability was highlighted by Singh *et al.,* (2022) in cowpea, where mid-range clusters exhibited high ecological flexibility. This group is likely to contain landraces or farmer-preferred types with balanced performance. Their genetic stability across traits makes them suitable as parents in cross-breeding to incorporate adaptability with higher-yielding traits from other clusters.

The combination of compact plant architecture and elongated seeds observed in cluster 4 might reflect selection for certain market traits or niche adaptability. However, the reduced seed thickness and seed weight suggest limited yield performance, making these genotypes less ideal for commercial seed production. The seed traits in this group resemble those identified by Ogundipe *et al.,* (2020) as characteristics of traditional accessions maintained for specific culinary or cultural preferences. Association between seed colour intensity and bioactivity was demonstrated by Kang *et al.,* (2022) in legumes, linking high pigmentation with antioxidant properties. Thus, cluster 5 may be important for breeding nutraceutical varieties.

Aliyu *et al.,* (2021) emphasized selecting high-biomass *Lablab* lines for dual-purpose forage and grain production as found among members of cluster 6. Cluster 7, with moderate vegetative traits, is a unique profile that represents a distinct morphological variant or a locally selected cultivar because round seeds are preferred quality in some markets for ease of handling and fast cooking. This genotype has great value in quality-focused breeding for culinary traits. This finding is in line with Chukwu *et al.,* (2023) who reported that seed shape is an important consumer preference trait in local legume markets and can be an indicator of geographic or cultural differentiation.

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The observed diversity among the seven clusters reflects considerable genetic heterogeneity in the *Lablab purpureus* germplasm evaluated. The clustering pattern aligns well with the PCA outcomes, validating the interdependence of both multivariate techniques.

The presence of two singleton clusters (Clusters 1 and 7) suggests that some genotypes are extremely divergent, possibly due to geographic isolation, unique selection pressures, or local adaptation. These outliers can be valuable for hybridization programs aimed at maximizing heterosis (hybrid vigor).

Cluster analysis also facilitates strategic parent selection in breeding programs. Crosses between accessions from distant clusters (e.g., Cluster 1 and Cluster 5 or Cluster 2) are likely to produce transgressive segregants with superior traits. This approach is endorsed by Oyetunde *et al.,* (2021), who recommend using cluster distance as a criterion for selecting parents to maximize variability in progeny.

CONCLUSION AND RECOMMENDATION

The combination of Principal Component Analysis (PCA) and Cluster Analysis has provided deep insights into the structure of phenotypic and genetic variation in *Lablab purpureus*. The PCA identified four principal components that explained most of the total variation, largely driven by plant architectural traits, seed morphometry, shape ratios, and colour intensity.

Cluster and hierarchical analysis further refined this understanding by classifying the genotypes into seven distinct clusters, each with unique trait profiles. The largest clusters (Clusters 3 and 4) exhibit intermediate traits, while singleton clusters (1 and 7) suggest unique genetic resources.
The findings emphasize the broad genetic base of the understudied *Lablab accessions* and the opportunity for genetic improvement. Breeders can use the identified clusters to select contrasting parental lines, improve target traits, and enhance adaptation. Furthermore, the identification of clusters with high biomass, superior seed quality, or unique pigmentation can support breeding for multiple uses: food, forage, and functional nutrition. This PCA-based study underscores the significant phenotypic and genetic diversity present among the *Lablab purpureus* accessions. By extracting principal components, the analysis revealed that the most critical traits contributing to variation were plant height, branching, terminal leaf size, seed size (length, width, and thickness), seed weight, and seed colour.
The four extracted components represent distinct agronomic domains:

1. **PC1:** Vegetative vigour and canopy structure,
2. **PC2:** Seed morphometrics and yield potential,
3. **PC3:** Seed shape ratios and dimensions,
4. **PC4:** Aesthetic traits (particularly seed coat colour).

These domains provide a robust framework for germplasm classification, selection, and conservation. The distinct clustering of traits in each principal component suggests that multi-trait selection indices can be developed to guide breeding objectives more efficiently.

The implications of these findings for *Lablab purpureus* improvement are profound. With increasing interest in underutilized legumes for climate-smart agriculture, identifying genotypes with superior agronomic and nutritional traits becomes imperative. The observed diversity provides a genetic reservoir that can be exploited for improving yield, seed quality, and adaptability to varying environmental conditions.

Furthermore, integrating PCA with cluster and hierarchical analyses enables a comprehensive understanding of genotype relationships, facilitating the identification of distinct groups for cross-breeding. This multivariate approach is superior to univariate analyses because it considers trait interdependence and avoids redundancy.

In conclusion, PCA has proven to be a vital tool in this genetic diversity study, unraveling complex relationships among traits and providing insights into selection strategies. The findings provide a scientific basis for the development of ideotypes with optimal combinations of yield, quality,

and stress-resilience traits in *Lablab purpureus*. Future breeding programs should incorporate molecular markers alongside morphological traits to validate and enhance selection accuracy.
Future work should use genotypes from distinct clusters as parents in hybridization and incorporate **molecular markers** and **genomic tools** to complement phenotypic diversity, ensuring a more holistic approach to *Lablab* improvement.

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EFFECTS OF SLOPE ON SOIL LOSS RATE FROM RILL EROSION IN BIU AREA, BORNO STATE, NIGERIA

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ABSTRACT
The study was conducted at six different sites (Piku, Kigir, Dam, Mirnga, Mandaragrau and Gunda) in Biu area, under different soil types, topography and vegetation to estimate the soil loss rates on slope due to rill erosion. The study was carried out on annual bases between March and December in 2020. The annual precipitation varied from 699.00 – 896.00mm. and the rainfall erosivity ranged from 351.00 – 485.00 $MJmmha^{-1}hr^{-1}yr^{-1}$, respectively across the sites. Soil erodibility (0.70 – 0.80) slope length (435.00 – 785.00m), and slope steepness (6 – 9%) cover management factor (0.12 – 0.23) and protection management (0.12), were used as predictor variables in Revised Universal Soil Loss Equation Version 2 (RUSLE2) 2016, across the sites. Six hectares of overland flow sites consisting of rills were selected at random at each site for the study. About 144 soil samples were collected from six sites and RUSLE2 model annual estimation of soil loss was 260.00 – 447.00, respectively. High soil loss was recorded at Piku site with a respective value of 447.00. Based on the result of this study, management of terraces, mulching, cover crops and vegetation, no – tillage method, buffer zones, contour bonds, check dams, grassed water ways and hillside water ponds are recommended to reduce the length of the slope and consequently the soil and water loss.

Keywords: Soil, Erosion, Slope, Steepness, Erosivity, Erodibility,

INTRODUCTION
Slope length is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or the runoff water enters a well-defined channel that may be part of a drainage network or a constructed channel (Wishmeir and Smith, 1978).

. Upland or rill-interill erosion is a two-phase process involving detachment and transport of soil particles. Detachment depends on:(a) combined kinetic energy of raindrop, overland flow, and the interaction between raindrop and overland flow, (b) resistance of the soil to the shearing forces listed above, (c) and the resistance or protective effects of crop residue mulch and of the canopy cover. The shearing effects of overland flow are related to its velocity and depth. The velocity of overland flow depends on slope gradient, its depth, and the time of concentration. The latter is a function of slope length. The time of concentration increases with increase in slope length. Consequently, the time available for overland flow to infiltrate into the soil is more on longer than on shorter slope lengths (Lal, 1988).

Slopping farming land accounts for nearly two-third of the total land of the Loess Plateau in China, and the average annual erosive modulus is as high as 25,000 t·km−2·a−1 (Gao *et al*.,2012). This situation makes the Loess Plateau a major source of soil losses, and slope plays a key role in the evolution of eroded soil surface in this loessal region. In order to illustrate the erosion processes, continual scientific efforts have been made to investigate the relationship between slope and erosion, which have been represented by many soil erosions models from the early Zingg from 1940's, to later Smith, Whitt, Musgrave, USLE and WEPP. Some consensus has been arrived at that the slope is an important factor influencing runoff, has a correlation with erosion rate and runoff rate (Fox and Bryann (2000): Ribonzi *et al*.,(2011): El *et al*., (2013): Shen *et al*., (2016), influences the duration of time for each stage of erosion (Zhao *et al*.,2013), and governs soil erosion (Kinnell and Cummings

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(1993): Koulouri and Glourga (2007): Assoulieue and Ben (2006); and runoff and erosion tend to increase when a rainfall event occurs on a steeper surface at a critical slope ranging between 5˚ and 25˚ (Tang *et al*., (1998): Mahmordabadi and Sajjadi (2016): Li *et al*., (2016): Wu *et al*., (2018).
The micro topographic surfaces are created by using farm tillage tools to form undulating terrains which comprise a mixture of soil grains, aggregates and clods, and whose height variance is rather small (Zheng *et al*., (2014). When the force of rainfall and runoff causes soil detachment and sediment transport, and creates depressions to store water, the surface roughness changes occur, which have an impact on the evolution of soil erosion, so to throw light on the dynamics of surface micro topography is critically important to understanding erosion (Darboux and Huang (2005): Gomez and Nearing (2005)

As rainfall is the precondition of runoff and soil water erosion, and a hill slope could exacerbate the soil and water loss as gravity aggravates the transportation of the runoff and sediment (Taye *et al*. 2013; Mishra *et al*. 2014; Nourani *et al*. 2015; Larsen *et al*. 2016), therefore, it is essential to understand the effects of the rainfall and slope gradient on the soil and water losses. Rainfall simulation experiments conducted in the arid Sistani region of Iran revealed that the sediment yield was strong at the beginning of the rainfall yet lowered over time when the soil became saturated (Shojaei *et al*. 2020). A field experiment was advanced to investigate the effects of the slope gradient on the surface runoff, runoff coefficient, and sediment yield under natural rainfall conditions, and it was indicated that the runoff responses to rainfall for plots with different slope gradients showed a linear behaviour that significantly increased with the gradient (Jourgholami *et al*. 2021). The objectives of the study are to: - estimate the effects of slope on soil loss, assess the impact of rainfall on soil loss, and state the soil conservation measures necessary to control the soil loss in Biu area.

MATERIALS AND METHODS

The Study Area

The study was conducted in Biu Local Government Area, Borno State, North eastern Nigeria. Six locations; Kigir (10^{o} 35' N, 12^{o} **12'** E), Dam (10^{0} 37' N, 12^{0} 9' E), Piku (10^{0} 37' N, 12^{0} 11'E), Mirnga (10^{0} 43'16 N, 12^{0} 8'54 E), Mandaragrau (10^{o}35'52 N, 12^{o} 12'30 E), and Gunda (10^{o}55'N, 11^{o}55'E), were used for the study. Soil sampling was conducted at six stated sites in 2021. In each site, 6 hectares of land were selected at random, (Shipitalo and Edward, 1998). At each site, four (4) land forms (crest, shoulder, back slope and fore slope), were identified and on each land form, one (1) soil sample at 30 cm depth, was collected, making the total of 24 samples, per each site. Since there are six locations (sites) (6 x 24) samples = 144 samples were collected for laboratory analysis. Each soil sample was collected when moist in a well labelled Polyethene bag. The soil samples were air – dried, sieved through a 2 mm sieve then prepared and analyzed for some physical and chemical parameters that relates to soil erosion. The soil samples were collected at the end of the growing season. The Universal Soil Loss Equation version 2 (RUSLE 2, 2016) was used to calculate the rates of soil loss at each site.

The rainfall was collected using a rain gauge devise for all rainfall events during the study period. The K- factor represents the combined effect of soil texture, organic matter, permeability, and structure on average long term erosion. Cover management factor (C value) was measured by semi detail survey of the crops grown on the field. Support practice factor was measured by semi detail survey of the terraces on the slope. Support practice factor (P) in RUSLE2 is defined as the ratio between soil loss with a specific support practice and the corresponding loss with upslope and down slope tillage.

RUSLE2, Soil Estimation

$a_i = r_i\, k_i\, l\, S\, c_i\, p_i$ - USDA – ARS, (2016) (1)

Where:

a_i = long – term average soil loss for ith day
r_i = erosivity factor
k_i = soil erodibility factor

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l = slope length factor
S = slope steepness factor
c_i = cover and management factor

Topographic Factor Estimation

The slope length was measured by GPS tool and slope steepness was calibrated by Theodellite. The effects of topography on soil erosion is accounted for by slope LS factor in RUSLE2, which combines the effect of slope length factor (L) and slope steepness factor (S). Investigation shows that the amount of runoff increases due to the continuous accumulation down the slope as the slope length (L factor) increases, the velocity of the runoff increases as the slope steepness (S) factor) increases. Upon obtaining the Land S values, the topographical factor (LS) values were calculated using the model provided by Wishmeir and Smith (1978) and Kirby (1980).

$LS = (Length/22.1)\ m\ (65.41 \sin^2 \Theta + 4.56 \sin \Theta + 0.065)$ (2)

$M = 0.6\ [1 - \exp(-35.835 \times S)]$ (3)

$\Theta = \tan^{-1}(S/100)$ (4)

Where:
L = Field slope (%)
S = Field slope steepness in degree
The variation in value is caused by the variation in the gradient and length of the slope.

Soil Erodibility

The soil erodibility factor (K) of the various sites (Table 2), reveals the resistance of soil to both detachment and transport. Soil erodibility factor (K) ranges from 0.70 – 0.80 across sites. The highest soil erodibility factor was recorded at Dam, Mirnga, Mandaragrau and Gunda sites at the range of 0.82 and the lowest value was recorded at Piku and Kigir with their respective value at 0.70. Table 7 reveals soil erodibility factor (K). Dam, Mirnga, Mandaragrau and Gunda sites had high soil erodibility than Piku and Mirnga sites. Erodibility defines the resistance of the soil to both detachment and transport

Cover Management Factor

The cover management factor (C – Value) of the study sites (Table 2) in 2020, ranged from 0.12 to 0.23. The highest C – value was recorded at Mirnga followed by Piku and Kigir and then Mandaragrau and Dam sites and their values which were recorded at 0.23, 0.14, 0.12, 0.12, and 0.12 respectively. The vegetation varies from grain corn and corn soybean rotation with ridge tillage at all the sites. The vegetation of the various sites varied from guinea corn, bean, and soybean, grain corn with ridge tillage and chisel plow. The C – value is dimensionless with values between 0 and 1 (Molla and Sisheber, 2017).

Protection Management Factor

Table 2 depicts protection and management factor (P – Value) in terms of land used. The study sites ranged within slope percentage of 5 – 10 %, respectively. Piku sites had the highest P – value followed by Kigir, Mirnga, Dam, and Mandaragrau. Protection and management factor (P – value), and topography of the study sites showed that Piku (9%) had high slope percentage followed by Kigir (8%) Mirnga (7%) site, Dam, Mandaragrau and Mirnga sites recorded the same value of 6%. Also, the P – value of all the sites was 0.12. The P – value reduce the amount and rate of the water runoff, and then reduced the amount of soil erosion. This observation concurs with that of Wishmeir and Smith (1978) that the P factor reflects the practice that will reduce the amount and rate of the water runoff and thus reduce the amount of soil erosion.

RESULTS AND DISCUSSION

Average Annual Precipitation, Rainfall and Runoff Factor and Erosivity Density

Table 1 describes the average annual precipitation, rainfall and runoff factor and erosivity distribution of the various study sites in Biu area. The rainfall data ranges from 2004 – 2011 and 2020 - 2021 for all the sites representing 10years precipitation data. The annual precipitation ranged from (604.80 - 1,045.40 mm) at Kigir and Piku (600.67 – 1001.97 mm), Dam (529.72 – 1050.99mm),

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Mirnga (567.56 – 1129.30 mm), Mandaragrau (628.4 – 1108.45mm) and Gunda (534.89 – 1147.80 mm). The average annual precipitation varied from 699.00 – 896.00 mm. The highest annual precipitation was recorded at Dam followed by Kigir, Piku, Mirnga, Gunda and Mandaragrau sites with their respective values at 896.00, 825.89, 810.00, 702.00, 699.00 and 697.00 mm. Higher rainfall intensities across sites in the study area causes high soil loss, this observation agrees with the report of Hudson, (1963) that rainfall intensity of about 25 $mmhr^{-1}$ was a threshold value, higher intensity than this being erosive.

Table 1: Average annual precipitation, rainfall and runoff factor, and erosivity at various sites in Biu area

Site (mm)	Annual precipitation (mm)	Rainfall and Runoff factor ($MJmmha^{-1}yr^{-1}$)	Erosivity
Piku	810.00A	512.29C	365.7D
Kigir	825.89A	510.29D	485.00A
Dam	896.00A	514.86B	414.00C
Mirnga	702.00B	535.43A	435.00B
Mand.	697.50B	494.86E	361.00E
Gunda	699.00B	446.57F	351.00F
$SE_{0.05}$	**23.121**	**0.1161**	**0.0387**

Source; 2020
SE = Standard error, Mand. = Mandaragrau site
Means followed by the same letter (s) in a column are not significantly different at $p < 0.05$

Effects of Slope on Soil Loss Rates in Biu Area

Table 2 depicts slope length and steepness of the study sites. Kigir recorded the highest slope length of 785.00 m followed by Piku, Mirnga, Dam, Gunda and Mandaragrau sites with their respective values of 713.00, 665.00, 643.00, 508.00 and 435.00 m. Also, Piku recorded the highest steepness followed by Kigir, Mirnga, Dam, Mandaragrau, and Gunda with their respective values at 9.00, 8.00, 7.00 and 6.00. Slope length ranged from moderate to high, while percentage of slope was ranked high in terms of soil loss across sites. Kigir site with high slope length and percentage has high risk of soil erosion than Piku, Mirnga, Dam, Gunda and Mandaragrau sites with shorter length and considerable percentages of slope steepness as a result of volume and velocity of runoff in the sites. Soil erosion occurred in all the sites, because of the percentages of slope steepness were above 5 %. Percentage slope steepness less than 5 % erosion hazard is negligible.

Soil loss rates (Table 3) at Piku, Kigir and Dam sites were higher than Mirnga, Mandaragrau and Gunda sites. This occurred as a result of high rainfall intensity recorded at the stated sites (Table 1). The kinetic energy of raindrop used to be high when the rainfall increased. This observation agrees with the reports of Zambon *et al*.,(2020) and Zhang *et al*., (2022) that the amount of rainfall on the slope surface per unit time increases with increasing rainfall intensity, the kinetic energy of the raindrops also increased. This phenomenon made the striking raindrops at high rainfall intensities more likely to damage the surface soil structure and loosen the surface soil when compared to the low rainfall intensities, thus increasing the likelihood of soil particles being carried away by the runoff. In addition, with the increase in the rainfall intensity, the runoff volume on steep slopes increased rapidly, which caused erosion and scouring on the soil to be more significant than that at low rainfall intensity. Eventually these effects lead to an increase in the sediment's loss.

As rainfall is the precondition of runoff and soil water erosion, and a hill slope could exacerbate the soil and water loss as gravity aggravates the transportation of the runoff and sediment (Taye *et al*. 2013; Mishra *et al*. 2014; Nourani *et al*. 2015; Larsen *et al*. 2016), therefore, it is essential to understand the effects of the rainfall and slope gradient on the soil and water losses in a purple soil area. In recent decades, researchers have paid significant attention to the influences of rainfall and topographic conditions on the soil and water loss (Maltsev &Yer-molaev 2019; Belayneh *et al*. 2020; Zhang *et al*. 2021).

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Effects of slope length on runoff per unit area are not clearly defined. Other factors remaining the same, runoff per unit area may decrease with increase in slope length (Lai, 1983). In contrast, Laflen & Saveson (1970) reported that runoff increased linearly with an increase in the ratio slope steepness: slope length. Wischmeier (1966) and Wischmeier & Smith (1978) reported either negligible effects of slope length on annual runoff per unit area of cropland, or slightly lower runoff on the longer slopes during the growing seasons and slightly higher during the dormant season. The effects of slope length on soil erosion are confounded by slope gradient, slope shape, and slope-induced alterations in soil properties. Other factors remaining the same, soil erosion supposedly increases in proportion to some power of slope length. Higher erosion on longer slopes may be due to increased runoff velocity on longer slope lengths and therefore, due to increase in rill erosion (Foster *et al,* 1977).

Table 2: Soil erodibility factor, slope length and steepness, C and P values of the various study sites in Biu area

Study sites	Soil erodibility (k)	Slope len.	Slope %	C – Value	P value
Piku	0.70B	713.00B	9.00A	0.14C	0.12
Kigir	0.70B	785.00A	8.00B	0.14C	0.12
Dam	0.82A	643.00D	6.00D	0.12D	0.12
Mirnga	0.82A	665.00C	7.00C	0.23A	0.12
Mandaragrau	0.82A	435.00F	6.00D	0.12D	0.12
Gunda	0.82A	508.00E	6.00D	0.12D	0.12
SE $_{0.05}$	**4.869**	**2.556**	**0.064**	**3.776**	

Source: 2020
Key: SE = Standard error, Mand. = Mandaragrau site, C – values = cover and management factor, P – value = protection and management factor, Slope len. = slope length, Slope % = slope steepness.
Means followed by the same letter (s) in a column are not significantly different at $p < 0.05$

Table 3: Annual soil loss estimated by empirical and RUSLE2 models (Kg $ha^{-1}yr^{-1}$), in 2020.

Study Site	Measured model	RUSLE2 model
Piku	337.39A	447.00A
Kigir	224.71C	330.00B
Dam	227.58B	308.00C
Mirnga	168.38F	269.00E
Mandaragrau	193.49D	292.00D
Gunda	184.88E	260.29F
SE $_{0.05}$	**0.107**	**0.108**

Source: 2020
Key: SE = Standard error.
Mean followed by the same letter (s) in column are not significantly different at $p < 0.05$

CONCLUSION AND RECOMMENDATION

The extent of rill erosion was quantified using empirical and RUSLE2 models prediction techniques under same condition of Biu environment. RUSLE2 estimates rates of rill and interill soil erosion was caused by rainfall and its associated overland flow. The pattern, rate and estimates of soil losses were confined to rainfall amount as the season progressed to a peak in the month of July and therefore decline with cessation of rainfall in October in the study area. Soil loss was significantly ($p < 0.05$) higher at Piku followed by Kigir, Mirnga, Mandaragrau, Gunda and Dam in this study. RUSLE2 model gave high prediction accuracies of soil loss, while the empirical model had moderate accuracies in terms of soil loss prediction in the study sites. However, both models showed low to high prediction strength at locational bases. On aggregate basis RUSLE2 model surpassed with greater strength of prediction accuracy than empirical model.

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Concerning management strategies to reduce soil losses, intervention will focus on the slope length and steepness, conservation management factor and support practice factor as the erodibility and runoff factor cannot be changed. Based on the result of this study, the recommendations were made:

i. Mulching; - mulch is any layer of material applied to the surface of the soil to protect the soil from the erosion and evaporative effects of wind and sun. Mulch can be plant material, like straw and wood chips or it can be gravel or non – living material like recycled glass, cinders, decorative rock and recycled rubber.

ii. **Cover Crops and Vegetation**; - cover crops increases soil health improves soil structure and reduces the need for costly inputs such as fertilizer and mechanical tillage. Cover crops protect water quality by slowing erosion and runoff and increases water infiltration and retention.

iii. No tillage method; - in zero tillage, the land for crop cultivation is left undisturbed from harvest to planting or not ploughed at all while in the case of minimum tillage, just holes for planting are made and only at the places where the crop is going to be planted or grain sown. A combination of no tillage with crop residue mulch is more effective in runoff and erosion control

iv. Buffer Zones; - buffer zone increases the capture of sediments and organic materials. It is revealed that buffer zone increase the trapping of sediments and infiltration from 10 to 90 %. Vegetative buffers decrease the runoff velocity of water.

v. **Terraces; -** terraces are mechanical structures such as an earthen ridge or stone wall which reduces the slope steepness and divides the slope into short gentle sloping sections. Terraces reduces the runoff velocity and soil loss, increases the soil moisture content through improve infiltration, reduce evaporation and can be created to divert runoff to a prepared or safe area for minimizing the effect of soil erosion to a tolerable level.

vi. **Contour Bunds**; - as progressive terraces, contour bunds are suited to flat areas of slope less than 16 %. Contour bunds can reduce the soil erosion and increase the soil water holding capacity in the intervention area.

vii. **Check Dam; -** check dams are structures constructed across a channel or a river to lesson water velocity and to catch sediments.

viii. **Anti – erosive ditches**; -an anti – erosive channel is a drainage channel constructed to prevent runoff water from upper hill to enter a cropped land. In this channel, water may infiltrate or may be diverted.

ix. **Grassed waterways**; - grassed waterways are more important in filtering by retaining runoff sediments, pollutants and other particulate matter within storm water and their performance will depend on soil permeability within the area.

x. **Hill side water ponds**; - rain water harvesting is a system of collecting water through different technologies such as storage of rain water on surface reservoirs and ground water recharge for future use. The use of ponds for retaining water reduces soil erosion.

xi. Retaining walls made of gabions for slope stabilization; - retaining walls are structures made of masonry, stone, brick, concrete or combination of these. They are used as erosion control structures. Comparatively to other retaining walls, the main advantage of gabions retaining walls is to reduce the runoff velocity or to increase the stability of sloping surface area with seepage problems.

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PREDICTION OF SOIL AND NUTRIENT LOSS RATES FROM RILL EROSION IN BIU AREA, BORNO STATE, NIGERIA

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ABSTRACT
The study was conducted on monthly and annual bases between March and December during 2020 at Biu area of Borno state consisting of six different sites (Piku, Kigir, Dam, Mirnga, Mandaragrau and Gunda) to estimate annual losses of soil and nutrient (N, P, K, Ca, Mg and S) due to rill erosion and to validate RUSLE2 model for prediction accuracies. The annual precipitation varied from 699.00 – 896.00mm. and the rainfall erosivity ranged from 351.00 – 485.00 MJmmha^{-1}hr^{-1}yr^{-1}, respectively across the sites. Soil erodibility (0.70 – 0.80) slope length (435.00 – 785.00m), and slope steepness (6 – 9%) cover management factor (0.12 – 0.23) and protection management (0.12) were used as predictor variables in Revised Universal Soil Loss Equation Version 2 (RUSLE2) 2016, across the sites. Six hectares of overland flow sites consisting of rills were selected randomly at each site for the study. About 168 soil samples were collected from six sites. The RUSLE2 model annual estimation of soil loss was 260.00 – 447.00 and 150.00 – 495.00 kgha^{-1}yr^{-1}, respectively. Annual validation RUSLE2 revealed the r^2 value of 0.8553. High soil and nutrient (O.M, N, P, K, Ca. Mg, and S) loss were recorded at Piku site with their respective values of 447.00, 3.82, 2.22, 1.95, 2.72, 2.35, 1.49 and1.02 kgha^{-1}yr^{-1}. Recommending the management of terraces, mulching, cover crops and vegetation, no – tillage method, buffer zones, contour bonds, check dams, grassed water ways and hillside water ponds to reduce the length of the slope and consequently the soil and nutrient loss.

Keywords: Erosion, Nutrient, Loss, Precipitation, Density, Erodibility

INTRODUCTION
Soil erosion is the detachment, movement and removal of soil from the land surface by precipitation leaving the landscape as run-off. Degradation of agricultural land by soil erosion is a worldwide phenomenon leading to loss of nutrients rich surface soil, increase run-off from more impermeable subsoil and decreased water availability to plant (Vipul *et al*, 2010, Gelder *et al*., 2017, Orgiazzi and Paragos 2018, Ahmed *et al*., 2020 and Stefanidis *et al*., 2022). Water erosion causes a series of on-site as well as off-site damages and problems on natural ecosystem. These damages include soil and nutrients loss and finally loss of productivity. Considering that mountain soils are generally shallow and their fertility is often concentrated in the upper most layers, soil erosion represents a crucial problem affecting the landscape at different scales and is a serious challenge for land management and soil conservation (Garcia-Ruiz and Lare Renault, 2011, Angasi *et a.l*, 2014). Each year, about 10 Mha of crop land are lost due to soil erosion, thus reducing the cropland available for world food production, overall, soil is being lost from agricultural areas 10 to 40 times faster than the rate of soil formation impairing humanities food security (Pimental and Bager, 2013).

The typical nutrients loss after 10 mm top soil is eroded, is equated to total nitrogen, phosphors, potassium and calcium to the order of 243.6, 90.0, 200.8, 650, and 1050 kgha^{-1}yr^{1}, respectively (Thompson and Basher 1999). In slopping land, soil and nutrients (NPK) losses were in the order 4.451kgha^{-1} yr^{-1} and 10.71-11.26, 0.56-0.64, 0.98-1.11 kgha^{-1}yr^{-1}, respectively (Allincal *et al*, 2011). In USA, Europe and India, soil loss recorded in the order of 8.84 tha^{-1}yr^{-1}, 150 and 130 M tha^{-1} respectively. In Iran and Uganda, soil and nutrients losses were estimated to be 27.44 t ha-$^{-1}$yr^{-1}, 114.20 kgha^{-1}yr^{-1}, 114.8 tha^{-1}yr^{-1} respectively (Izaraide *et al*. 2007; Montamarella, 2008; Semalulu *et al*., 2014; Abdulrahman *et al*, 2015; and Rastgar *et al*., 2015). Nigeria with a land area of 910,771 km^2

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of which 37.33 % is currently put under arable agriculture within permanent crops and others are occupying 3.14 and 59.53 %, respectively are largely affected by water erosion than wind erosion, with menace more pronounced in the southern parts compared to the northern parts of Nigeria, as a result of regional precipitation (amount and intensity and soil types (Lal, 1995 World Bank Report 2010, CIA, 2012). However, the vast bare lands and intensified agricultural activities in northern Nigeria predisposed the soil to greatest rates of water erosion on disturbed upland area which made the rills to be active in the northern guinea Savannah (Amaza, 2007).

Among the forms of water erosion (sheet, inter rill, rill gully, ephemeral gully and stream bank), rill erosion, remains the main cause for concern, since it contributes significantly to water and soil loss (high sediments concentration), thus removing organic matter and Productivity of soils decline through the consequences of soil loss and erosion, especially top soil, because of loss nutrients, physical deterioration that is change of land form and decrease of soil thickness which reinforced unexpected change in land use. For this reason, estimation of soil loss and or is crucial to implement preventive measures. Despite the soil and nutrients losses, there is still lack of information on the scale and magnitude of the scourge in Biu, and therefore the need to design appropriate management techniques in order to, reduce soil and nutrients loss on farmlands. The objectives of the study are to: - estimate soil and nutrient loss in the study area, and to measure soil and climate parameters that influence rill erosion in the study area.

MATERIALS AND METHODS

The Study Area

The study was conducted in Biu Local Government Area, Borno State, North eastern Nigeria, in 2020. Six sites; Kigir (10^{o} 35' N, 12^{o} **12'** E), Dam (10^{0} 37' N, 12^{0} 9' E), Piku (10^{0} 37' N, 12^{0} 11'E), Mirnga (10^{0} 43'16 N, 12^{0} 8'54 E), Mandaragrau (10^{o}35'52 N, 12^{o} 12'30 E), Gunda (10^{o}55'N, 11^{o}55'E), were used for the study and soil sampling was conducted at each of the sites. In each site, 6 hectares of land were selected at random, (Shipitalo and Edward, 1998). At each site, four (4) land forms (crest, shoulder, back slope and fore slope), were identified and on each land form, one (1) soil sample at 30 cm depth, was collected, making the total of 24 samples, per each site. Since there are six locations (sites) (6 x 24) samples = 144 samples were collected for laboratory analysis. Also, at each site a Transect of 200 m by 100 m was selected. Each soil sample was collected when moist in a well labelled Polyethene bag. The soil samples were air – dried sieved through a 2 mm sieve then prepared and analyzed for some physical and chemical parameters that relates to soil erosion. All the soil samples were collected at the end of the growing season.

The organic carbon content of the soil sample was determined using Walkley and Black (1934) potassium dichromate wet – oxidation method. The value of organic matter was obtained by multiplying the organic carbon content of the soil by a factor of 1.724 (Walkley and Black, 1965). Total nitrogen content of the soil was determined by the Kjeidahl's wet digestion method (Bremnar, 1965). Available phosphorus content of the soil sample was determined by bicarbonate extraction method (Olsen and Dean 1965) for near neutral and slightly alkaline soils while for acidic soils, determination of the available phosphorous was done by Bray No 1 method (Black, 1965). The exchangeable cations in the soil samples were determined in the extract of 1N ammonium acetate (NH_4OAC) (Black 1965). The exchangeable cation and magnesium cation of the soil were determined titrimerically while the exchangeable potassium and sodium was determined by flame photometer. Sulphur was determined by calorimetric method using methyl blue (Tabatabaei, 1982).

The rainfall was collected using a rain gauge devise for all rainfall events during the study period. The K- factor represents the combined effect of soil texture, organic matter, permeability, and structure on average long-term erosion. The slope length was measured by GPS tool and slope steepness was calibrated by Theodolite. Cover management factor that is the C value was measured by semi detail survey of the crops grown on the field. Support practice factor was measured by semi detail survey of the terraces on the slope. Support practice factor (P) in RUSLE2 is defined as the ratio between soil loss with a specific support practice and the corresponding loss with upslope and down slope tillage.

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Nutrient Content Determination

Soil nutrient content was determined by Harvey and Baker (2002) method;

Soil nutrient content = Soil nutrient (kg or %) **x** Soil bulk density **x** Depth of soil **x** Area of soil

Soil Nutrient Loss Determination

Surface runoff and soil loss were calculated from the six stated sites in the study area. Soil loss, nitrogen, phosphorus, potassium, magnesium, calcium and sulphur in the sediments were analysed in the laboratory. Sediment yield volumes were determined during 2020 runoff seasons, in the study area. The soil samples were air dried pass through a 2 mm sieve. The nutrient loss was calculated by Lemma *et al*., (2017) model:

Nutrient loss (Kg) = Soil loss (Kg ha^{-1} yr^{-1}) x % Nutrient content of soil x Field size (ha).

Measured Model Estimation (Observed)

Volume of rill (M^3) = 1.57 x width x depth x length - Lemma *et al*., (2017).

Where 1.57 is л /2

Mass of soil loss was estimated using the below equation

Mass of Soil Loss by rills (kg ha^{-1} yr^{-1}) = volume of rills (M^3) x Bulk density (t/m^3) / Field size (ha)

RUSLE2, Predicted

$a_i = r_i k_i l S c_i p_i$ - USDA – ARS, (2016)

Where:

a_i = long – term average soil loss for ith day
r_i = erosivity factor
k_i = soil erodibility factor
l = slope length factor
S = slope steepness factor
c_i = cover and management factor

The Empirical Model

$Y = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \ldots\ldots\ldots\ldots\ldots + \beta 12X12$

Y = estimate of soil loss

α and β = regression parameters

X_1 = soil clay.
X_2 = soil organic matter content
X_3 = aggregate stability
X_4 = infiltration rate
X_5 = soil bulk density
X_6 = plastic limits
X_7 = rainfall and run off factor
X_8 = erodibility
X_9 = slope length and steepness
X_{10} = support practice factor
X_{11} = vegetation
X_{12} = soil shear strength

RESULTS AND DISCUSSION

Average Annual Precipitation, Rainfall and Runoff Factor and Erosivity Density

Table 1 describes the average annual precipitation, rainfall and runoff factor and erosivity distribution of the various study sites in Biu area. The rainfall data ranges from 2004 – 2011 and 2020 - 2021 for all the sites representing 10years precipitation data. The annual precipitation ranged from (604.80 - 1,045.40 mm) at Kigir and Piku (600.67 – 1001.97 mm), Dam (529.72 – 1050.99mm), Mirnga (567.56 – 1129.30 mm), Mandaragrau (628.4 – 1108.45mm) and Gunda (534.89 – 1147.80 mm). The average annual precipitation varied from 699.00 – 896.00 mm. The highest annual precipitation was recorded at Dam followed by Kigir, Piku, Mirnga, Gunda and Mandaragrau sites with their respective values at 896.00, 825.89, 810.00, 702.00, 699.00 and 697.00 mm. Higher rainfall

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intensities across sites in the study area causes high soil loss, this observation agrees with the report of Hudson, (1963) and Kowal, (1970) that rainfall intensity of about 25 $mmhr^{-1}$ was a threshold value, higher intensity than this being erosive.

Table 1: Average Annual Precipitation, Rainfall and Runoff Factor, and Erosivity at Various Sites in Biu Area

Study site	Annual PPT. (mm)	Rainfall and Runoff Factor (mm)	Erosivity ($MJmmha^{-1}hr^{-1}yr^{-1}$)
Piku	810.00A	512.29C	365.7D
Kigir	825.89A	510.29D	485.00A
Dam	896.00A	514.86B	414.00C
Mirnga	702.00B	535.43A	435.00B
Mand.	697.50B	494.86E	361.00E
Gunda	699.00B	446.57F	351.00F
$SE_{0.05}$	**23.121**	**0.1161**	**0.0387**

Source; 2020
SE = Standard error, Mand. = Mandaragrau site
Means followed by the same letter (s) in a column are not significantly different at $p < 0.05$

Soil Erodibility

The soil erodibility factor (K) of the various sites (Table 2), revealed the resistance of soil to both detachment and transport. Soil erodibility factor (K) ranges from 0.70 – 0.80 across sites. The highest soil erodibility factor was recorded at Dam, Mirnga, Mandaragrau and Gunda sites at the range of 0.82 and the lowest value was recorded at Piku and Kigir with their respective value at 0.70. Table 7 reveals soil erodibility factor (K). Dam, Mirnga, Mandaragrau and Gunda sites had high soil erodibility than Piku and Mirnga sites. Erodibility defines the resistance of the soil to both detachment and transport.

The stated sites with high erodibility had low level of organic matter, low soil infiltration rates, low porosity and high run off depicting high soil erosion risk, and the sites with low erodibility showed low soil erosion risk. This concurs with the report of Peng *et al*., 2008; Gimenez – Moreira *et al*., 2010; Leh *et al*.,(2013), that soil erodibility depends on soil and geological characteristics, such as parent materials, texture, structure, organic matter content, porosity, catena and many more. Mirnga site had high silt content than Gunda, Kigir, Dam and Piku sites (Figure 3). Soil with high silt content has low resistance to detachment and transport than soil with lesser silt content. This observation agrees with that of Mhangara *et al*., (2012) that generally, soil become of low erodibility if the silt content is low, regardless of corresponding high content in sand and clay fraction.

Topography

Table 2 depicts slope length and steepness of the study sites. Kigir recorded the highest slope length of 785.00 m followed by Piku, Mirnga, Dam, Gunda and Mandaragrau sites with their respective values of 713.00, 665.00, 643.00, 508.00 and 435.00 m. Also, Piku recorded the highest steepness followed by Kigir, Mirnga, Dam, Mandaragrau, and Gunda with their respective values at 9.00, 8.00, 7.00 and 6.00. Slope length ranged from moderate to high, while percentage of slope was ranked high in terms of soil loss across sites. Kigir site with high slope length and percentage has high risk of soil erosion than Piku, Mirnga, Dam, Gunda and Mandaragrau sites with shorter length and considerable percentages of slope steepness as a result of volume and velocity of runoff in the sites. Soil erosion occurred in all the sites, because of the percentages of slope steepness were above 5 %. This observation concurs with that of Stefanidis et al., (2022), that percentage slope steepness less than 5 % erosion hazard is negligible.

Cover Management Factor

The cover management factor (C – Value) of the study sites (Table 2) in 2020, ranged from 0.12 - 0.23. The highest C – value was recorded at Mirnga followed by Piku and Kigir and then Mandaragrau and Dam sites and their values which were recorded at 0.23, 0.14, 0.12, 0.12, and 0.12

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respectively. The vegetation varies from grain corn and corn soybean rotation with ridge tillage at all the sites. The vegetation of the various sites varied from guinea corn, bean, and soybean, grain corn with ridge tillage and chisel plow. The C – value is dimensionless with values between 0 and 1 (Molla and Sisheber, 2017).

Protection Management Factor

Table 2 depicts protection and management factor (P – Value) in terms of land used. The study sites ranged within slope percentage of 5 – 10 %, respectively. Piku sites had the highest P – value followed by Kigir, Mirnga, Dam, and Mandaragrau. Protection and management factor (P – value), and topography of the study sites showed that Piku (9%) had high slope percentage followed by Kigir (8%) Mirnga (7%) site, Dam, Mandaragrau and Mirnga sites recorded the same value of 6%. Also, the P – value of all the sites was 0.12. The P – value reduce the amount and rate of the water runoff, and then reduced the amount of soil erosion. This observation concurs with that of Wishmeir and Smith (1978) and Renard *et al*., (1997) that the P factor reflects the practice that will reduce the amount and rate of the water runoff and thus reduce the amount of soil erosion.

Table 2: Soil Erodibility Factor, Slope Length and Steepness, C and P Values of the Various Study Sites in Biu Area

Study sites	Soil erodibility (k)	Slope len.	Slope %	C – Value	P - Value
Piku	0.70B	713.00B	9.00A	0.14C	0.12
Kigir	0.70B	785.00A	8.00B	0.14C	0.12
Dam	0.82A	643.00D	6.00D	0.12D	0.12
Mirnga	0.82A	665.00C	7.00C	0.23A	0.12
Mandaragrau	0.82A	435.00F	6.00D	0.12D	0.12
Gunda	0.82A	508.00E	6.00D	0.12D	0.12
$SE_{0.05}$	**4.869**	**2.556**	**0.064**	**3.776**	

Source: 2020

Key : SE = Standard error, Mand. = Mandaragrau site, C – values = cover and management factor, P – value = protection and management factor, Slope len. = slope length, Slope % = slope steepness.

Means followed by the same letter (s) in a column are not significantly different at $p < 0.05$

Soil Loss Rates in Biu Area

Annual soil loss by Empirical and RUSLE 2, models in the study sites in 2020 is shown in Table 3 in 2020. The soil loss generally differed significantly ($P<0.05$) among sites and season. The soil loss estimated by empirical model was significantly ($P<0.05$) higher at Piku followed by Dam, Kigir, Mandaragrau, Gunda and Mirnga. The RUSLE 2 predicted soil loss was significantly ($P<0.05$) higher at Piku (447.00 $kgha^{-1}yr^{-1}$), Kigir (330.00 $kgha^{-1}yr^{-1}$), Dam (307.00 $kgha^{-1}yr^{-1}$), Mandaragrau (292.00 $kgha^{-1}yr^{-1}$), Mirnga (269.00 $kgha^{-1}yr^{-1}$), and Gunda (260.00 $kgha^{-1}yr^{-1}$) respectively. The respective range for empirical and RUSLE 2, models was 168.38 – 337.00 and 260.00 – 447.00 $kgha^{-1}yr^{-1}$. The soil loss measured by empirical model was significantly ($p <0.05$) higher at Piku followed by Dam and Kigir then Mandaragrau, Gunda and Mirnga sites with their respective values at 337.10, 227.58, 224.71, 193.49, 184.88 and 168.38 Kg $ha^{-1}yr^{-1}$, in the study sites.

The annual soil losses across sites in the study area was influenced by the intensity of rainfall recorded (Table, 1), soil erodibility, slope length and steepness, vegetation and protection management factor (Table, 2) this observation concurs with the report of Moller and Sisheber (2017) that soil erosion is influenced by soil erodibility, rainfall intensity, slope length and steepness, vegetation (poor land cover), and protection management factor (improper land management)

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Table 3: Annual Soil Loss Estimated by Empirical and RUSLE2 Models (Kg $ha^{-1}yr^{-1}$),

Study Site	Empirical model	RUSLE2 model
Piku	337.39A	447.00A
Kigir	224.71C	330.00B
Dam	227.58B	308.00C
Mirnga	168.38F	269.00E
Mandaragrau	193.49D	292.00D
Gunda	184.88E	260.29F
SE $_{0.05}$	**0.107**	**0.108**

Source: 2020
Key: SE = Standard error.
Mean followed by the same letter (s) in column are not significantly different at $p < 0.05$

Annual Validation of Soil Loss in Biu Area

Figure 1 shows the performance of RUSLE2 and empirical models in predicting soil loss in the entire study area in 2020. The model recorded the r^2 value of 0.8553. The RUSLE2 model prediction accuracy in Biu area, in terms of soil loss was 85.53. This observation concurs with the report of Thomaz, (2013) about the range of 44.9 – 92%.

The model's high prediction ability across sites was because it is land use independent and applies to all conditions where rill erosion occurs when natural soil is exposed to the erosive forces of impacting raindrops and water drops falling from vegetation and runoff produced by Hortonian overland flow. This observation concurs with the report of Lemma *et al*. (2017), that the RUSLE2 (2016) was land use independent and applies to all conditions where rill erosion occurs when natural soil was exposed to the erosive forces of impacting raindrops and water drops falling from vegetation and run off produced by Hortonian overland flow.

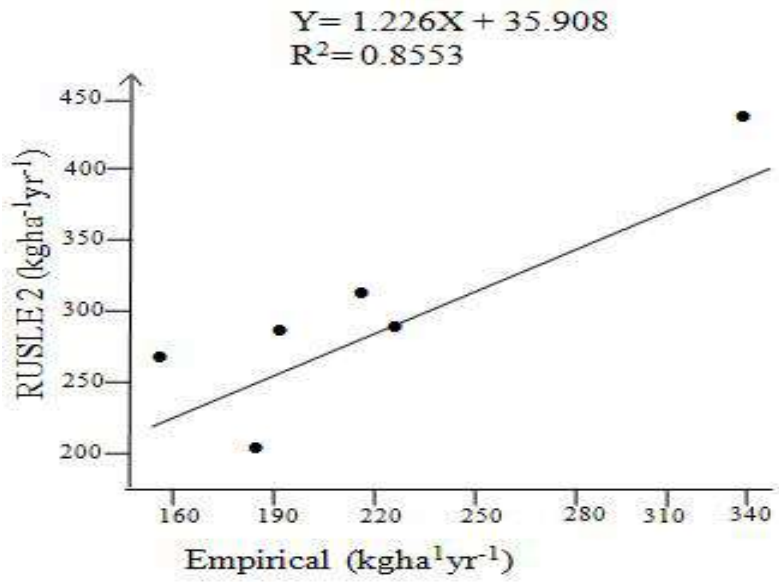

Figure 1: *Annual validation of soil loss using aggregate empirical and RUSLE2, estimates in the study area.*

Nutrient Loss

Table 4 shows soil nutrient loss at various sites in Biu area in 2020. Soil organic matter loss ranged from 2.01 to 3.80$kgha^{-1}yr^{-1}$. The soil organic matter loss was significantly ($p < 0.05$) higher at Piku followed by Kigir, Mirnga, Gunda, Mandaragrau and Dam sites with their respective values at 3.80, 2.72, 2.36, 2.35, 2.24 and 2.01$kgha^{-1}yr^{-1}$. The soil organic matter loss across sites was higher than N, P, K losses. This observation concurs with the report of Schick *et al*., 2000; Ali *et al*., 2007;

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Lemma *et al*.,(2017) that the loss of organic matter in sediments was higher followed by the loss of N, P, K. Nitrogen loss at various sites ranged from 1.37 to 2.69kgha^{-1}yr^{-1}.

Table 4: Soil Nutrients Loss at Various Sites in Biu Area

Site	O.M	N	P	K	Ca	Mg	S
Kgha^{-1}yr^{-1}							
Piku	3.82A	2.22A	1.95A	2.72A	2.35A	1.49E	1.02E
Kigir	2.72B	1.48B	1.34B	1.82B	1.69B	1.62D	1.69B
Dam	2.01E	1.14E	1.94A	1.22F	1.29F	1.72A	1.85A
Mirnga	2.35C	1.34C	1.20C	1.69C	1.61C	1.74A	1.62C
Mandaragrau	2.24D	1.22D	1.02E	1.47E	1.37E	1.66C	1.08D
Gunda	2.36C	1.21D	1.11D	1.54D	1.44D	1.68B	1.64C
SE $_{0.05}$	**9.851**	**9.400**	**0.010**	**1.972**	**6.266**	**8.650**	**7.058**

Source: 2020
KEY: SE = standard error, O.M = organic matter, N = Nitrogen, P = Phosphorus, K = Potassium, Ca = Calcium, Mg = Magnesium, S = Sulphur
Mean followed by the same letter (s) in column are not significantly different at $p < 0.05$

Soil and Nutrient Loss

Table 3 and 4 depicted annual soil and nutrients loss at various sites in Biu Area in 2020. Soil loss was significantly ($P<0.05$) higher at Piku with corresponding nutrients loses in the form of organic matter (O.M), nitrogen, Phosphorus, Potassium, Calcium, Magnesium and Sulphur, followed by Kigir, Dam, Mandaragrau, Mirnga and Gunda sites. Soil and nutrients losses at Piku site were recorded at 447.00, 3.80, 2.20, 1.95, 2.72, 2.35, 1.49 and 1.02 Kgha^{-1}yr^{-1}, respectively. Gunda site had soil O.M, N.P.K, Ca, Mg and S losses at 260.00, 2.36, 1.21, 1.11, 1.54, 1.44, 1.68 and 1.64Kgha^{-1}yr^{-1}, respectively. This observation concurs with the report of Schick *et al*., (2000); Ali *et al*., (2007); Lemma *et al*., (2017) that the loss of organic matter in sediments was higher followed by loss of K, N, and P.

CONCLUSION AND RECOMMENDATION

The extent of rill erosion was quantified using empirical and RUSLE2 models prediction techniques under same condition of Biu environment. RUSLE2 estimates rates of rill and interill soil erosion caused by rainfall and its associated overland flow. **5**Soil nutrients (N, P, K, Ca, Mg and S) were aiso estimated at all the sites. The pattern, rate and estimates of soil and nutrients losses were confined to rainfall amount as the season progressed to a peak in the month of July and therefore decline with cessation of rainfall in October in the study area. Soil and nutrients loss were significantly ($p < 0.05$) higher at Piku followed by Kigir, Mirnga, Mandaragrau, Gunda and Dam in this study. RUSLE2 model gave high prediction accuracies of soil loss, while the empirical model had moderate accuracies in terms of soil loss prediction in the study sites. However, both models showed low to high prediction strength at locational bases. On aggregate basis RUSLE2 model surpassed with greater strength of prediction accuracy than empirical model.

Concerning management strategies to reduce soil and nutrients losses, intervention will focus on the slope length and steepness, conservation management factor and support practice factor as the erodibility and runoff factor cannot be changed. Based on the results of this study, the following recommendations were made:

i. Mulching; - mulch is any layer of material applied to the surface of the soil to protect the soil from the erosion and evaporative effects of wind and sun. Mulch can be plant material, like straw and wood chips or it can be gravel or non – living material like recycled glass, cinders, decorative rock and recycled rubber.

ii. **Cover Crops and Vegetation**; - cover crops increase soil health improves soil structure and reduces the need for costly inputs such as fertilizer and mechanical tillage. Cover crops protect water quality by slowing erosion and runoff and increases water infiltration and retention.

iii. No tillage method; - in zero tillage, the land for crop cultivation is left undisturbed from harvest to planting or not ploughed at all while in the case of minimum tillage, just holes for planting are made and only at the places where the crop is going to be planted or grain sown. A combination of no tillage with crop residue mulch is more effective in runoff and erosion control

iv. Buffer Zones; - buffer zone increases the capture of sediments and organic materials. It is revealed that buffer zone increase the trapping of sediments and infiltration from 10 to 90 %. Vegetative buffers decrease the runoff velocity of water.

v. Terraces; - terraces are mechanical structures such as an earthen ridge or stone wall which reduces the slope steepness and divides the slope into short gentle sloping sections. Terraces reduces the runoff velocity and soil loss, increases the soil moisture content through improve infiltration, reduce evaporation and can be created to divert runoff to a prepared or safe area for minimizing the effect of soil erosion to a tolerable level.

vi. **Contour Bunds**; - as progressive terraces, contour bunds are suited to flat areas of slope less than 16 %. Contour bunds can reduce the soil erosion and increase the soil water holding capacity in the intervention area.

vii. **Check Dam; -** check dams are structures constructed across a channel or a river to lesson water velocity and to catch sediments.

viii. **Anti – erosive ditches**; -an anti – erosive channel is a drainage channel constructed to prevent runoff water from upper hill to enter a cropped land. In this channel, water may infiltrate or may be diverted.

ix. **Grassed waterways**; - grassed waterways are more important in filtering by retaining runoff sediments, pollutants and other particulate matter within storm water and their performance will depend on soil permeability within the area.

x. **Hill side water ponds**; - rain water harvesting is a system of collecting water through different technologies such as storage of rain water on surface reservoirs and ground water recharge for future use. The use of ponds for retaining water reduces soil erosion.

xi. Retaining walls made of gabions for slope stabilization; - retaining walls are structures made of masonry, stone, brick, concrete or combination of these. They are used as erosion control structures. Comparatively to other retaining walls, the main advantage of gabions retaining walls is to reduce the runoff velocity or to increase the stability of sloping surface area with seepage problems.

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CASSIA TORA SEED AS AN ALTERNATE HOST FOR *CALLOSOBRUCHUS SUBINNOTATUS* (COLEOPTERA: BRUCHIDAE) IN STORED BAMBARANUT

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ABSTRACT
The study was aimed to determine the possibility of *C. subinnotatus* as an alternate pest attacking *cassia tora* seed. An infested *C. tora* seed were collected from Soro market in Ganjuwa LGA in Bauchi state. A fresh *C. tora* seed were sorted and transferred into an earthen clay pot. Thereafter, weevils were transferred into the earthen clay pot. After two weeks, dead and live parent stocks were completely sieved out to await the adult emergence. A fresh uninfected Bambara ground nut seeds were fumigated for 48 hours spread on a clean polythene mat covered with baft cloth to remove any residual effect of the fumigant and to exclude reinfestation. 10 pairs of laboratory reared F_2 generation of *C. subinnatatus* were introduced into the treated and untreated Bambara nut seeds already contained in plastic jars. The top of plastic jars was covered with a fine muslin cloth and kept at room temperature (29 – 32^{o}C) in the laboratory and observation on oviposition, adult emergence, number of exit hole was made for one month. Oviposition, adult emergence, number of exit hole was of observed on Bambara ground nut seed. The result showed Sharp, a small, round punctured holes were observed on the surface of Bambara ground nut. The eggs were singly laid inside the seeds. Upon hatching, the first instar larva exits through the seeds and hover around the seed cotyledons and turning it into a mass of reddish colour suggesting that farmers should avoid storing Bambara ground nut in a place where there is infested *Cassia tora* seeds.

Keywords: *Cassia tora*, *Callosobruchus sobinnatatus*, Bambaranut, F_2 genaration.

INTRODUCTION
Cassia tora is considered an annual weed, is very stress-tolerant, and is easily grown. In Nigeria, it occurs as a wasteland rainy season weed and its usual flowering time is after the monsoon rains, during the period of October to February. *Senna tora* grows in dry soil from sea level up to 1800 meters (Augustine *et al*., 2010). The seed can remain viable for up to twenty years (Subramanion *et al*., 2012). Up to 1000 plants can emerge per square meter following rain. Once the seed has matured, it is gathered and dried in the sun. In South Asia, it usually dies off in the dry season of July–October *Cassia tora* seed is a common herbaceous animal plant and an estimated 30, 000 metric tonnes of the seeds are produced annually (Ingweye *et al.,* 2010). It belongs to the family of Fabaceae (Caesalpinaceae) and other names for the plant include sickle senna, coffee weed, coffee pod or "java bean" (English), gyeolinyeongja (Korean) and *Tafasa* (Hausa) (Muhammad *et al*., 2024). In Nigeria, *Cassia tora* seed is mostly grown in the Northern part of the country in areas were it not been cultivated during the rainy season. It tolerates a wide range of climate and temperature though, it prefers warmth and it is a good source of energy and protein meters (Augustine *et al*., 2010). *Cassia tora* has the following approximate composition: carbohydrate 66-69 %, protein 14-19 %, fat, 5-7 % and anti-nutritional anthraquinone, 1-2 % (Li *et al*., 2004). Senna is an invasive weed capable of dominating farmlands due to its high seed production capability. All parts of this plant are useful, including the leaves, seeds, and roots as reported by Shreeji Agro (2014) and Aliyu (2006). the leaves are obovate and alternate, consisting of three pairs of leaflets. The leaflets are opposite and pinnately arranged. The leaves are widely eaten as an additional source of food mixed with groundnut cake

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"kuli-kuli" amongst the Hausa community and it is use for making soup. The flowers are brightly yellowed. The rhombohedral brown seeds are enclosed in highly beaked, curved, brown pods of 12-18 cm long enclosed with 18-28 seeds. It is a dry dehiscent pod-bearing plant. Due to its vigorous growth habit, it is typically the first plant to sprout following the first rain after a long period of dry season, making it an important source of pasture for grazing animals. The cosmetic and livestock feed formulation industries both value *C. tora* seeds as raw materials in the cosmetic industry as well as in the formulation of livestock feeds including fishes (Altrafine, 2013; Dasuki *et al*., 2014). The leaves are a precious food product commodity across international borders. The dried leaves of *C. tora* are traded internationally, between Nigeria and Niger Republic (Muhammad *et al*., 2017). The weed was widely reported to be used in ethnomedicine. Aliyu (2006) reported the utilization of *C. tora* leaves in mild laxatives, eye diseases, liver stimulants, heart tonics, dysentery, and anthelmintics or relieving constipation. Altrafine (2013) reported dried and fresh leaves are used in northern Nigeria in the treatment of ulcers, ringworm, and other parasitic skin diseases. The seeds of the plant are used greatly by the Ancient Chinese as an herb (Sheeji Agro, 2014). Altrafine (2013) reported leaves of *C. tora* as containing natural chemicals such as chrysophanic acid-9-anthrone, a valued fungicide often used as a natural pesticide in organic farms in India. However, the seed of *C. tora* is vulnerable to attack by insect which significantly damage the seed in a small period of time, this study is therefore carried out to determine the alternate host other than *C. tora* seed to avoid reinfestation of this insect on other crops.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at General laboratory, Faculty of Agriculture Sa'adu Zungur University Bauchi. Bauchi state is located between latitude 10^0 22'E and $9^0$48'E and situated at 690.3m above the sea level in Savannah zone of Nigeria.

Samples of *C. subinnatatus* were collected from previously infested Cassia seeds obtained from Soro market in Ganjuwa Local Government Area of Bauchi State, Nigeria (Plate vi). The insects were brought to the laboratory and kept at room temperature 28 + 2 ^{0}C and relative humidity 70 + 5%. 10 kg of sound uninfested *C. tora* (Plate ii) seeds was weight and transferred into an earthen clay pot. Thereafter, *C. sobinnotatus* were transferred into the earthen clay pot. A 20 perorations were made for the ventilation of an insects tied firmly and were allowed to oviposit under crowded conditions in a light:dark regime of 12L:12D at room temperature and relative humidity for Two weeks. Dead and live parent stocks were completely sieved out to await the emergence of F_1. The same procedure was used with F_1 generation to obtain F_2 generation used for the experiment.

Disinfestation of Bambara Nut Seeds

The Seeds were manually sorted to remove broken seeds with holes and other contaminants were sieved out using a mesh to remove insects and remaining contaminants. The sorted seeds were fumigated with Aluminium Phosphide (Phostoxin tablets) at the rate of 0.2 g/kg for 72 hours under airtight conditions to exclude any possible infestation that may affect the seeds as described by (Awoke *et al*. 2014). After 72 hours, the fumigated seed was spread on a clean polythene mat (plate ii)) covered with baft cloth to remove any residual effect of the fumigant and to exclude reinfestationfor 48 hours.

Observation

The observation on adult emergence was made at weekly interval to detect the infestation and assess the level and nature of damage which include oviposition, number of exit holes and adult emergence.

RESULTS AND DISCUSSION

Nature of Damage of *Callosobruchus subinnotatus* on Bambara nut

Sharp, a small, round punctured holes were observed on the surface of Bambara nut (Plate iv). The eggs were singly laid inside the seeds. Upon hatching, the first instar larva (plate iv) exits through

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the seeds and hover around the seed cotyledons and turning it into a mass of reddish colour. The eggs were also laid on the surface of the seeds (plate vii). Exit holes was serves as evidence of larval activity on the seeds. Pupation occurred inside the seeds. Later, the adult emerges after metamorphosis completion and starts another life cycle. This study agreed with that of Abbas *et al*. (2010) who reported a method for bringing the host plant to the laboratory and confirming the relationship between the host and the pest if the invasion in the field could not be confirmed. This is in line with that of Muhammad *et al*., (2022) who reported that *C. subinnotatus* is widely known to be a primary pest of Bambara nut, Vigna subterranean (L.) Verdcourt. Proximate analysis of *C. tora* showed that it contain high amount of protein and carbohydrate which could serves as nutrition to the insect under study. Shahid *et al.* (2022) have earlier reported that under ideal laboratory conditions, adult female insects should be bred on the target host plant. If the pest completes its life cycle and produces a crawler sac in the host plant, the host plant should be documented as the pest scale insect's host. The insect is reported in this research as an alternative host in periods when Bambara nut is not available.

CONCLUSION AND RECOMMENDATION

From the result obtained, it could be concluded that *Cassia tora* seed is an alternate host for *C. subinnotatus* attacking Bambara nut under storage. To prevent infestation of *Calosobruchus subinnotatus* (a type of weevil) that attacks Bambara nut, farmers should avoid introducing *Cassia tora* seeds into their storage facilities.

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EFFECT OF SENNA *TORA* LEAF MEAL COMBINED WITH YEAST-FERMENTED SORGHUM STALKS ON GROWTH PERFORMANCE AND ECONOMICS OF RED SOKOTO BUCKS

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ABSTRACT
The study evaluated the effects of *Saccharomyces cerevisiae* inoculant on the silage quality of sorghum stalks and its nutritional impact when combined with *Senna tora* leaf meal (STLM) in diets for growing Red Sokoto bucks (RSBs). Sorghum stalks were ensiled with yeast and molasses under anaerobic conditions for 21 days. Fifteen (15) healthy RSBs of between 8 – 9 months with an average weight of 9.62 ± 0.88 kg were randomly assigned to five dietary treatments over a 47-day trial. The diets incorporated varying proportions of ensiled sorghum stalks (ESS) and STLM: A (0% ESS:100% STLM), B (100% ESS:0% STLM), C (95% ESS:5% STLM), D (90% ESS:10% STLM), and E (85% ESS:15% STLM), formulated per 100 kg of dry matter. STLM demonstrated high nutritional value, with elevated crude protein (26.99%), metabolizable energy (2,265.60 kcal/100 g), and low fiber content (8.85%). Phytochemical analysis revealed tannins (8.03 mg/100 g), phytates (4.61 mg/100 g), glycosides (1.09 mg/100 g), and trace sennosides (0.1 mg/100 g), while saponins and cyanide were absent. Diets containing (STLM: ESS) significantly influenced ($P<0.05$) nutrient composition, with treatment C showing the highest nitrogen-free extract (NFE) of 48.00% and lowest crude ash (6.99%) and fiber (22.37%), enhancing NFE ($P < 0.05$). Growth performance was notably improved by the inclusion of STLM and ensiled sorghum stalks, with treatment E having the highest ($P<0.05$) average daily gain (85 g/day) and most efficient feed conversion ratio (5.62 kg) feed/kg gain; . Diet E (85% ESS:15% STLM)) is hereby recommended for optimum nutrient utilization and feed efficiency in Red Sokoto Bucks.

Keywords: Red, Sokoto, Bucks, Saccharomyces, Cerevisiae, Sorghum

INTRODUCTION
In Sub-Saharan Africa, goat rearing remains a vital source of livelihood for smallholder farmers, contributing to household nutrition, income stability, and adaptive capacity in the face of climate variability. As farming systems increasingly shift toward sustainable, integrated crop–livestock models, there is growing interest in utilizing locally available feed resources to reduce costs and improve resilience (Ndona *et al*., 2024; Ngambi *et al*., 2025; Assan, 2021). *Senna tora* (also known as *Cassia tora* or sicklepod) is a leguminous species gaining attention for its potential in small ruminant nutrition (Assan, 2021). Its foliage offers a moderate supply of crude protein (12.4%) and fibre (18.8%), along with key minerals such as calcium and phosphorus (Buba *et al*., 2024). Despite these benefits, its use in goat diets is limited by the presence of antinutritional compounds namely tannins, anthraquinones, and lectins which can interfere with digestion and overall health (Kumar *et al*., 2019; Singh & Sharma, 2020). Tannins, for instance, may reduce protein availability by forming indigestible complexes (Mueller-Harvey, 2006).

Sorghum stalks, when processed into silage or pelleted complete rations, serve as a reliable roughage source for goats, providing sufficient fiber and energy while supporting consistent weight gain and maintaining favorable nitrogen and mineral balance (Dhore *et al*., 2025). Recent advances in feed processing have further enhanced the nutritional value of sorghum stalks.

The purpose of this study is to investigate the potential of *Senna tora* leaf meal (STLM) in suitable combination with yeast treated sorghum stalks as a cost-effective alternative to conventional feed concentrates in goat production systems. Specifically, we evaluate the chemical composition and

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antinutritional profile of STLM, identify optimal inclusion levels in (STLM-ESS) based diets, and assess their effects on growth performance and economic returns in growing Red Sokoto bucks.

MATERIALS AND METHODS

Study Area and Environmental Conditions

The research was carried out at the Ruminant Unit of the Teaching and Research Farm, of the Department of Animal Science, Federal University Gashua, Yobe State, Nigeria.The experimental site experienced a very high average temperature in March and April, reaching up to 41.34°C, while the rainy season spans from June to September, with August being the wettest month (237.09 mm). During the dry season, relative humidity averages between 12% and 35%, with April recording 18.48% (Climatemp, 2025).

Experimental Design and Animal Management

Fifteen (15) clinically healthy Red Sokoto bucks (RSBs), with age of 8-9 months and weight average of 9.6 ± 0.88 kg, were sourced from the Garin Alkali livestock market and subjected to veterinary screening prior to the trial. Animals were randomly allocated to five dietary treatments in a Completely Randomized Design (CRD), with three replicates per group. Each buck was housed individually in a well-ventilated 1.2×0.8 m pen enclosed with wire mesh. A two-week quarantine period preceded the experiment, during which ivermectin (1 mL/50 kg BW) and oxytetracycline (1 mL/10 kg BW) were administered. Bucks were fed a total mixed ration (TMR) at 5% of body weight (600 g/day DM), split into two meals at 08:00 am and 5:00 pm, with ad libitum access to clean water. Feed refusals were removed prior to each feeding. Initial body weights were recorded, and weekly measurements were taken throughout the 47-day trial. Following a two-week acclimatization period, data on feed intake, nutrient consumption, price of feed ingredients and feed conversion ratio were collected.

Ensiling Process of Sorghum Stalks

The yeast (*Saccharomyces cerevisiae*) used for the fermentation process was sourced from Animal Care Consult, Kano, Nigeria. Following the procedure outlined by Musa *et al*. (2024), a 5-liter solution containing 50 g of yeast and 2 kg of molasses was prepared and thoroughly mixed with 92.95 kg of chopped sorghum stalks to produce a 100 kg silage batch. Two such batches were prepared for the experiment. The mixture was packed into thick black polythene bags and sealed tightly to promote anaerobic fermentation. Air was expelled manually by compressing the bags as much as possible, using a heavy metal weight carefully placed on top to minimize oxygen exposure. After a 21-day fermentation period, the silage was opened and exposed to ambient air overnight in a shaded area to allow the dissipation of volatile ammonia gases, as recommended by Olafadehan *et al*. (2016).

Measurement, Source, and Formulation of Experimental Diets

Senna tora leaves were sourced from the Garin Alkali Livestock Market, thoroughly cleaned to remove impurities, air-dried, and milled into leaf meal (STLM). Sorghum stalks and all supplementary feed ingredients were procured from the Gashua Market in Yobe State. Five experimental diets were formulated and labeled as A, B, C, D, and E. Diet A served as the control, containing no yeast-treated sorghum stalks (ESS) or STLM. Diet B consisted entirely of (100% ESS + 0% STLM:), while diets C, D, and E incorporated increasing levels of STLM at 5%, 10%, and 15%, respectively, with corresponding reductions in ESS (i.e., C: 95% ESS + 5% STLM; D: 90% ESS + 10% STLM; E: 85% ESS + 15% STLM), based on 100 kg of dry matter (DM). The detailed composition of each diet (kg/100 kg DM) is presented in Table 1.

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Table 1: Gross Composition of Experimental Diets (kg/100kg DM)

Ingredients	A	B	C	F	E
Ensiled Sorghum Stalks (ESS)	0.00	15.0	14.25	13.5	12.75
Senna tora leaf meal (STLM)	0.00	0.00	0.75	1.50	2.25
Cowpea husk	22	7	7	7	7
Maize	20	20	20	20	20
Wheat bran	20	20	20	20	20
Peanut Cake	10	10	10	10	10
Ziziphus spp. leaf meal	25	25	25	25	25
Salt	1	1	1	1	1
Ruminant premix	2	2	2	2	2
TOTAL	100kg	100kg	100kg	100kg	100kg
Calculated analysis					
Crude protein (%)	13.49	13.42	13.33	13.48	
GE (KJ/100g DM)	8.22	8.31	8.29	8.24	

GE: Gross energy, A; (0% ESS: STLM), B; (100%: 0%ESS), C; (95%ESS:5% STLM), D; (90%ESS:10%STLM) and E; (85%ESS: 15% STLM) kg/100kg of dry matter (DM)

Phytochemical Analysis

Phytochemical screening of *Senna tora* leaf meal was carried out to identify bioactive compounds relevant to ruminant nutrition. Air-dried and ground samples were analyzed for tannins, saponins, alkaloids, and glycosides using spectrophotometric methods, following protocols described by (Subramanian et al., 2021).

Chemical Analysis of Experimental Diets

Representative samples from five experimental diets containing *Senna tora* leaf meal (STLM) and yeast-treated sorghum stalks (ESS) were collected in sterile bags (labelled A–E) and transported for laboratory analysis. Samples were oven-dried at 60 °C for 96 h, ground (Wiley mill), and sieved (1 mm mesh). Proximate composition was determined in triplicate following AOAC (2016) protocols. Moisture was measured gravimetrically (105 °C), ash via dry ashing (550 °C), and crude protein by micro-Kjeldahl digestion (Cu–Se catalyst, H_2SO_4, distillation, titration). Lipid content was extracted using petroleum ether (40–60 °C) in a Soxhlet apparatus, and crude fibre was quantified by sequential acid–alkali digestion and correction for ash. Nitrogen-free extract (NFE) was calculated by difference. Fibre fractions (NDF, ADF, ADL) were analyzed using an ANKOM fibre analyzer (Van Soest *et al*., 1991), with hemicellulose and cellulose derived by subtraction. Gross energy (MJ/kg DM) was estimated using the predictive equation: GE = (%CP × 16.7) + (%EE × 37.7) + (%CHO × 16.7) described by (Robinson *et al*., 2004).

Growth Performance Study

Bucks were weighed individually at the beginning of the experiment and, thereafter, weekly for the duration of the experiment. Weighing was done before the morning feeding. The parameters determined for the evaluation of growth performance were initial weight (g), average daily feed intake (g), average daily weight gain (g) and feed conversion ratio. Weight gain for each animal was calculated by subtracting the initial weight (g) from the final weight (g), while the feed conversion ratio was calculated by dividing the total feed intake (g) by the total weight gain (g).

Economic Evaluation

Profitability of feeding ruminants with diets containing *Senna tora* leaf meal (STLM) and *Saccharomyces cerevisiae*-treated sorghum stalks silage was assessed relative to a control diet. Total feed costs were calculated based on ingredient prices, and key economic indicators average weight gain, feed cost per kg gain, and feed intake per kg gain were evaluated. Cost savings (in Naira) were computed by comparing feed cost per kg gain against the control, then converted to USD using the Central Bank of Nigeria exchange rate (1 USD = NGN 1666.00, as of 24/06/2025).

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Statistical Analysis

All data were subjected to analysis of variance (ANOVA) using SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA, 2004) within a Completely Randomized Design (CRD) framework. Dietary treatment was modeled as the primary fixed effect. Where significant differences were detected, mean separation was performed using the Least Significant Difference (LSD) test. Statistical significance was declared at $P < 0.05$.

RESULTS AND DISCUSSION

The Proximate Profiles of *Senna tora* Leaf Meal (STLM) and Sorghum Straw (SS)

The result revealed that *Senna tora* leaf meal (STLM) had 26.99 % Crude Protein (CP) and 2,266 kcal ME 100 g^{-1}, whereas SS contained only 5.56 % CP and 683 kcal ME 100 g^{-1}. The CP and ME values of ESS were close to 3.7 % CP and 18 MJ GE kg^{-1} DM for sorghum residues (INRA. 2017). Conversely, STLM had higher CP within the range (17–39 %) reported for high-protein *S. tora* ecotypes (Bañares, *et al*. 2019) and matches the 27 % CP value recently measured for *C. tora* foliage (Sahu, *et al*. 2019). The higher ether extract (7.04 % vs. 4.60 %) further boosts the energy density of STLM, positioning it as a dual protein–energy diet capable of correcting the N and energy deficits of straw-based rations. ESS exhibited an extreme crude-fibre concentration (39 %), aligning with 39–40 % CF and 77 % NDF for sorghum straw (INRA. 2017). Such lignified cell walls depress fermentability and voluntary intake. STLM, by contrast, contained only 8.85 % fibre, providing a readily fermentable carbohydrate pool that can stimulate rumen microbial growth when co-fed with high-fibre residues. Both feeds were ash-rich (16.08 % in STLM; 14.49 % in SS), suggesting that either ingredient could contribute macro- and micro-minerals. High ash levels in legume leaves are often linked to desirable Ca and trace-element concentrations. Leaf meals with 24–27 % CP have repeatedly improved straw intake and average daily gain.

Table 2: Nutritional Value of *Senna tora* Leaf Meal and Ensiled Sorghum Stalks Treated with Yeast (% DM basis)

Parameter	*Senna tora* Leaf Meal	Sorghum straw*
Crude Protein	26.9	5.56
Ether Extract	7.04	4.60
Moisture Content	5.45	4.24
Dry Matter	94.56	95.51
Crude Fibre	8.85	39
Ash Content	16.08	14.49
Nitrogen-Free Extract	35.60	32.11
Carbohydrate Content	44.44	ND
Metabolizable Energy (Kcal/100g)	2265.60	683

***(Tian *et al*., 2024)**

Phytochemical Composition of *Senna tora* Leaf Meal (STLM)

The phytochemical analysis of Senna tora leaf meal revealed the presence of several bioactive compounds with moderate values (Table 3). Tannins were detected at 8.03 mg/100 g, a level consistent with the moderate range (3–8 mg/100 g) reported to enhance protein protection in ruminants without impairing digestibility (Min & Solaiman, 2018). Phytates were present at 4.61 mg/100 g, which is slightly above the 3–4 mg/100 g threshold commonly associated with reduced mineral bioavailability. While phytates was 4.61 agreeing with the value of *Cassia tora* fed to sheep. (Nkwocha *et al*., 2014). Saponins and cyanide were not detected in the analyzed samples, suggesting a favorable safety profile. This contrasts with findings in some tropical forages where saponins exceed 3 mg/100 g and may impair rumen microbial activity (Roy *et al*., 2014). Glycosides were present at 1.09 mg/100 g, a level considered low and unlikely to exert toxic effects. Sennosides, known for their laxative properties, were detected at 0.1 mg/100 g, indicating minimal risk of gastrointestinal disturbance under typical feeding conditions. These results suggest that STLM contains beneficial

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phytochemicals at safe concentrations, supporting its potential as a functional feed ingredient in small ruminant diets. The absence of toxic compounds and the presence of moderate tannins and glycosides may contribute to improved nutrient utilization and immune modulation, as observed in recent goat trial. (Hamid *et al*., 2025; Min & Solaiman, 2018).

Table 3: Phytochemical Composition of *Senna tora* Leaf Meal (STLM)

Phytochemical	Presence (+) / Absence (−)	Value (mg/100g)
Tannins	+	8.03
Phytates	+	4.61
Saponins	-	0.00
Glycosides	+	1.09
Cyanide	_	0.00
Sennosides	+	0.10

The chemical analysis of ration A–E showed that dry-matter, organic-matter contents, ADF and NDF did not differ statistically ($P > 0.05$), whereas all other measured parameters varied significantly (Table 4). Ration C recorded the highest dry matter (92.09 %) and organic matter (93.01 %), pointing to better preservation and limited residual moisture an outcome comparable to that reported for leguminous feeds by Zhang *et al*. (2023). Crude-protein values fell between 13.45 % (ration E) and 15.28 % (ration A). The crude protein values observed in this study, ranging from 13.45% to 15.28%, align with recent findings that confirm dietary CP levels of (13.00% - 16.00%) effectively support maintenance and growth in Boer crossbred goats (Hamid *et al*., 2025). Crude-ash content ranged from 6.99 % in sample C to 10.67 % in sample D ($P < 0.05$), a span consistent with the mineral residues typically observed in plant-derived feedstuffs (Kumar *et al*., 2022). Crude fibre peaked in sample E at 30.13 %, the overall range of 22.37–30.13 % was significant ($P < 0.05$) and mirrors variation documented for tropical forages (Adeyemi *et al*., 2021). Crude fat of ration E reached 2.17 %, whereas ration D contained only 0.67 %. This parameter was significant ($P < 0.05$), and the higher lipid level in sample E may reflect fermentation influences noted by Chen *et al*. (2023). The NFE was significant ($P<0.05$), The nitrogen-free extract (NFE), that is the readily soluble carbohydrate fraction of ration C was 48.00 %, with ration A having the lowest at 36.63 %. Acid-detergent fibre (ADF) dropped from 29.23 % to 25.21 %, and neutral-detergent fibre (NDF) from 31.21 % to 28.02 %. Although these reductions were not statistically significant ($P > 0.05$).

Table 4: Nutrient Composition of Experimental Rations (% DM)

	Treatments						
Item (%)	A	B	C	D	E	SEM	P-value
Dry Matter	89.53	90.29	92.09	90.79	91.70	4.78	0.34
Organic Matter	89.62	89.51	93.01	89.33	91.70	4.96	0.26
Crude ash	10.38^{a}	10.49^{a}	6.99^{c}	10.67^{a}	8.06^{b}	1.75	0.02
Crude fibre	25.57^{a}	23.24^{a}	22.37^{c}	25.63^{a}	30.13^{a}	1.35	0.03
Crude protein	15.28^{a}	13.82^{b}	13.56^{b}	15.20^{a}	13.45^{b}	1.40	0.02
Crude fat	1.67^{b}	1.17^{c}	1.16^{c}	0.67^{d}	2.17^{a}	0.26	0.04
NFE	36.63^{c}	41.57^{b}	48.00^{a}	46.53^{a}	37.90^{c}	2.30	0.04
ADF	29.23	28.11	27.76	26.04	25.21	3.75	0.17
NDF	31.21	30.14	29.46	29.00	28.02	3.57	0.05

NFE; Nitrogen free extract, NDF; Neutral detergent fibre, ADF; acid detergent fibre, A; (0% ESS: STLM), B; (100%: 0%ESS), C; (95%ESS:5% STLM), D; (90%ESS:10% STLM) and E; (85%ESS: 15% STLM) kg/100kg of dry matter (DM)

Table 5 below shows the growth performance of Red Sokoto Bucks fed diets containing varying levels of *Senna tora* leaf meal and yeast treated ensiled sorghum stalks. Final weights (FW) showed significant differences ($P < 0.05$), with goats in group E reaching the highest average of

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14.40 kg, compared to 12.57 kg in group A. This suggests that diets containing higher levels of *Senna tora* leaf meal and yeast-treated sorghum stalks may enhance growth outcomes of the Red Sokoto bucks (RBs). Weight gain (WG) followed a similar trend, increasing from 2.67 kg (A) to 4.17 kg (E), with a significant effect ($P < 0.05$). Average daily weight gain (ADW) ranged from 53 g/day (A) to 85 g/day (E), also statistically significant ($P < 0.05$). The growth performance of Red Sokoto bucks (RBs) in the present study showed significant variation across dietary treatments, with final weights ranging from 12.57 kg (A) to 14.40 kg (E) and average daily gains from 53 g/day to 85 g/day, respectively. These results are consistent with recent findings by Hyelda *et al*. (2017), who reported that supplementing urea-treated maize stover with *Balanites aegyptiaca* leaf forage significantly improved weight gain and nutrient digestibility in Red Sokoto goats. Their highest treatment group achieved an average daily gain of 52 g/day, closely matching the lower end of the present study's range. Similarly, Ibrahim *et al*. (2014) demonstrated that inclusion of *Guiera senegalensis* (Sabara leaf meal) at 20–30% in goat diets enhanced body weight and feed conversion ratio, with significant improvements in final weight and nutrient uptake. Total feed intake (TFI) and daily feed intake (DFI) in the present study increased significantly across treatments, ranging from 18.63 kg to 23.42 kg and 397.53 g/day to 498.28 g/day, respectively ($P < 0.05$). Total feed intake (TFI) and daily feed intake (DFI) increased with values of 18.63 kg to 23.42 kg and 397.53 g/day to 498.28 g/day, respectively ($P < 0.05$). This increase may reflect enhanced palatability and digestibility of the yeast-treated silage, consistent with Faverdin (2024), who emphasized the role of nutrient composition and microbial fermentation in regulating feed intake in ruminants. These values are consistent with recent findings by Hamid *et al*. (2025), who reported that Boer crossbred goats fed protein-optimized diets exhibited daily feed intakes between 420 g/day and 510 g/day, depending on crude protein concentration and fiber digestibility. Feed conversion ratio (FCR), a critical indicator of feed efficiency, was significantly improved in groups C, D, and E ($P < 0.05$). The lowest FCR was observed in group C (5.37), indicating superior efficiency compared to group A (6.98). Lower FCR values suggest better utilization of feed for weight gain, a trend supported by VandeHaar *et al*. (2016), who highlighted Feed conversion ratio as a key driver of sustainability in ruminant production systems. This trend mimics the results of Mutimura *et al*. (2025), who found that Galla goats fed a Mulato II–Leucaena leaf meal blend achieved FCRs as low as 5.2, outperforming Napier-based diets with FCRs above 6.5, indicating superior nutrient utilization and growth efficiency. The study highlights superior nutrient utilization and enhanced growth efficiency in bucks fed diets incorporating *Senna tora* leaf meal and yeast-treated sorghum stalks. A key objective was to achieve an effective protein–fibre balance tailored for growing goats. This goal aligns with recent findings indicating that optimal growth and feed efficiency are supported when dietary crude protein levels range between 14–18%, and crude fibre levels fall within 22–28%, depending on the feed source and its digestibility (Chana *et al*., 2025; Zhang *et al*., 2025). study, Ration E, which incorporates E; (85%ESS: 15% STLM), resulted in the highest feed cost saving of $0.16 per male goat compared to conventional diets.

Table 5: Growth Performance of Red Sokoto Goats Fed Diets Containing Varying Levels of *Senna tora* Leaf Meal and Yeast-treated Ensiled Sorghum Stalks

	Treatments						
Item	A	B	C	D	E	SEM	P-Value
Initial Weight (kg)	9.90	10.50	9.62	9.90	10.23	1.15	0.33
Final Weight (kg)	12.57 ^{b}	13.34 ^{ab}	13.35 ^{a}	13.86^{a}	14.40^{a}	1.20	0.02
Weight gain (kg)	2.67 ^{b}	2.84 ^{b}	3.73 ^{a}	3.96 ^{a}	4.17 ^{a}	0.90	0.04
Average Daily Gain (g/d)	53.00 ^{d}	59.00 ^{c}	77.00 ^{b}	79.00 ^{a}	85.00 ^{a}	6.18	0.02
Total Feed Intake (kg)	18.63 ^{c}	20.46 ^{b}	20.02 ^{b}	21.56 ^{b}	23.42 ^{a}	1.80	0.04
Daily Feed Intake DMI (g/d)	397.53^{d}	435.25 ^{c}	426.05^{c}	458.63^{b}	498.28 ^{a}	16.90	0.03
FCR (kg feed kg^{-1} gain)	6.98 ^{a}	7.20 ^{a}	5.37 ^{c}	5.44^{c}	5.62 ^{c}	0.40	0.02
Feed cost/kg ($)	0.39	0.30	0.27	0.25	0.23	-	-
Feed cost saving ($)	-	0.09	0.12	0.14	0.16	-	-

SEM: Standard Error of the Mean, A; (0% ESS: STLM), B; (100%: 0%ESS), C; (95%ESS:5% STLM), D; (90%ESS:10% STLM) and E; (85%ESS: 15% STLM) kg/100kg of dry matter (DM)

CONCLUSION AND RECOMMENDATION

Incorporating *Senna tora* leaf meal and yeast-treated sorghum stalks in the diets of RS bucks demonstrates the potential of locally available, unconventional feed resources to enhance both productivity and sustainability. Optimizing dietary formulation with these components led to marked improvements in , total weight gain and average daily gain with Diet E (85% ESS:15% STLM) yielding the highest growth performance. Feed conversion ratios were also improved, particularly in Diet C (95% ESS:5% STLM), indicating more efficient nutrient utilization. These findings underscore the value of integrating agro-industrial by-products into animal nutrition strategies, offering a cost-effective and environmentally responsible approach to improving growth performance in intensive production systems. Diet E (85% ESS:15% STLM) is hereby recommended for optimum nutrient utilization and feed efficiency in Red Sokoto

ETHICAL APPROVAL STATEMENT

This Research is approved by the Animal Research Ethics Committee of Federal University Gashua, Protocol No. FUGA/C/ANS/2025/00033, dated 03 March, 2025.

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USES OF INDIGENOUS METHOD IN HANDLING CASHEW PRODUCT IN KOGI STATE, NIGERIA

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ABSTRACT
The study examined the indigenous method in handling cashew production Kogi State, Nigera.Simple random selection was used to select 240 respondents.Data were collected using structured questionnaires and analyzed using descriptive statistics. The results of the study shows that about35%of the respondents in the study area were within the age bracket of 41 – 50 years, majority (75%)of the respondents were male with household size of 1-5 people (57.1%) and 33.8% of the respondents possessed considerable experience of 6-10years and above in cashew farming. Study also reveals that 26.7% of the respondents' cultivated1ha while 42.5% of the respondents cultivated between 2-4 ha. Similarly, 30.8% cultivated above 4 ha. More than half(54.2%) of the respondents used both hired and family labour in cashew farming, while 23.3% and 16.7% used hired labour and family labour respectively in carrying out their farming activities. The study shows the Majority(77%)of the respondents used to bag the cashew nut for sale, it also revealed that majority(81.3%) of farmers do not use hand shelling for cashew nut and more than half(55.4%) of the respondents do not sundry cashew before sale and majority(70.8%) of respondents used to weigh cashew. Cashew farmers were of the view that cashew nut shell liquid is a by – product of cashew processing industry as this occupied the first position on the ranking with Mean ratio of 2.22, while cashew apple is said to have many medicinal values ranked 4th with mean ratio 2.10. It can be concluded that cashew has a great economic value which has increased their income. It was recommended among others that adequate training must be carried out to sensitize the farmers about the benefits of using indigenous method in handling cashew product and the extension services provided should be extended to the farmers in the study area in other to increase their awareness about surplus supply of cashew nuts to address their paucity.

Keywords; Cashew, Farmers, Indigenous, Handling.

INTRODUCTION
Anacardiumoccidenatale L., commonly called cashew is an important dicotyledonous tropical evergreen tree belonging to the family Anacardiaceae, order Sapindal, and genus Anacardium. The genus comprises about eight species, among which Cashew (*A.occidentale*) is of economic importance due to its edible fleshy apple and kernel (Adelere *et al*., 2020; Cherian and Lekshmi, 2021). It originated in Brazil and adapted to the different parts of the world where it is cultivated as a major cash crop, most especially in West African countries such as Ghana, Republic of Benin, Cote d-Ivoire, Nigeria and Guinea-Bissau . In the past, the cashew tree was mostly grown to control soil erosion, mitigate desertification, as an ornamental plant and for the production of wood used in furniture making. Whereas, in recent times, great attention has been drawn to the cashew fruit due to its enormous economic importance and value-added products obtained from its various parts (Alabi *et al*., 2023,). In Nigeria, cashew tree cultivation has become very popular across many parts of the country, where it serves as a major household business and a source of livelihood.

Sadly, the initiatives aimed at promoting effective cashew cultivation methods have not produced the anticipated outcomes. This means that the comprehensive adoption of best agricultural

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practices by growers is still not a reality, and the productivity of cashew orchards continues to be low. (Houndahouan *et al*., 2018).

The cashew tree's kernel and apple are currently underutilized in Nigeria in terms of generating revenue. Since the harvesters only eat a small percentage of the fresh apples, there is still a lot of waste on farms. The household income is decreased by this waste. Therefore, it is essential to investigate value addition for cashew apples and nuts. Value addition has been shown to increase product revenue and shelf life for commodities like cocoa. (Lawal and Jaiyeola, 2007). This study determined the awareness of value addition among cashew farmers in kogi state Nigeria.

The major objective of the study was to investigate the uses of indigenous method in handling cashew product in kabba bunu Local Government of Kogi State.

The specific objectives were to;

1) describe the socio economic characteristics of cashew farmers in the study area;
2) identify indigenous method employed by farmers in handling cashew products;

METHODOLOGY

The Study Area

The study was conducted in Kogi State, located in the middle belt region of Nigeria. The study area lies between latitude 6o 30'N and 8o 48'N and longitude 5 o 23'E and 7o 48'E. The main tribes are the Igala, Ebira and Yoruba. The crops commonly cultivated include; Cashew, Cocoa, Palm tree, Coffee, Groundnut, Maize, Cassava, Rice, yam and Melon

Methods of Data Collection

To achieve the objectives of this study on the uses of indigenous methods in handling cashew products in Kogi State, Nigeria, both primary and secondary data were collected.

1. Primary Data

Primary data were obtained directly from respondents through the following instruments:

*Structured Questionnaire: A well-designed questionnaire was administered to cashew farmers, processors, and marketers across selected communities in Kogi State. The questionnaire captured information on socio-economic characteristics, indigenous handling methods, challenges, and perceived effectiveness of these methods.

*Interviews: Oral interviews were conducted with key informants such as community leaders, experienced farmers, and extension agents to gain deeper insights into traditional knowledge and cultural practices.

*Focus Group Discussions (FGDs): Group discussions were organized with small clusters of cashew farmers and processors to generate collective views, validate individual responses, and identify common indigenous practices.

*Observation: Direct field observation was employed to physically examine the indigenous handling methods such as drying, storage, and processing techniques used by respondents. These helped to cross-check and validate information obtained from questionnaires and interviews.

2. Secondary Data

Secondary data were sourced from existing literature, including journal articles, government reports, academic theses, conference papers, and publications from relevant institutions such as the National Cashew Association of Nigeria (NCAN). These provided a broader context and background information to complement the primary data

Sampling Procedure and Sample Size A multistage sampling technique was used to select 240 respondents for the study. The first stage was purposely selected of kabba-bunu local government in Yoruba speaking areas due to high production of cashew. Stage 2 involved the selection of two communities from the local government which are oke-Dayo and kakun.The third stage: involved a random selection of (120) farmers from each communities to make the total number of 240 farmers due to high number of cashew farmers in the local government. The respondents were therefore subjected to well structure questionnaires.

Methods of Data Analysis

Data were analysed using descriptive statistical tools- mean, mode and frequency distribution

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RESULTS AND DISCUSSION

Socio – economic Characteristics of Respondents

The section presents the socioeconomic characteristics of cashew farmers in the study area. Table 1 provides the summary.

Table 1: Distribution of the Respondents based on the Socio-economic Characteristics (n=240)

Parameters	Frequency	Percentage	Mean
Gender			
Male	181	75	
Female	59	25	
Marital status			
Single	40	16.7	
Married	184	76.7	
Widowed	3	1.3	
Divorced	13	5.4	
Age (years)	36	15	
≤20-30	55	22.9	
31-40	83	35	
41-50	41	17.1	**45**
51-60	16	7	
61-70	9	4	
71-80			
Farming experience (years)			
≤5	55	22.9	
6-10	92	38.3	
11-15	41	17.1	**12**
>15	52	21.7	
Educational status			
No formal education	26	10.8	
Arabic education	32	13.3	
Primary education	28	11.7	
Secondary education	54	22.5	
Tertiary education	100	41.7	
Farm size (ha)			
<1	64	26.7	
2-4	102	42.5	
>4	74	30.8	**5**
House hold size			
≤5	137	57.1	**5**
6-9	74	30.8	
10-12	20	8.3	
>12	9	3.8	
Type of labour use	47	19.5	
Hired labour	63	26.3	
Family labour	130	54.2	
Both			

Source: Field survey, 2025.

The resulting Table 1 revealed that 75% of cashew farmers were male while 25%were female indicating that more males were involved in cashew production than the female.Table 1 shows that majority(76.7%) of the respondents were married while 16.7% were single. The mean age of the respondents was 45 years indicating that those involved in cashew production are advanced in age. The findings also revealed that a significant proportion (38.3%) of the respondents have had long farming experience in cultivating cashew with the mean farming experience of 12 years. The length of time a farmer has engaged in farming serves as a strong indicator of the practical experience and

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indigenous knowledge accumulated in cashew nut production. This suggests that years of farming not only enhance technical competence but also improve the ability to adapt indigenous methods for better handling and productivity. This finding is consistent with the results reported by earlier studies.

Nwaru *et al*. (2006) viewed that the number of years spent in farming business may give an indication of the practical knowledge acquired on how to cope with the inherent farm production processing and marketing challenges.About22.5%and41.7%of the respondent's secondary and tertiary schools respectively. This implies that education contributes to adoption of new technology, participation in developmental programmes and sustainable usage of innovation for a long time until a new innovation is discovered as the best course of action by adopters. Oluwatosin (2011) corroborated this finding that more educated farmers are more likely to adopt progressive farming practices and new technologies and thus increase their overall efficiency.The finding further revealed that 26.7% of the farmers cultivate less than 1ha while 42.5% of farmers cultivate between 2-4 ha. Also, 30.8% cultivate above 4 ha. 54.2% of the respondents used both hired and family labour in cashew farming, while 23.3 and 16.7% used hired labour and family labour respectively in carrying out their farming activities.It means that the small-scale farmers constitute about 50% in the lot of cashew farmers in Kogi State.

Indigenous Method Employed by Farmers in Cashew Value Addition

Table 2 shows that majority (88.8%) of the respondents were using hands to harvest their cashew and also 67.9% of the respondents used to sort out cashew before sale while77% used to bag the cashew nut for sale. The result further revealed that majority(81.3%) of the respondents do not use hand shelling for cashew nut and more than half(55.4%) of the respondents do not sundry cashew before sale. Majority (70.8%) of the respondents used to weigh cashew. This implies that farmers have the knowledge of weighing cashew nut which leads to increase their income in line with Crusoe, (2006) Study that most farmers lack knowledge in handling the crop for maximum yield.

Other indigenous method of handling cashew product followed in like manner. It also revealed that majority of famers has inadequate knowledge about handling value addition to cashew products (Crusoe, 2006).

Table 2: Distribution of Respondents based on the Indigenous Method Employed by Farmers in Handling Value Addition to Cashew Products

Method	Frequency	Percentage
Hand Picking	213	88.8
Washing	51	21.2
Peeling	51	21.2
Sorting Out	163	67.9
Sundry of Cashew	107	44.6
Weighing	170	70.80
Roasting on the Fire	107	44.6
Hand Shelling	45	18.7
Hand Pressing to extract Juice	93	38.7
Bagging	185	77
Salting	76	31.7

Source: Field survey, 2025.

CONCLUSION AND RECOMMENDATIONS

Based on the findings of the study, it is concluded that increase in age and level of education of the cashew farmers, the more the value addition to cashew by the farmers as access to information by the farmers will be encouraged. Also farmers highlighting their relevance, effectiveness, and limitations in the production-to-consumption chain. Findings revealed that local farmers and processors rely heavily on traditional practices for harvesting, drying, storage, and processing due to affordability, accessibility, and cultural familiarity. These indigenous techniques have contributed to the preservation of cashew quality, reduction of post-harvest losses, and sustenance of rural

livelihoods. However, the research also established that while indigenous methods remain valuable, they often lack efficiency compared to modern technologies, leading to lower productivity and limited competitiveness in larger markets. The integration of indigenous knowledge with modern processing techniques would therefore not only improve product quality and shelf life but also enhance income generation, employment opportunities, and food security in the state.

i. Adequate training must be carried out to sensitize the farmers about the benefits of indigenous method in handling cashew.
ii. The extension services provided should be extended to the farmers in the study area in other to increase their awareness about surplus supply of cashew nuts to address their paucity.
iii. Cashew farmers should adopt high yielding, improved varieties that have shorter germination period and requires less labour for harvest.
iv. Helping hands can be extended to smallholder cashew nut farmers by NGOs and private bodies to establish their own processing factories at an affordable rate and manage them as private bodies and engage in international cashew nut sales.
v. Government needs to create a framework under which smallholder cashew nut farmers can be provided with basic cashew nut production inputs to facilitate timely availability and application of inputs

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PROFITABILITY ANALYSIS OF THE ADOPTION OF VALUE ADDITION TECHNOLOGIES BY WOMEN RICE PROCESSORS IN BENUE AND KOGI STATES, NIGERIA

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ABSTRACT
This study examined the profitability of the adoption of value addition technologies by women rice processors in Benue and Kogi States, Nigeria. Multi stage sampling procedure was used to select 358 women rice processors for the study. Data were collected using structured questionnaire and analysed using descriptive statistics, chi- square, mean score from likert scale and gross margin. The result on Table 1 showed women rice processors capabilities on rice improved milling technology (=2.23), cleaning and polishing rice value operation (=2.42), rice destoning (=2.34) , improved drying value addition technology(=2.14), sorting, grading and certification rice value operations (=2.03), packaging(=2.26) and storage (=2.25). On the other hand, processors in Kogi state showed their capabilities on rice improved milling (=2.05), cleaning and polishing (=2.09), destoning (=2.02), packaging (=2.06) and storage (=2.06). and have access to labour, storage, processing equipment, preservative skills, Information on market for rice value added product and good sources of paddy with the mean score of 2.29, 2.03, 2.14, 2.10, 2.09 and 2.35 respectively. However, chi-square test on both states processors showed that improved milling, Improved drying, Packaging, Product branding & labeling and Storage were significant at 5%. The study found out that rice processing is profitable in the study areas with returns per naira invested in indigenous, modern and both methods of rice processing are ₦1.10, ₦1.24 and ₦1.17 respectively. Women rice processors in Benue and Kogi States are highly capable of adding value to their rice through most of the value addition technologies available except in few cases. The study therefore recommends that both public and private agencies should make productive resources for rice value addition accessible to women processors as this will accelerate the rate of adoption of modern improved technologies.

Keywords: Rice, Value, Addition, Technologies, Women, Processors

INTRODUCTION
In recent times, the concept of value addition in the agricultural sector of Nigeria's economy is given priority attention by both government and non-governmental organizations towards improving the income generation of the rural communities, especially among the women folk whose participation in the post-harvest management of crops cannot be over emphasized. Nigeria has a highly diversified agro-ecological condition which makes it possible for the production of a wide range of agricultural products. Despite Nigeria's potential competitive advantage of favorable agro-ecological and natural conditions in several agricultural commodities (including roots and tubers, cereals and legumes, tree crops and livestock), past and present agricultural policies and programmes have not been able to adequately and significantly address the constraints faced by small-scale farmers (Okoro and Ujah, 2009)..

Agricultural activities in Nigeria and most African nations are characterized by gender division of labour (Adejo, *et al,* 2015). Studies have shown that 79% of rural women take agriculture as their primary occupation and about 70-80% of them are involved in processing of agricultural commodities (Onuekwusi, *et al*, 2017). Despite their immense contributions to the agricultural sector, they are always relegated to the background. They have limited or no access to productive resources such as land, credit and extension services.

Value addition to agricultural products refers to stages such as cleaning, drying, grating, grinding, sorting, grading, packing, packaging, branding and marketing. According to Boland (2009),

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value-added agriculture is the process of increasing the economic value and consumer appeal of an agricultural commodity. It is an alternative production and marketing strategy requiring the understanding of food safety issues taking cognizance of the consumer preferences (Ja'afar-Furo, *et al.,* 2011). Enhancing the value chain can improve the livelihood of smallholder farmers, ensure competitiveness in the global market, and ultimately contribute to economic growth.

The role of women in agricultural production in Nigeria can never be over emphasized. Various researches conducted on the contribution of women to agricultural development in the country revealed women contribution to the farm work is as high as between 60 and 90% of the total farm task performed. The contribution of the women ranges from such tasks as land clearing, land tilling, and planting, weeding, fertilizer/manure application to harvesting, food processing, threshing, winnowing, milling, transportation and marketing as well as the management of livestock (Damisa, *et al.,* 2007)

Ayoola, *et al*. (2012) revealed that women play vital roles in food production, processing and marketing in Nigeria; producing about 60-80 percent of total output, and contributing about 60-80 percent of agricultural labor force. They also contribute more than two-thirds of their produce towards household subsistence. Women are largely involved in the production, processing and trading of rice and other food crops such as sorghum, maize, cassava, cowpea, melon, pepper, vegetables and yam. Despite the contribution that women farmers make in the production and processing of rice grains in the country, there is general believe on gender inequality in the access to productive resources in the north central Nigeria. They have limited access to productive resource (Damisa, *et al.,* 2007). There is need to correct these challenges faced by rice women processors by investigating the level of rice value addition technologies they are engaged in, in terms of packaging, improved processing, sorting and grading, destoning, improved drying, cleaning and polishing.

The women ability and capability are most often not readily taken into consideration before the said technologies are designed for them while basic socio economic characteristic that could push the adoption of rice processing technologies have not been identified. The cost and return on a technology use may either motivate or discourage the use of a technology.

It is essential to establish this factor as it affects the women rice processors in the study area. Most of the research findings in many literatures have not really addressed the levels of capabilities of women in using improved technology explicitly rather emphases have been on adoption of rice processing technologies.

The main objective of this study is profitability analysis of the adoption of the value addition technologies by women rice processors in Benue and Kogi States, Nigeria while the specific objectives are to

i. Describe the socio-economic characteristics of the respondents.
ii. identify value addition technology capabilities of women rice processors.
iii. examine the access of women processors to productive resources for rice value addition
iv. comparatively analyze costs/returns of women processors using indigenous, modern and both methods of value addition technologies.

METHODOLOGY

The Study Area

The research was carried out in Benue and Kogi States of Nigeria. Kogi State was created on August 27th 1991 from Kwara and Benue States with the Capital at Lokoja. Geographically, it is located between latitude $6^{0}30^{'}$N and $8^{0}5^{'}$N and Longitude $5^{0}51^{'}$E and $8^{0}00^{'}$E sharing boundaries with Kwara, Ondo, Ekiti, Niger, Benue, Nassarawa, Anambra, Enugu, Edo States as well as the Federal Capital Territory Annual rainfall stands between 1016mm and 1524mm. It has a maximum temperature of 33.2^{o}C and average temperature of 22.8^{o}C, with an average humidity of 70%. Kogi State is marked with two distinct seasons in a year; these are wet and dry seasons. The wet season spans between middle of March and October and the dry season is usually experienced between the months of October and March. Kogi State had a total population of about 5,103,626 people in 2024

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(using the state projected growth rate of 3.0% by NBS) and a land area of about 30, 354, 74 square kilometres.

The confluence of river Niger and river Benue creates alluvial fertile soil which is very good for crop production. According to Kogi State Economic Empowerment Development Strategy (KOSEED) (2004), Kogi State has about 2 million hectares of cultivated land but only about 0.5 million hectares are under cultivation. About 73.5% of the cultivated land (1,470 ha) can be cultivated in the raining season while 26.5% (530,000ha) is suitable for dry season farming. The agricultural sector provides a very wide opportunity for investment complemented with the services of the Kogi State Agricultural Development Project (KSADP).

Kogi State registered rice farmers were estimated to be about 9, 708 of which 40% (3, 883 farmers approximately) of them were said to be women (KSADP and FG Anchor Borrowers, 2019). The people of Kogi State also rear animals like cattle, sheep, goats, swine, poultry and fish.

Benue State is one of the North Central States in Nigeria. It is inhabited predominantly by the Tiv, Idoma and Igede peoples, who speak Tiv Idoma, and Igede languages respectively. Its capital is Makurdi. Benue is a rich agricultural region; popularly grown crops include; sweet potatoes, cassava, soya bean, guinea corn, flax yams, sesame, rice, and groundnuts, Palm Tree. The State lies in the Southern Guinea Savanna between latitudes 6°25'N and 8°8'N and longitudes 7°47'E and 10°E' (Onlinenigeria, 2003)

The wet season spans between middle of March and October and the dry season is usually experienced between the months of October and March. Benue State has a land area of about 30,800 Km^2. The area is inhabited by the Tiv (the largest ethnic group in the state), the Idoma, and a number of smaller groups, all are mainly agricultural people. It has a population of about 6,550,607 people in 2024(using the state projected growth rate of 3.0% by NBS). Mining is important in several scattered areas: south of the Benue River there are lead deposits near Akwana and limestone deposits near Yandev; north of the river there are saline springs in the Benue valley and major deposits of tin, niobium, and marble.

Benue state population of registered rice farmers is said to be 10,346 farmers of which about 55% (5,690 farmers approximately) of them were said to be women (Benue Agricultural and Rural Development Authority-BNARDA and Anchor Borrowers, 2019).

Target Population and Sampling Techniques

The population for this study comprises all the registered women rice processors with Agricultural Development Projects in Benue (5,690 women rice farmers), and Kogi States (3,883 women rice farmers) of Nigeria. A sample size of 360 women processors were selected using a multi – stage sampling techniques. The first stage was purposive selection of three (3) Agricultural zones from each state of the study area (Benue and Kogi) based on the concentration of rice women processors in these agricultural zones. These sums up to six (6) Agricultural zones. The second stage involved purposive selection of two (2) blocks from each zone to give a total of twelve (12) blocks. In the third stage, two (2) cells were selected randomly from each block of the agricultural zones in the study areas giving a total of twenty-four (24) cells. The fourth stage, fifteen (15) registered women rice processors were selected randomly from each of the selected cell to give a total sample size of three hundred and sixty (360) respondents for the study

Data Collection

Data were collected through the use of interview schedule and a well structured questionnaire. The enumerators to elicit the information were trained on data collection and ethical conduct involved in data collection. The questionnaire was used to collect information on the following areas:

A. Socio-economic characteristics of the respondents
B. Value addition technology capabilities of women rice processors
C. Access of women processors to improved value addition technologies.
D. Costs and returns on rice grain value addition

Method of Data Analysis

Data for this study was analyzed using both descriptive such as frequency count percentages, mean , mode and mean score from Likert type of scale and inferential statistics such as, , Chi – square

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analysis and Cost and return analysis. Descriptive analysis was used to achieve objective i, ii and iii, Chi – Square statistics was further used to test hypothesis for the significant difference in the technology capabilities of women in value addition in the two (2) selected states of objective ii and cost and return analysis was used to achieve objective iv

Access of women rice processors to improved value addition technologies was measured on 3-point Likert type rating scale: not accessible (1point), accessible (2points) and highly accessible (3points). The mean can be calculated as follows:

$= \frac{\sum fx}{N}$ Where: = Mean response, $\sum$ = Summation, f = number of respondents choosing a particular scale point, x = value of each scale N = total number of respondents. Any mean score greater than 2 is high while the mean score less than 2 is low

Chi – Square statistics to test value addition technology capabilities of women rice grains processors. The calculation of Chi-Square statistics is given as follows:

$$\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

Where χ^2 = Chi-square value

f_o = the observed frequency of the value addition technology capability by rice processors

f_e = the expected frequency of the value addition technology capability by rice processors

As depicted in the formula, the Chi-Square statistic is based on the difference between what is actually observed in the data and what would be expected if there was truly no relationship between the variables.

Decision Rule: The Null Hypothesis is rejected when $\chi^2_{Computed} \geq \chi^2_{Tabulated}$ under the degree of **freedom df = (R-1) (C-1)**

Cost and return analysis for value addition on rice

From the equation TC = TFC + TVC …….. (1)

Where, TC = Total cost, TFC = Total fixed cost, TVC = Total variable cost

GI = Gross income = Q x P……. (2)

Where, Q = quantity of rice, P = unit price of rice

NI = Net income = GI – TC …….. (3)

Where, GI = Gross income, TC =Total cost

To determine profitability of rice, ratio was calculated as follows:

GR = TC/GI…… (4)

Where, GR = Gross ratio, TC = Total cost, GI = Gross income

RESULTS AND DISCUSSION

Socio-economic Characteristics of the Respondents in Benue and Kogi States

Age

The age distribution of women rice processor as shown in Table 1 indicates that Majority (75%) of the farmers in Benue State were between 31 and 50 years with the mean age of about 40±8.62years' standard deviation while (75.30%) of the respondents in Kogi State were between 31 and 50 years with the mean age of about 42±9.25years' standard deviation. This implies that women rice processors in Benue and Kogi States were in their active and productive ages which could help them to participate highly in rice value addition technologies. This result agrees with Adam et al. (2018) who said that most of the participants in rice processing value chain are within the ages of 31-40years.

Marital Status

The distribution of respondents' marital status shows that majority of them (72.80%) were married, a few were single (22.22%), divorced (2.80%) and widowed (2.22%) in Benue State, likewise in Kogi State majority(73.10%) were married, while a few were single (11.20%), divorced (9.00%) and widowed (6.20%) as it is indicated in the Table. This implies that majority of the women rice processors in the study area are married. Marital status has being found to influence social

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organization and economic activities such as agriculture and resource management within a household (Nyunza and Mwakaje, 2012).

Educational Qualification

As indicated in Table 1, majority of the respondents (93.30%) in Benue State had formal education of which 8.90%, 40.00% and 44.40% of them attained primary, secondary and higher education respectively. Also in Kogi State majority of the respondents (86.50%) had formal education of which 21.90%, 33.10% and 35.50% of them attained primary, secondary and higher education respectively. Education is important for training and skill enhancement planning and implementation for rice processors by extension service providers since it is easier to train processors who are literate. Education is a factor in the adoption of modern practices. It is generally considered an important variable that could enhance adoption of new technology. This study is in agreement with the finding of Akarue and Ofoegbu (2012) who stated that most rice farmers can read and write.

Household Size

With respect to household size, 94.45% of the respondents in Benue State had between 1 and 10 persons with the mean household size of 5±2.73persons' standard deviation. While majority (73.66%) of the respondents in Kogi State had between 1 and 10 persons with the mean household size of 7±7.56persons' standard deviation. This implies that respondents in the study areas had large household size. This is of great importance in farm production as rural households rely more on family members than hired workers for labour on their farms.

Years of farming Experience

The distribution of respondents in terms of years spent in rice processing, it was found that 68.89% of the Benue State respondents had rice processing experience of between 1 and 10 years, while 22.22% of them had the experience of 11 and 20 years. In Kogi State, it was found that 59.55% of the respondents had rice processing experience of between 1 and 10 years, while 28.08% of them had the experience of 11 and 20 years. The higher the year's experience of the rice processor, the more informed and skilled, they become. As experience plays a very important role in the performance of any enterprise. This suggests that the production of rice by processors in the study area would be high. The result is in consonance with Olaolu et al. (2013) who stated that Long period of experience is an important advantage in farm productivity since it encourages faster adoption of farm innovations.

Extension Contact

Majority of the respondents (99.99%) in Benue State had contacts of between 0 - 5 with extension agents in a year with the mean number of contact to be about 0±0.57years' standard deviation. In a similar way, majority of the respondents (96.63%) in Kogi State had contacts of between 0 - 5 with extension agents in a year with the mean number of contact to be about 2±1.99years' standard deviation. This shows that the number of contacts is very low compared to a*priori* expectation of about '40 and above' number of contacts with 80 farmers required of an ADP's Training and Visit extension system in Nigeria (Agbarevo and Obinne, 2010).

Annual income

The income distribution of the respondents as shown in Table 1 indicated that most (64.44%) of the women rice processors in Benue State earned between ₦101, 000- ₦300,000 per annum. While most (58.42%) of the women rice processors in Kogi State earned between ₦101, 000- ₦400, 000 per annum. This study agrees with the finding of Abah et al. (2015) whose study showed that majority (65.48%) of respondents made 200,000 Naira or less in sales income/annum and that most of the farmers are small holder farmers with small market share of the paddy rice market

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Table 1: Socio-economic Characteristics of Respondents in Benue and Kogi States (n= 180)

Variable	Benue			Kogi State		
	Freq	(%)	Mean	Freq		Mean
Age (years)						
20 – 30	29	16.11		12	6.70	
31 – 40	82	45.56		73	41.00	
41 – 50	53	29.44	**40**	**61**	34.30	
51- 60	12	6.67		26	14.70	**42**
61 -70	4	2.22		6	3.40	
Total	**180**	**100**		**178**	**100**	
Marital Status						
Single	40	22.22		20	11.20	
Married	131	72.80		131	73.10	
Divorced	5	2.80		16	9.00	
Widowed	4	2.22		11	6.20	
Total	**180**	**100**		**178**	**100**	
Level of Education						
No formal education	12	6.70		24	13.50	
Primary education	16	8.90		39	21.90	
Secondary education	72	40.00		59	33.10	
OND/NCE,HND/Degree	80	44.40		56	31.50	
Total	**180**	**100**		**178**	**100**	
Household size						
≤ 5	125	69.45		63	35.40	
6 – 10	45	25.00	**5**	77	43.26	**7**
11 and above	10	5.50		7	2.26	
					1.1	
Total	**180**	**100**		**178**	**100**	
Years spent in rice processing						
≤ 10	124	68.89		106	59.55	
11 – 20	40	22.22		50	28.08	
21 – 30	6	3.33	**11**	22	12.36	**12**
> 30	10	5.50				
Total	**180**	**100**		**178**	**100**	
Annual income (₦)						
≤ 100,000	39	21.67		34	9.10	
101,000 – 200,000	60	33.33		41	23.03	
201,000 – 300,000	56	31.11	**307,083.33**	35	19.66	
301,000 – 400,000	13	7.22		28	15.73	
401,000 – 500,000	5	2.70		10	5.62	
> 500,000	7	3.89		30	16.85	
Total	**180**	**100**		**178**	**100**	
Extension contacts/Annum						
0 contact	164	91.10	**0**	68		
1- 5	16	8.89		104		
> 5		58.43				
Total	**180**	**100**		**178**	**100**	

Source: Field Survey, 2019

Value Addition Technology Capabilities of Women Rice Processors

The distribution of respondents according to their value addition technology capabilities on rice in Benue state on Table 2 shows that majority of women rice processors indicated their

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capabilities in rice value addition technologies as capable; rice improved milling machine (which is a modern technology) with the mean score of 2.23, This capability of women on improved rice milling machine in the study area is not unconnected with the fact that there are improved milling machines spread all over the rice producing areas in Nigeria. cleaning/polishing rice value operation with the mean score of 2.42, rice destoning mean score of 2.34, improved drying value addition technology mean score of 2.14, sorting, grading rice value operations mean score of 2.03, packaging in customized bag mean score of 2.26, storage operations in rice processing mean score of 2.55.

The result also revealed that women rice farmers in the study area have low capability in the area of rice branding and labeling with the mean score of 1.92. This indicates that the women rice processors mean scores on product branding operation was below the mean 2 hence, the women rice processors value addition technology capability on this operation is low. Currently, product branding is an area where rice processors in the study area especially those operating on a small scale capacity are lagging behind. Product branding is one of the marketing functions that influence customers' decision to purchase an item. Hence, it is an integral aspect of product advertisement.

This result implies that rice processors in Benue state were highly capable in improved milling, cleaning/polishing, destoning, improved drying, sorting, grading and certification, packaging and storage rice value addition operations, while product branding and labeling was rated low. Drying is done by spreading the paddy across the pavement, preferable on a protective mat, and occasionally stirring it so the sun will dry it evenly. this is in consonance with the result of research carried out by Oyediran (2016), which showed that rice were dried manually(traditional method) (100%) by the rice processors. and that Small-scale rice processors used tarpaulins, bare ground or on a concrete floor.

Table 2: Distribution of Women Rice Processors base on Value Addition Technology Capabilities in Benue State (n= 180)

Rice value addition Technologies	Not capable (1)	capable (2)	Highly capable (3)	Sum of Responses	Mean Score
Improved milling machine	3	133	44	401	2.23**
Cleaning/polishing machine	2	100	78	436	2.42**
Destoning machine	2	115	63	421	2.34**
Improved drying (5-10% moisture content)	11	132	37	386	2.14**
Sorting and grading	18	138	24	366	2.03**
Packaging in Customized bags	14	105	61	407	2.26**
Product branding & labeling	58	78	44	346	1.92*
Storage (metal silos)	12	56	112	460	2.55**

Source: Field Survey, 2019
Note: Multiple responses. Any mean greater than 2 = capable and any mean less than 2 = not capable.

The distribution of respondents according to their value addition technology capabilities on rice in Kogi state as contained in Table 3 shows that women rice processors in Kogi state are capable in rice improved milling technology with the mean score of 2.05, cleaning/polishing rice value operation with the mean score of 2.09, rice destoning with the mean score of 2.02, packaging with the mean score of 2.06, storage operations in rice processing with the mean score of 2.50.

The result also revealed that women rice farmers in the study area have low capability in the area of improved drying value addition technology with the mean score of 1.87, sorting, grading and certification rice value operations with the mean score of 1.45 The respondents here have no standardized sorting, grading and certification methods. However, grading is done by considering the magnitude of broken rice found in the polished rice. Also, rice product branding and labeling operation with the mean score of 1.47. This indicates that the women rice processors mean scores on these operations were below the mean 2 hence, the women rice processors value addition technology capability on this operation is low. In this area, branding is done by labeling with chalk, charcoal and

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ink of various colours used to inscribe identification sign or number on the sack containing rice. However, a better branding and labeling is done by larger milling factory like that of Confluence Rice Mill.

This result implies that women rice processors in Kogi State were highly capable in improved milling, cleaning/polishing, destoning, packaging and storage rice value addition operations, while improved drying, sorting, grading and certification, product branding and labeling was rated low. Winnowing can also be done through standing adjacent to the direction of wind pouring the grains into an open headed container beneath the operator. This agrees with that of Rathna (2016), who revealed that cleaning is done by winnowing and gravity separation by hand. Rice that contain stones are of low quality to consumers, hence, to command good market for rice, it has to be totally free of stones. Even though machine for destoning rice are available, stones in rice can be handpicked to make it clean and safe for consumption. This result is in tandem with that Adam *et al*. (2018) who reported that women were mostly involve in cleaning (winnowing and destoning) rice and making fit for consumption.

Table 3: Distribution of Women Rice Processors base on Value Addition Technology Capabilities in Kogi State (n = 178)

Rice value addition Technologies	Not capable (1)	Capable (2)	Highly capable (3)	Sum of Responses	Mean Score
Improved milling machine	18	132	28	366	2.05**
Cleaning/polishing machine	18	129	33	373	2.09**
Destoning machine	17	140	21	360	2.02**
Improved drying (5-10% moisture content)	50	101	27	333	1.87*
Sorting and grading	108	59	11	259	1.45*
Packaging in Customized bags	44	79	55	367	2.06**
Product branding & labeling	113	47	18	261	1.47*
Storage (metal silos)	15	58	105	446	2.50**

Source: Field Survey, 2019
Note: Multiple responses. Any mean greater than 2 = capable and any mean less than 2 = not capable.

Table 4: Chi–Square Test on Value Addition Technology Capabilities of Women Rice Grains Processors in Benue and Kogi State

Rice value addition operations	χ^2 calculated	χ^2 tabulated
Improved milling	3.63**	5.99
Cleaning/polishing	7.02	5.99
Destoning	7.42	5.99
Improved drying	3.67**	5.99
Sorting, grading &certification	6.04	5.99
Packaging	3.43**	5.99
Product branding & labeling	5.30**	5.99
Storage	0.66**	5.99

Source: Field Survey, 2019

Table 4 shows the result of Chi- Square analysis on value addition technology capabilities of women rice grains processors in Benue and Kogi States. It was revealed that Cleaning/polishing, destoning , Sorting, grading &certification were not significantly different while Improved milling, Improved drying, Packaging, Product branding & labeling and Storage were significant at 5%. Decision rule: The Null Hypothesis is rejected when $\chi^2_{Computed} \geq \chi^2_{Tabulated}$ under the degree of freedom df = (R-1) (C-1). The reason for the non-significant difference such as cleaning/polishing, destoning,

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Sorting, grading and certification is not farfetched because it is a known fact that women in both Benue and Kogi States had little or no access to modern milling technologies especially as most of them were not able to destone rice properly or overtly; too, sorting, grading and certification as reported earlier where at a less advanced and standardized levels among women rice processors in both States, and even the whole country where rice were produced and processed. While the significant variables might be connected to the fact that Benue State had more modern milling factories than Kogi State. For instance, Kogi had few Small-scale rice milling industries with Confluence rice as the Large Scale industries while Benue State had more small-scale industries and larger milling industries compared to Kogi. Hence it is obvious that women in Benue State were more capable in these processing value addition technologies like improved milling, improved drying, packaging, product branding and labeling, and storage than those from Kogi State. This implies that women rice processors in Benue State now patronize the large scale processing rice industries. This goes to say that the establishment of large scale processing industries has a positive radiating effect on the small scale

Women Rice Processors' Access to Productive Resources for Value Addition

The distribution of respondents according to their access to productive resources for rice value addition in Table 5 indicates that women rice processors in Benue and Kogi State had access to productive resources for rice value addition in terms; labour with a mean score of 2.29, storage facilities with the mean score of 2.03, processing equipment with the mean score of 2.14, market information on rice value added product with the mean score of 2.09 and access to good source of paddy with the mean score of 2.35.

The result of the study further revealed that credit facilities with the mean score of 1.55, access to land for rice value addition with the mean score of 1.91, processing and storage skills with the mean score of 1.83, extension services/innovative ideas with the mean score of 1.34 and packaging of their products with the mean score of 1.80. It can be said that women rice processors has less access to these productive resources for rice value addition technologies since the mean score is below 2. This is due to that fact that women farmers lack access to participate in research and extension training and most of the rice processing operations are carried out and guided mostly by men. This implies that majority of the women rice processors in the study area have little or no access to extension services, indicating that women are being side lined and denied access to innovative ideas on rice value addition. Women access to extension services is deterred as these extension services are male dominated and corruption is pervasive making it difficult for women to practice agriculture and other activities. Women lack access to skills and knowledge of agro-technology. Gender disparities in agro-technological knowledge and skills limit women participation and earning power, both at the production stage of the value chain, and in processing and marketing, women often consult male parties to act as advisor in deciding such market factors as pricing and management (USAID and WFP, 2017).

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Table 5: Mean Distribution of Women Rice Processors on their Access to Productive Resources for Rice Value Addition (n= 358)

Productive resources	Not accessible (1)	Accessible (2)	Highly accessible(3)	Sum of Responses	Mean
Labour	21(5.87)	207(57.82)	129(36.03)	822	2.29**
Credit facilities	171(47.77)	176(49.16)	11(3.07)	556	1.55*
Land acquisition	113(31.56)	164(45.81)	81(22.63)	684	1.91*
Storage facilities	41(11.45)	267(74.58)	50(13.96)	725	2.03**
Processing equipment	50(13.97)	207(57.82)	101(28.21)	767	2.14**
Processing and storage skills	76(21.23)	269(75.14)	13(3.63)	653	1.83*
Preservative skills	83(23.18)	155(43.29)	120(33.52)	753	2.10**
Technical information on rice value addition	231(64.53)	122(34.09)	5(5.59)	490	1.37*
Extension service/innovative ideas on rice value addition	255(71.23)	84(23.46)	19(5.31)	480	1.34*
Information on market for rice value added products	80(22.34)	164(45.81)	114(31.84)	750	2.09**
Packaging equipment	112(31.29)	205(57.26)	41(11.45)	645	1.80*
Good sources of paddy	28(7.82)	178(49.22)	152(42.46)	840	2.35**

Source: Field Survey, 2019
Figures in Parenthesis represent (%) Note: Multiple responses. Any mean above 2 = highly accessible and any mean below 2 = low accessibility

Costs and Returns Analysis of Women Rice Processor Using Indigenous, Modern and both Method of Value Addition Technologies in Benue and Kogi State

Result on table 6 shows that 3.35% of the respondents adopt indigenous method of rice processing, 56% adopt the modern method of rice processing while majority (81.00%) of women rice processors in the study area adopt both the indigenous and modern method of rice value addition. women rice processors in the study area mostly carry out some processing operations (like soaking of paddy, parboiling, drying) traditionally before undergoing the modern method of processing.

Table 6: Distribution of Respondents according to the Method of Rice Value Addition Adopted

Method of processing	Frequency	Percentage
Indigenous	12	3.35
Modern	56	15.64
Both indigenous & modern	290	81.00
Total	358	100.0

Source: Field Survey, 2019

CONCLUSION AND RECOMMENDATION

Women rice processors in Benue and Kogi States are highly capable of adding value to their rice through most of the value addition technologies available except in few cases. A test on value addition technology capabilities of women rice grains processors in Benue and Kogi States shows that Improved milling, Improved drying, Packaging, Product branding & labeling and Storage were significant at 5%. Women rice processors in the study area have access to productive resources for rice value addition as in labour, storage, processing equipment, preservative skills, Information on market for rice value added products which will enable them to perform pretty well and make profit.

Based on the outcome of this study, the following recommendations were made:

i. Since rice processing is profitable in the study area, the study recommends that the women rice processors should form unions and/or reorganize the ailing unions to enable them have high negotiation power on the prices of their produce/products.

ii. Inadequate training of women farmers is one of the drawback factors against their technological capabilities. Hence, provision of up to date training by public extension and other programmes interventions from non-public organizations for rice processors will boost their capabilities and adoption of the rice processing technologies.

iii. As it was comparatively found in this study, the return per naira invested using the various method of rice processing and value addition shows that the modern method appreciable have a better returns. Hence, effort should be geared towards making a paradigm shift from indigenous method to modern one since most women processors are using both indigenous and modern

iv. Access of women rice processors to mechanized or modern processing technologies in affordable and adaptable conditions have been a major problem in the rice processing sector, and particularly among women farmers. Therefore, priority attention should be given to policies directed toward making available subsidized modern technologies adoptable and adaptable to their local conditions.

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