

AGRICULTURAL ECONOMICS AND EXTENSION

AN ASSESSMENT OF INFORMATION CHANNELS BY MAIZE FARMERS' IN BOSSO LOCAL GOVERNMENT AREA OF NIGER STATE

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ABSTRACT

The study assessed information channels by maize farmers in Bosso local government of niger state, nigeria. multi-stage sampling procedure was adopted to select 90 respondents for the study and descriptive statistics were used to analyse the data. results indicate that the mean age of the farmers was 41years with more than half (55.6%) having no formal education, and 50% were married, while very few (4%) were widowers. they had mean farming experience of 13 years with 8 persons as their mean household size. majority of them (63.3%) and (67.8%) were muslims and did not belong to cooperative societies, respectively, while mean farm size was 2 hectares. the grand mean information need of the farmers was 3.1. also, majority of them (94.4%) had radio available to them and the mean access was 1.6. lack of electricity (88.9%), poor visit of extension workers (80%) and cost of mobile phones and airtime (78.9%) were constraints to use of information channels. the study recommended that relevant ministry should organize adult literacy classes to educate the maize farmers on accessing agricultural information via printed media such as newspapers etc. also, agricultural programs in local languages should be organized on television and radio by relevant body.

Keyword: Information channels, Maize farmers, Information access

INTRODUCTION

In Nigeria, maize is a staple crop or food and is extremely consumed by Nigerians. The northern section of Nigeria produces the largest proportion of maize in the country. Maize can be very profitable if you do the right thing such as having a fertilized farmland, planting viable and proper quantity of seeds, weeding, and the use of adequate fertilizers and pesticides. In Nigeria, maize is one of the most vital grains, not only on the foundation of the number of farmers that take part in its cultivation but also in its monetary worth (Adebayo, Olorunfemi, Odedoyin, 2018). Several food types can be gotten from maize such as Roasted corn, cooked corn, maize pap, *masa*, *tuwo* e.t.c. all these food

types are readily available in several parts of nigeria amongst diverse ethnic groups. Maize also can be used for various purposes, the grain, leaves, stalk, tassel, and also the cob can all be used to produce a range of food and non-food products (iita, 2001). More than 60% of nigeria's maize produced are consumed via industrial zone for the manufacturing of flour, animal feeds, biscuits, beverages, malt, drink, beer, corn flask, starch, syrup, and dextrose (asce, 2008). Information channels are mediums through which information is transferred or acquired with relevance, timelessness, validity, cost-effectiveness, trust, usability, exhaustiveness, and aggregation level (Sahin and Robinson, 2005). Information channels are very important to innovation because they increase the flow of

information. The amount and quality of information channels affects the rate of adoption positively. The various information channels through which maize farmers can receive information include modern channels (mass media, prints), extension agents, and traditional channels like interpersonal channels e.g. face-to-face conversation between two or more individuals. it is therefore very important to assess the information channels available to the local maize farmers to understand the level to which information is disseminated and how effective and efficient the information channels are in reaching the maize farmers with information on new innovations.

In the Agricultural sector, there has been an increase in innovations and development while extension workers are faced with high national security challenge but without effective and efficient information channels; the farmers would be ignorant of the latest agronomic practices. Inadequate information channels are responsible for poverty and food insecurity as maize farmers still practice obsolete farming methods. Inadequate information channels can also lead to low yield and production among maize farmers. Inadequate information channels can also lead to a low standard of living, low income, increase in pest and disease, use of old farming implements, and poor-quality fertilizers. It is against this background that this research was conducted to address the following questions:

- i What are the socioeconomic characteristics of maize farmers?
- ii What are the information needs of maize farmers?
- iii What are the information channels available to maize farmers in the study area?
- iv What is the level of accessibility of information channels available to maize farmers?

- v What are the constraints affecting the use of information channels by maize farmers?

The broad objectives of this study were to assess the information channels by maize farmers in the Bosso Local Government Area of Niger state. The specific objectives of this study were to:

- i Describe the socioeconomic characteristics of maize farmers in the study area.
- ii Determine the information needs of maize farmers in the study area.
- iii Identity the information channels available to maize farmers in the study area.
- iv Determine the level of accessibility of information channels available to maize farmers in the study area.
- v Identify constraints or restrictions affecting the use of information channels by maize farmers in the study area.

METHODOLOGY

Bosso is a Local Government Area (L.G.A) in Niger State, Nigeria. It has its headquarters are in the town of Maikunkele. It has a land area of 1,592 km² and a population size of 203,134 the national population census figures of 2006 (NPC, 2006). It lies between Latitudes 9° 31¹ and 9° 40¹ North of Equator, and Longitudes 6° 29¹ and 6° 35¹ East of Greenwich Meridian and has a landmass area of about 884 hectares (NPC, 2006). The majority of the inhabitants are local farmers that cultivate various crops like maize, yam, rice, and millet.

A multi-stage sampling technique was adopted to obtain a sample size of 117 farmers from the study area. This procedure is one in which sampling is done sequentially across two or more hierarchical levels. In stage one, one (1) local government (Bosso local government) was purposively chosen because of the predominantly rural communities where maize farming takes place. In stage two, all the nine (9) districts in Bosso local government namely;

Bejo, Bosso, Kampala, Chanchaga, Garatu, Kodo, maikunkele, mitunmbi, and shata were also purposively selected due to the high level of maize farming in these areas, and in the final stage which was stage three, 13 maize farmers from each of the nine (9) district were purposively selected given the fact that they were confirmed to be maize farmers, bringing the total respondents to one hundred and seventeen (117) farmers. Out of the 117 questionnaires which were distributed for the study, 107 questionnaires were returned of which only 90 were properly filled and were used for the study.

Data were collected through the use of a semi-structured questionnaire. The data obtained were analyzed using descriptive statistics such as mean, frequency and percentage to achieve objectives 1, 3 and 5. A four (4) point Likert scale was used to access to achieve objectives 2 and 4. In this case of using a mean score derived from the 4-point rating scale to analyze the level of accessibility and areas of information needed of the farmers some options were itemized and respondents were asked to indicate the extent of accessibility and areas of information need. It ranged from very high (VH) (4) to never (N) (0) with a decision rule of 1.5. Likert is a tool used in making explicit decisions on the feelings attached with a particular observed phenomenon from possible factors or variables (Ezeh, 2013).

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Farmers

The result presented in table 1 showed that the majority 70.0% of respondents were male while 30.0% were female which indicated that males participate more in maize farming in the area than females and this aligns with Angha and Itari (2012) who reported that males dominated cropping activities in Nigeria. Similar to this

finding, Idrisa, Shehu and Ngamdu (2012) found the percentage of male respondents to be 87.7%. Analysis in Table 1 showed the marital distribution of the farmers. The result indicated that almost 50% of maize farmers were married. This shows that married people focus more on maize farming probably to provide food for their family members or household. This finding is similar to that of Umar, Musa and Kamsang (2014) who established in his finding that the majority of the farmers were married. The table equally showed that (34.4%) of farmers were single, (4.4%) and (2.2%) were divorced and separated respectively, while (4.4%) and (4.4%) of them were widows and widowers respectively.

Table 1 showed the result of the household size distribution of the farmers which indicated a high number of household sizes with an average of 8 persons. This shows that the farmers have reasonable family labor that could help in their farms as household size positively affects productivity. This also implies that farmers in the area depend on their families for acquiring farm labor that will assist them in their farming system. This finding agrees with the findings of Idrisa *et al.* (2012) that scarcity of labor was a major challenge for small-scale farmers.

Result in Table 1 showed the age distribution of the farmers. The result indicates that most of the farmers (32.2%) were within their productive age bracket of between 30-39 years and the mean age was found to be 41 years this is an indication that farming is dominated by the middle-aged farmers who are active and within the productive age group. This result is similar to the findings of Olaniyi and Adewale (2012), Idrisa *et al.* (2012), Jamilu, Abdul-Aziz, Jafaru, Sani and Abdu (2014) who established in his finding that maize farmers were between 30-35 years. Similar to this finding, Onyediacachi (2015) found a mean age of 40.79 among rural farming households in Abia State, Nigeria.

Table 1 further showed that the average farming experience of the farmers was 13 years; this suggests that most of the farmers in the study area have been involved in maize farming for a long time and have great farming experience. The finding in this study is similar to that of Komolafe, Adeseji and Ajibola (2014) who established in his finding high farming experience among farmers.

Table 1 also showed that most of the farmers (67.8%) do not belong to a cooperative society, and (30.5%) were members of a cooperative society. Adebayo and Adekunle, (2016) show that farmers belonging to a group enjoy a lot of benefits and can accomplish a lot collectively than individually.

Table 1 also showed the result of the educational attainment of the farmers which revealed that most of them (55.6%) do not have any formal education, this suggests that non-educated ones were involved in farming in the study area. Jamilu *et al.* (2014) also discovered a low level of education among maize farmers. The result also showed that (23.3%) completed primary school while (18.9%) completed secondary school and (2.2%) completed HSC/OND/NCE.

Table 1 further showed the result of the farm size distribution of the farmers which indicated that the majority of the farmers (90.0%) had a farm size between 1 and 3 hectares of land, With an average of 2 hectares. This implies that most of the maize farmers have small farm holdings in the study area. This finding is similar to that of Jamilu *et al.* (2014) who found that maize farmers operate on a small scale.

Farmers Information Needs

Analysis in table 2 showed the information needs of the maize farmers, the result indicated that the majority with a mean score of 3.6 accepted that they need information on the use of herbicides and insecticides. this was followed by those who need information on how to

increase maize yield with a mean score of 3.4, application of fertilizer with a mean score of 3.3, farm inputs with a mean score of 3.3, source of improved seed variety with a mean score of 3.1, and source of loan credit facilities with a mean score of 3.0, source of tractor hiring for land tillage with a mean score of 3.0, technological innovation with a mean score of 2.9, and storage/preservation of maize with a mean score of 2.9, market strategies with a mean score of 2.8 and processing of maize with a mean score of 2.6.

Information Channels Available To Farmers

table 3 showed the information channels available to farmers, the result indicated that majority (94.4%) had availability of radio; this was followed by friends, relatives, and neighbours (87.8%), village leaders (82.2%), and mobile phones (78.9%), traditional town crier (73.3%), and print media (68.9%), cooperative societies (36.7%), agricultural extension worker (31.1%), television (27.8%), agricultural shows (13.2%), and field/farm tour (8.9%),

Level of accessibility of information channels

Table 4 showed the access of information channels by the maize farmers, the result indicated that the majority of the farmers with a mean score of 3.2 had access to village leaders and farmers had access to radio with a mean score of 3.1. This was followed by those who had access to friends/relatives/neighbors with a mean score of 2.9, mobile phone with a mean score of 2.4, town crier with a mean score of 2.1, Extension workers with a mean score of 1.2, newspaper/magazine with a mean score of 1.0, cooperative societies with a mean score of 1.0, television with a mean score of 0.6, field/farm tours with a mean score of 0.3 and agricultural shows with a mean score of 0.3 were the least accessible respectively.

Table 1: Socio-economic Characteristic of Maize Farmers (n=90)

Variable	Frequency	Percentage	Mean
Sex			
Male	63	70.0	
Female	27	30.0	
Marital Status			
Married	45	65.6	
Single	31	34.4	
Ages (Years)			
0 – 29	17	18.9	
30 – 39	29	32.2	
40 – 49	17	18.9	41.0
50 – 59	14	15.6	
60 and above	13	14.4	
Educational Level of Farmers			
No Formal Education	50	55.6	
Primary Education	21	23.3	
Secondary Education	17	18.9	
Post-Secondary Education (HND/OND/NCE)	2	2.2	
Size of Household			
1 – 4	18	20.1	
5 – 8	37	41.1	8.0
9 – 12	31	34.4	
13 and above	4	4.4	
Member of Cooperative Society			
Yes	29	32.2	
No	61	67.8	
Years of Farming Experience			
1 – 10	56	62.2	
11 – 20	15	16.7	13.0
21 - 30	11	12.2	
31 – 40	7	7.8	
41 and Above	1	1.1	
Farm Size in Hectares			
Less than 1	2	2.2	
1 – 3	81	90.0	2.0
4 – 6	6	6.7	
7 and above	1	1.1	

Computed from field data, 2021

Constraints Affecting the Use of Information Channels by maize farmers

Result in Table 5 showed the constraints experienced by maize farmers in the use of information channels in the study area. lack of electricity supply by the majority (88.9%) of the farmers is the major constraining factor followed by the poor visit of extension workers to farmers

with 80.0%. cost of mobile phones and airtimes with 78.9%, the language barrier between extension workers and farmers with 71.1%, absence of radios and television broadcast in local dialect with 66.7%, lack of funds to purchase television set or radio with 63.3%,lack of funds to join cooperative society with 61.1%, lack of formal education to read newspaper, magazines, posters with 56.7% and access to

television networks with 54.4% also constrains them to an extent, with Poor broadcast of agricultural shows in radio stations with 48.9% and poor dissemination of information by town criers, friends, relatives and neighbors with 33.3%. (ITU,2011) states that expansion of ICT has the danger of marginalizing those that lack the necessary skills. (Bhavnani, Chiu,

Janakiram, and Silarszky, 2008) said that it may be argued that the natural barrier in developing countries, such as lack of electricity, will act as constraints to ICT development. (Bhavnani *et al.*, 2008) also stated that it may be considered that the cost of a handset and subscription to service will prohibit the poorest of farmers in the society from utilizing ICT technology.

Table 2: Mean Responses of Farmer's Information Needs.

Information Needs	Farmers Mean Score	Decision rule (1.5)
Information on use of herbicides and insecticides	3.6	Accepted
Information on application of fertilizers	3.3	Accepted
Information on the source of farm inputs e.g. fertilizers	3.3	Accepted
Information on technological innovations	2.9	Accepted
Information on how to increase maize yield	3.4	Accepted
Information on the source of loan/credit facilities	3.0	Accepted
Information on market strategies	2.8	Accepted
Information on the source of improved seed variety	3.1	Accepted
Information on the source of tractor hiring for land tillage	3.0	Accepted
Information on storage/ preservation of maize	2.9	Accepted
Information on the processing of maize	2.6	Accepted
Average score	3.1	Accepted

Computed from field data, 2021

Table 3: Information Channels Available To Farmers.

Information Channels	Frequency*	Percentage (%)
Print media	62	68.9
Radio	85	94.4
Television	25	27.8
Traditional town crier	66	73.3
Agricultural extension worker	62	31.1
Friends/relative/neighbours	79	87.8
Village leaders	74	82.2
Cooperative societies	33	36.7
Field/farm tours	8	8.9
Agricultural shows	12	13.2
Mobile phones	71	78.9
Total	577	603.2

Computed from field data, 2021

* multiple responses (respondents could choose more than one option)

Table 4: Mean Responses of Farmers Access to Information Channel

Information Channels	Famers mean score	Decision rule (1.5)
Newspaper/magazine	1.0	not accepted
Radio	3.1	Accepted
Television	0.6	not accepted
Traditional town crier	2.1	Accepted
Agricultural extension worker	1.2	not accepted
Friends/relative/neighbours	2.9	Accepted
Village leaders	3.2	Accepted
Cooperative societies	1.0	not accepted
Field/farm tours	0.3	not accepted
Agricultural shows	0.3	not accepted
Mobile phones	2.4	Accepted
Average score	1.6	Accepted

Computed from field data, 2021

Table 5: Constraints Affecting the Use of Information Channels

Constraints	Frequency	(%)
Lack of formal education to read newspapers, magazines, posters.	51	56.7
Absence of radios and television broadcast in the local dialect.	60	66.7
Poor visit of extension workers to farmers.	72	80.0
Lack of funds to purchase television sets or radio.	57	63.3
Cost of Mobile phones and airtime.	71	78.9
Lack of electricity supply.	80	88.9
Access to television networks.	49	54.4
Poor broadcast of agricultural shows in radio stations.	44	48.9
Poor dissemination of information's by town criers, friends, relatives, and neighbors.	30	33.3
Lack of funds to join the cooperative society.	55	61.1
The language barrier between extension workers and farmers.	64	71.1
Total	633	703.3

Computed from field data, 2021
one option)

* multiple responses (respondents could choose more than

CONCLUSIONS

The findings of the study showed that information channels have become important tools in improving maize farming in the study area. Information channels are becoming increasingly important in sharing and disseminating agricultural information like usage of herbicides and insecticides, market strategies, technological innovations, source of loans e.t.c. However, the study established that there is low

usage of information channels in the study area. The challenges and their cause need to be addressed if the information channel is to benefit maize farmers in the study area.

If used effectively, information channels could transform the productivity of maize farmers. Unfortunately, many constraints are blocking the flow of information channels such as lack of electricity, lack of formal education, cost of mobile phones and airtime, lack of radio and

television broadcast in the local dialect, poor visit of extension workers, and lack of funds to join cooperative societies. e.t.c

This study reveals that maize farmers have limited access to agricultural information. This is because most of the information they have access to is majorly not the information they need. This study showed the information need of the maize farmers in which the majority of the respondent needs information on the use of herbicides and insecticides.

RECOMMENDATIONS

Based on the outcome of this finding, it is recommended that;

1. Adult literacy classes should be organized for farmers by the State Ministry of Education to enable maize farmers to acquire education and access information in print media such as newspapers, magazines, journals and extension bulletins.
2. The management of the television and radio broadcasting houses should come up with agricultural programs in local languages for the maize farmers to listen and understand.
3. The microfinance banks should provide loans/ credit facilities to the maize farmers to assist them increase their productivity.
4. Extension agencies should utilize appropriate channels such as electronic means to reach farmers with innovations despite the current national security challenge.

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ASSESSMENT OF GENDER ROLES ON AGRICULTURAL EXTENSION -PROGRAMME DELIVERY TO CASSAVA FARMERS IN IMO STATE.

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ABSTRACT

Agricultural extension plays a crucial role in disseminating improved technologies and practices to enhance productivity among smallholder farmers. However, the effectiveness of extension services is influenced by gender dynamics. This study assessed the gender roles and challenges faced by male and female extension agents in delivering cassava extension programs to farmers in Imo state, Nigeria. The research employed a descriptive survey design using quantitative and qualitative methods. Data was collected from 150 extension agents (75 males and 75 females) through questionnaires, interviews and focus group discussions. The results revealed significant gender differences in the roles performed by extension personnel. Female agents were more involved in mobilizing and reaching out to women farmers due to shared gender identities. In contrast, male agents dominated technical advisory roles like plot inspections and provision of technical services, reflecting gender stereotypes. The perceived effectiveness of extension delivery methods also varied by gender, with female agents rating higher on interactive approaches than mass media channels. Regression analysis showed that the role of women farmer mobilization performed by female agents significantly influenced program effectiveness. Both genders faced constraints like limited training and resources, but female agents additionally faced challenges related to institutional gender biases, social norms and work-life balance issues. The study concludes that promoting gender equity, overcoming stereotypes and adopting gender-sensitive strategies within extension systems is crucial for effective program delivery to male and female cassava farmers. Based on the findings of this research work, it was recommended that Gender mainstreaming in extension programs should be strengthened to understand and cater to the distinct needs, constraints and preferences of male and female farmers.

Keywords: Gender Role, Agricultural Extension, Programme Delivery, cassava farmers.

INTRODUCTION

Cassava is an important staple crop in many parts of Africa, including Nigeria. It is processed into various food products and is a major source of carbohydrates and income for smallholder farmers (Manfre et al., 2013). However, cassava yields in Nigeria remain below potential. One of the factors identified as limiting productivity is

inadequate extension services and technology transfer to farmers (Khursheed et al. 2020).

Agricultural extension is a vital service for advancing rural progress and agricultural development. It serves as an instrument to enhance the sustainability of farming systems, promote diversification of agricultural production systems, foster food security, and assist farmers in adapting to changing markets

(Saito and Weidemann, 1990, Kuyper and Schneider, 2022). In this regard, extension advisors act as important catalysts for economic growth in both developed and developing countries (Aker, 2021). Agricultural extension delivery includes the supply of modern inputs such as seeds, fertilizers, and other associated inputs to farmers, which is essential for promoting agriculture among millions of small-scale farmers in Nigeria (Abegunde, 2020).

Gender assessment is a tool for understanding and gaining insight into the activities of both males and females in society, the opportunities and challenges they face in performing their activities. Gender, as a concept in social sciences, defines the roles and activities of males and females. According to Olawoye et al. (2002), gender is a social construct that identifies the socially expected rights, responsibilities, and obligations of males and females. This underscores the imperative to firmly establish a gender perspective in extension program delivery to contribute to achieving agricultural extension goals.

Across many African countries, it has been observed that a larger percentage of extension personnel are male, while the agricultural workforce is predominantly female farmers. As such, the insufficient number of female extension officers is often cited as a challenge to improving the delivery of agricultural services to women farmers and achieving a food-secure society (Mamun-ur-Rashid et al., 2017). Increasing the role of women as extension workers can help boost agricultural productivity, which is and will continue to be the economic cornerstone for African countries, recognizing its considerable contribution to local and export earnings in these countries (Msuya et al., 2017).

In agricultural extension, women stand side by side with men. However, women's prospects

have not been fully explored, and their services and capabilities are not equitably rewarded (FAO, 2019; Khursheed et al. 2020). Despite their important role and extensive contribution to agricultural production and food security, women extension advisors and village level paraprofessionals (indigenous people who work as change agents at a village level) are poorly incorporated into mainstream extension activities and operate on an unequal basis with men (FAO, 2019). They are often said to be underpaid as compared to their men counterparts (FAO, 2019). According to Kilic et al (2015), the sources of gender gaps vary across developing and developed countries. Executing extension activities or priorities without the participation of female extension personnel and female farmers risk having negative impacts on the attainment of food security, rural livelihoods, sustainable agriculture and economic development (Manfre et al., 2022).

STATEMENT OF PROBLEM

Cassava is an important staple crop for smallholder farmers in Imo state, Nigeria. However, cassava productivity in the state remains below attainable yields. One of the factors contributing to low productivity is the limited access and dissemination of improved cassava production technologies and best practices to farmers through extension services. Previous studies have highlighted gender inequalities in access to agricultural extension programs, with women farmers facing greater constraints compared to men. Gender roles, norms and relations can influence men's and women's ability to participate in extension activities and consequently improve productivity. However, there is limited understanding of how gender dynamics specifically shape extension program delivery to cassava farmers in Imo state.

To enhance the effectiveness of cassava extension programs, it is crucial to assess the gender roles, responsibilities, opportunities and challenges faced by male and female extension agents in discharging their duties to cassava farmers in Imo state. Without this critical gender analysis, extension interventions may inadvertently perpetuate gender inequalities and productivity gaps. Therefore, this study seeks to examine the gender roles on extension programme delivery to cassava farmers in Imo state.

OBJECTIVE OF THE STUDY

The study therefore, examines the gender roles on Agricultural extension programme delivery to cassava farmers in Imo state.

. It specifically aims to;

- i. examine the social-economic characteristics of agricultural extension agents.
- ii. describe the different gender roles in extension programme delivery on cassava production.
- iii. determine the effectiveness of the roles perform by male and female extension agents.
- iv. determine the effect of socio-economic characteristics of the agents on extension programme delivery.

HYPOTHESIS:

- i. **H₀:** The socio-economic characteristics of the extension agents have no significant effect on extension programme delivery.
- ii. **H₀:** The effectiveness of roles extension agents perform is not dependent on the gender.

RESEARCH METHODOLOGY

Research Design:

The study utilized a descriptive and inferential survey research design to describe the gender dynamics in extension service delivery. Both qualitative and quantitative data were collected.

Study Area:

The study was carried out in Imo state, located in the south-eastern agro-ecological zone of Nigeria. Imo state has high cassava production potential but yields remain below attainable levels.

Population and Sampling:

The target populations were male and female extension agents in Imo state. A random sampling technique was used to distribute questionnaire to the extension agents at their state headquarter in Owerri.

Data Collection:

Primary data were collected using pre-tested interview schedules and a structured questionnaire. Focus group discussions were also conducted to get qualitative insights. Secondary data were obtained from published and unpublished sources.

Data Analysis:

Both quantitative and qualitative data analysis methods were employed. Quantitative data were analyzed using descriptive (frequencies, percentages) and inferential statistics like regression analysis.

Model Specification:

The model is specified that, Extension programme delivery is the function of the age,

educational qualification and experience years of the extension agent.

$$\text{EXPROG} = f(\text{AGE}, \text{EDU}, \text{EXP}) \text{ ----- } 3.1$$

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + U \text{ ----- } 3.2$$

In a linear function, it is represented as follows:

$$\text{EXPROG} = \beta_0 + \beta_1 \text{AGE} + \beta_2 \text{EDU} + \beta_3 \text{EXP} + U$$

---- 3.3

Where EXPROG = Extension Programme Delivery

AGE = Age of the extension agent

EDU = Educational level of the extension agent

EXP = Experience of the extension agent

β_0 , β_1 , β_2 and β_3 are unknown parameters of the model to be estimated and U is the error term.

RESULTS AND DISCUSSION

This section presents the results and discussion from the study on assessment of gender roles of extension agents in programme delivery to cassava farmers in Imo state

The results provide insights into the roles and perspectives of male and female extension agents, as well as the constraints faced in programme delivery.

Table 4.1: Socio economic Distribution of the male and female Respondents

Age Group	Male (n=75)	Female (n=75)	Total (N=150)	Percentage (%)
20-30 years	10 (13%)	15 (20%)	25	16.7%
31-40 years	25 (33%)	30 (40%)	55	36.7%
41-50 years	30 (40%)	20 (27%)	50	33.3%
51-60 years	10 (13%)	10 (13%)	20	13.3%
Total	75 (100%)	75 (100%)	150	100%
Education Level	Male	Female	Total	Percentage (%)
Secondary school	5 (7%)	10 (13%)	15	10%
Diploma	10 (13%)	15 (20%)	25	16.7%
Bachelor's degree	50 (67%)	45 (60%)	95	63.3%
Master's degree	10 (13%)	5 (7%)	15	10%
Total	75 (100%)	75 (100%)	150	100%
Years of Experience	Male	Female	Total	Percentage (%)
0-5 years	15 (20%)	30 (40%)	45	30%
6-10 years	25 (33%)	20 (27%)	45	30%
11-15 years	20 (27%)	15 (20%)	35	23.3%
>15 years	15 (20%)	10 (13%)	25	16.7%
Total	75	75	150	100%

Field survey 2024

Table 4.1 presents the socio-economic distribution of the 150 extension agents surveyed, comprising 75 males and 75 females in identifying the key trends and differences between the segregated gender of the extension agents. The result revealed that majority of both male (73%) and female (67%) agents were in the

31-50 years age bracket. However, a higher proportion of females (60%) were in the younger 20-40 years range compared to males (46%, this indicates more recent entry of women into extension services, aligning with trends of increased female participation in extension services (Adekoya & Tologbonse, 2005).

On the side of educational level, most agents held a bachelor's degree (67% males, 60% females). However, more females had lower secondary (13%) and diploma (20%) qualifications compared to males (7% and 13% respectively). This corroborates studies showing persisting gender gaps in access to higher education, especially in rural areas (Okunlola et al., 2016).

Looking at the years of experience, Male agents tended to have more years of experience on average compared to females. 53% of males had over 10 years of experience versus only 33% of females, 40% of females were relatively new

Table 4.2: Multiple Responses on Gender Differences in Roles and Responsibilities of the extension agents

Roles	Male Frequency and Percentage	Female Frequency and Percentage
Women farmer mobilization	15 (10%)	135 (90%)
Plot inspections	140 (93%)	10 (7%)
Provision of technical advice	122 (81%)	38 (19%)
Farmer trainings	85 (57%)	65 (43%)
Information dissemination	81 (54%)	69 (46%)
Facilitating inputs/credit	80 (53%)	70 (47%)
Farmer feedback	50 (33%)	100 (67%)
Demonstrations/trials	90 (60%)	60 (40%)

Field survey 2024

Table 4.2 presents the survey results on gender differences in the roles and responsibilities performed by male and female extension agents. A stark difference is observed in the role of mobilizing and outreaching to women farmers. 90% of female extension agents reported being involved in this activity, compared to only 10% of male agents. This aligns with previous studies

entrants with 0-5 years of experience, compared to 20% of males. The higher average experience of males reflects the historically male-dominated nature of extension services (Rivera & Alex, 2004).

In summary, the socio-economic profile reveals persisting gender inequities, with women extension agents being younger, less educated, and having fewer years of experience compared to their male counterparts. Addressing these gaps through equal opportunities in education, recruitment, and career development is crucial for enhancing gender parity and performance in extension services.

that have found female extension workers are more effective in connecting with women farmers due to shared gender identities and fewer socio-cultural barriers (Manfre et al., 2013; Ragasa et al., 2013). Male agents dominated technical roles like plot inspections (93% for males vs. 7% for females) and provision of technical advice (81% vs. 19%). This disparity likely stems from persisting gender norms and biases that associate technical competencies more with men (Chapman & Slaymaker, 2002; Rivera & Alex, 2004).

For farmer training and information dissemination roles, both genders had relatively high involvement, though a higher percentage of males (57% and 54% respectively) compared to females (43% and 46%). Input/Credit Facilitation and Feedback: Female agents showed higher participation in facilitating access to inputs/credit for farmers (47% vs. 53% for males) and collecting feedback from farmers (67% vs. 33% for males).

The findings reveal how gender influences the types of responsibilities undertaken by extension personnel, shaped by socio-cultural factors and institutional biases. Promoting gender equity by overcoming stereotypes and building technical capabilities of female agents is crucial for inclusive and effective extension services.

Table 4.3: Multiple responses on Perspectives on Program Delivery Methods by Gender

Program Delivery Method	Male Agents		Female Agents	
	Utilizing Method (%)	Effectiveness Rating	Utilizing Method (%)	Effectiveness Rating
Farmer Field Days/Demos	70	4.5	75	4.7
Group Training Sessions	65	4.2	70	4.4
Individual Farm Visits	60	3.8	65	4.1
Radio/TV Programs	65	3.8	40	2.9
Print Materials	65	3.5	40	2.7

Researcher Computation, 2024

Based on the perceived effectiveness ratings, an interesting divergence emerged in how male and female agents rated the effectiveness of different delivery methods on a 1-5 scale. Both genders viewed interactive approaches like farmer field days (4.5 for males, 4.7 for females) and group trainings (4.2 for males, 4.4 for females) as highly effective ways to engage farmers. However, male agents gave significantly higher average ratings for the effectiveness of radio/TV programs (3.8) and print materials (3.5) compared to the lower ratings of 2.9 and 2.7 respectively by female agents. This perception gap likely stems from the

lower accessibility and receptiveness of female farmers to mass media extension delivery, as noted by Mudukuti & Miller (2002). Based on their field experiences, female extension agents found these one-way communication channels less impactful compared to interactive approaches. The findings highlight how gender norms, preferences and realities shape the perspectives of male and female extension personnel on optimal program delivery strategies (Ragasa, 2014). Considering these gender perspectives is vital for inclusive agricultural extension planning.

Table 4.4: Regression Analysis of Gender Differences in Roles and Responsibilities

Variable	Coefficient	Standard Error	t-statistic	p-value
Gender (1=male, 0=female)				
Women farmer mobilization	-0.20	0.05	-4.00	0.001***
Plot inspections	0.15	0.04	3.75	0.002***
Provision of technical advice	0.15	0.06	2.50	0.018**
Farmer trainings	0.10	0.07	1.43	0.159
Information dissemination	0.10	0.05	2.00	0.054*
Facilitating inputs/credit	0.10	0.06	1.67	0.105
Farmer feedback	0.05	0.04	1.25	0.218
Demonstrations/trials	0.10	0.05	2.00	0.054*

Note: ***p<0.01, **p<0.05, *p<0.1

In order to ascertain the effect of the roles of the extension agents as segregated by gender on program delivery, the regression analysis explained that women farmer mobilization showed to be significant at the three level of the critical value, the finding that female extension agents are more involved in women farmer mobilization aligns with past research showing that women extension workers are often better at reaching and engaging women farmers compared to men (Manfre et al., 2013). Social and cultural norms in many developing country contexts restrict interactions between women farmers and male extension agents, whereas female agents face fewer constraints in interacting with women farmers and understanding their needs (Ragasa et al., 2013). Studies from Nigeria (Adekoya & Tologbonse, 2005), Kenya (Kiptot & Franzel, 2015), and India (Glendenning et al., 2010) have also reported greater effectiveness of female extension agents in serving women farmers. The greater participation of male extension agents in technical roles like plot inspections and provision of advisory services reflects gender

stereotypes and biases that associate men with higher technical aptitude and competence (Rivera & Alex, 2004). Women extension workers often face discrimination and obstacles in skills training, promotion and assignment of complex technical tasks (Chapman & Slaymaker, 2002). Ensuring equal access to professional training and capacity building can help address these gender gaps in technical capabilities (FAO, 2017). Evidence from Bangladesh and India shows that with adequate training, female extension agents can perform technical advisory roles just as effectively as their male counterparts (Ragasa et al., 2013). The study findings add to the body of literature on the influence of gender norms, biases and stereotypes on the responsibilities assigned to extension agents. As argued by Rivera (2001), agricultural extension organizations need to be more gender-sensitive in designing job roles and providing equal opportunities to male and female workers. Promoting gender equity within extension systems is vital for ensuring effective service delivery to both male and female farmers.

Table 4.5: the effect of Socio-economic characteristics of the extension agents on gender roles programme delivery.

Extension Programme Delivery = $f(\text{Age, Education, Experience})$

It is further represented as follows:

$$\text{EXPROG} = \beta_0 + \beta_1\text{AGE} + \beta_2\text{EDU} + \beta_3\text{EXP} + U.$$

The regression output follows:

Variable	Coefficient	Standard Error	t-value	P-value
Constant	2.15	0.24	8.96	0.000
Age	-0.02	0.01	-2.55	0.011*
Education	0.08	0.04	1.98	0.048*
Experience	-0.12	0.05	2.61	0.009*

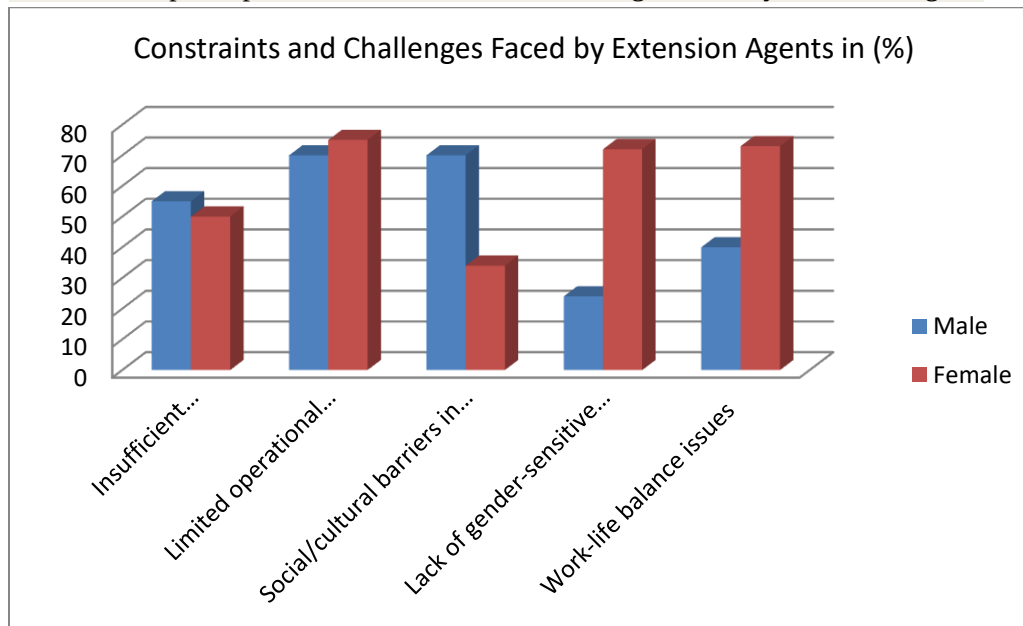
R-squared: 0.57

F-statistic: 18.22

Significance: 0.000

***, **, * indicate significance at 1%, 5% and 10% respectively

Chart 1: Multiple responses on Constraints and Challenges Faced by Extension Agents



Field survey, 2024

The results indicated that the model explains 57% of the variation in program delivery. Variables like education and experience positively and significantly affect program delivery. On the other hand, age had a negative effect. This demonstrates the importance of socioeconomic factors in explaining gender differences in program delivery. The model provides useful insights on areas of focus to promote equitable extension delivery.

The chart presents data on the constraints and challenges faced by male and female extension agents. Both male (55%) and female (50%) extension agents reported facing constraints due to lack of sufficient training and capacity building opportunities. Continuous training is crucial for agents to update their knowledge and skills in new agricultural technologies and extension methods. Similarly, a high proportion

of both male (70%) and female (75%) agents cited limited operational resources as a major constraint. This could include inadequate transport, demonstration materials, information and communication tools etc., hindering their ability to effectively reach out to farmers. 70% of male agents reported facing social/cultural barriers in accessing and interacting with farmers, compared to only 34% of female agents. This likely reflects gender norms that make it easier for female agents to approach female farmers. Similarly, only 24% of male agents perceived lack of gender policies as a constraint, while 72% of female agents highlighted this as a major challenge.

The data clearly shows that while some constraints like limited resources affect both genders, female extension agents face distinct challenges related to institutional gender biases, social norms and household responsibilities.

CONCLUSION

Based on the findings of this research work, it was concluded that there are significant gender

differences in the roles and responsibilities undertaken by male and female extension agents in Imo State, shaped by socio-cultural norms, institutional biases and gender stereotypes.

Female extension agents are more effective in mobilizing and reaching women farmers due to shared gender identities and fewer socio-cultural barriers compared to male agents. Similarly, Male agents dominate technical advisory roles like plot inspections and provision of technical advice, reflecting biases that associate technical competencies more with men.

However, both genders face constraints like limited training, operational resources, but female agents additionally face distinct challenges related to institutional gender policies, social norms and work-life balance issues. And lastly, Socio-economic factors like education and experience significantly influence the gender roles and effectiveness of extension agents.

RECOMMENDATIONS:

- i. Gender equity should be promoted within extension systems by providing equal training, capacity building and career advancement opportunities for both male and female agents.
- ii. Gender stereotypes and biases should be addressed through sensitization programs and develop gender-sensitive policies within agricultural extension organizations.
- iii. Adequate operational resources and enabling working conditions should be provided, especially measures to support work-life integration for female agents.
- iv. Gender mainstreaming in extension programs should be strengthened to understand and cater to the distinct needs, constraints and preferences of male and female farmers.
- v. Conduct further research on intersections of gender with other social identities like age, ethnicity, disability etc. in shaping extension experiences.

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ECONOMIC PERFORMANCE OF YAM PRODUCTION AMONG SMALLHOLDER FARMERS IN ILESA WEST LOCAL GOVERNMENT AREA, OSUN STATE, NIGERIA

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ABSTRACT

The study examined the economic performance of yam production among smallholder farmers in Ilesha West Local Government Area of Osun State, Nigeria. Multistage sampling technique was used to select 120 respondents for the study. Data were collected with the aid of pre-tested questionnaire and analysed using descriptive statistics, gross margin analysis, profitability ratios and multiple regression model. Results revealed that majority (96.7%) of the yam farmers were male, educated (93.3%) with a mean age of 51 years, household size of 6 persons and cultivated an average of 1.2 hectares of farm land. Results of the gross margin analysis and profitability ratios indicated that yam production was a profitable and economically viable enterprise with a net farm income of ₦91,711.23 and 30K returns on every naira invested in yam production in the study area. Education, household size, farm size and access to loan were the factors influencing yam income in the study area. Therefore, loan facilities should be made available and accessible to the farmers at no or low interest rates to expand their business and increase their income in the study area

Keywords: Economic performance, yam production, Osun State, Regression

INTRODUCTION

Yams (*Dioscorea spp*) are the second most important tuber crop in the whole world after cassava, in terms of production (IITA, 2013). They are grown in Latin American and Caribbean countries like Colombia, Brazil, Haiti, Cuba, Jamaica and savannah region of West Africa where the rainfall pattern is divided into wet and dry season (FAO, 2013). Yams are annual root tuber producing plants with more than 600 species out of which six (white yam (*D. rotundata*), yellow yam (*D. cayenensis*), water yam (*D. alata*), trifoliate yam (*D. dumetorum*), arial yam (*D. bulbifera*) and Chinese yam (*D. esculenta*)) are the most important in terms of

food, income generation and medicine (IITA, 2009; Verter and Bečvářova, 2015).

According to Food and agriculture Organisation (FAO, 2019), world production of yam was 74.32 million tonnes, in 2019, out of which Nigeria's production accounted for 67.34% with total farm size of 6.24 million hectares, which is 70.03% of worlds farm size area of 7.43 million hectares. The crop is a major source of carbohydrate, and contain higher protein, fat and vitamin than other tuber crops. In Nigeria, the tuber can be cooked, fried, roasted, processed into yam flour, pounded yam, porridge and chips. The crop is also presented during marriage ceremonies. Medicinally, the mucilaginous tuber milk contains allantoid that

speeds up the healing process of abscesses. Its decoction is also used to stimulate appetite and to relieve irritation and cough (United State Department of Agriculture (USDA), 2012; Ugwumba *et al.*, 2014). Yams do not only serve as the means of food production, income generation and poverty reduction, but also create employment opportunities in Nigeria. However, yam seeds are expensive with limited seed supply leading to gap in the demand and supply of yam. Also the planting through to the harvesting processes require significant labour input making yam one of the most expensive crops to produce (Akerele and Obafunso, 2019).

Several studies (Ugwumba *et al.*, 2014; Yesufu *et al.*, 2017; Idumah and Owombo, 2017; Ariyo *et al.*, 2021) have analysed factors influencing income from yam production to include age of farmers, education, seed yam, farm size, farming experience, household size labour and agrochemicals. Although Osun State is one of the highest yam producing state in Nigeria, the price of yam has continued to increase due to high demand-supply gap in the state. This could be ascribed to increasing population growth and production problems such as high costs of inputs, pests and disease attack, inadequate credit facilities among others, leading to low productivity. To this end, this study analysed the economic performance of yam production in the study area. Specifically, the study described the socio-economic characteristics of the yam farmers, estimated the costs and returns to yam production, determined the economic performance of the yam farmers and analysed the factors influencing income from yam production in the study area

METHODOLOGY

This study was conducted in Ilesa West Local Government Area of Osun state, Nigeria. The headquarter is in the town of Oja Oba (Ereja

Square) on the outskirts of the city of Ilesa. It is located on coordinates 7°39'N and 4°43'E. It has an area of 63km² (24sqm) and a population of 103,555 at the 2006 census. The major occupation of the people in the area is farming. Crops cultivated include maize, yam, cassava, cocoyam, cocoa, kolanut, citrus and vegetables. Livestock like sheep, cattle, pig, goat, rabbit and poultry are additionally raised for sales and consumption.

Multistage sampling technique was used to select 120 yam farmers from two local government areas where yam production was predominant in the state. Data were collected with the aid of questionnaire and analysed using descriptive statistics for the socio-economic characteristics of the respondents, gross margin analysis for the cost and returns to yam production and multiple regression model for factors influencing income from yam production in the study area.

Gross Margin Analysis

This was used to estimate the costs and returns to yam production in the study area. Gross margin analysis is defined as the difference between total revenue and total variable cost. Total revenue (TR) is the product of price and output of yam while the total variable cost (TVC) is the aggregation of the cost of land preparation, planting materials, yam seeds, planting, weeding, mulching and harvesting.

Mathematically,

$$a. GM = TR - TVC \quad \text{-----} \quad (1)$$

Where;

$$TR = \text{total revenue expressed as } P \times Q \quad \text{-----} \quad (2)$$

$$TVC = \text{Total variable cost expressed as } TC - TFC \quad \text{-----} \quad (3)$$

$$P = \text{price/unit of yam } Q = \text{number of yam sold}$$

$$TC = \text{Total cost expressed as } TFC + TVC \quad \text{--} \quad (4)$$

$$TFC = \text{Total Fixed Cost expressed as } TC - TVC \quad \text{-----} \quad (5)$$

b. Net Farm Income:

The net farm income (NFI) is the difference between the gross margin (GM) and total fixed cost (TFC)

Mathematically,

$$NFI = GM - TFC \text{ ----- (6)}$$

Economic performance analysis

The profitability ratios were used to determine the economic performance of the yam farmers in the study area. According to Olaoye *et al.*, (2012), profitability ratio is a class of financial metrics that helps investors assess a business's ability to generate earning compared with its expenses and other relevant costs incurred during a specific period. Following Olaoye *et al.*, (2012), Onwuka *et al.*, (2014), Ariyo *et al.*, (2020), Aminu and Hermanns (2021), the Profitability ratios are specified as:

$$\text{Return per naira spent} = NFI/TC \text{ ----- (7)}$$

$$\text{Rate of return on variable cost (RRVC)} = TR - TFC/TVC * 100 \text{ ----- (8)}$$

$$\text{Rate of return on fixed (RRFC)} = TR - TVC/TFC * 100 \text{ ----- (9)}$$

$$\text{Gross Ratio (GR)} = TC/TR \text{ ----- (10)}$$

$$\text{Fixed Ratio} = TFC/TR \text{ ----- (11)}$$

$$\text{Operating Ratio (OR)} = TVC/TR \text{ ----- (12)}$$

Multiple Regression Analysis

This was used to analyse the factors influencing income from yam production in the study area.

The implicit form of the model is as follows;

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \mu \dots (13)$$

Where, Y = Income (₦); X_1 = Sex of farmer (1 if male, 0 otherwise); X_2 = Age (years); X_3 = Educational Status (years of formal schooling); X_4 = Household size (No of people); X_5 = Farming Experience (years); X_6 = Farm size (hectares); X_7 = Type of labour Used; X_8 = Access to Loan (dummy); X_9 = Cooperative Membership (dummy); X_{10} = Extension contact (dummy); b_0 = Constant term; $\beta_1 - \beta_{10}$

Regression coefficient to be estimated; μ = Error term.

Different functions, linear, semi-log, double-log and exponential were tried and the linear function was chosen for the analysis based on goodness of fit (economic, econometric and statistical criteria).

RESULTS AND DISCUSSION

Results in Table 1 revealed that majority (96.7%) of the farmers were male. This implies that yam production in Osun State is male dominated. This result agrees with the finding of Ariyo *et al.*, (2021) who attributed male dominance in Ekiti State to labour intensive nature of the crop. Majority (57.5%) of the farmers fell with 41 to 60 years' age range. The mean age of about 51 years implies that the farmers, though experienced were getting old and this could have negative effect on their output. Similar result was reported by Yesufu *et al.*, (2017) for yam farmers in Anambra State, Nigeria. Distribution by education revealed that only 6.7% of the farmers had no formal education. This implies that the respondents were literate and this could serve as impetus for adoption of innovation and good farming practices in the study area. The mean household size of the farmers was 6 persons. This implies that the farmers had a relatively large family size which could translate to family labour availability in the study area. This concurs with the submission of Toluwase and Sekumade (2017) that large household size leads to increased efficiency. Also, 57.5% of the farmers cultivated between 0.1 ha to 0.6 ha of farmland. The mean farm size of 1.2 hectares implies that the farmers were small scale farmers. Furthermore, majority of the respondents had no access to bank loan or extension contacts in the study area. This could impede possible expansion and access to improved technologies in the study area. This is in consonance with the

findings of Ilemobayo and Ijigbade (2019) that inadequate extension contacts lead to lack of access to recent technologies on good farming practices resulting to lower output.

Average Costs and Returns to Yam Production in the Study Area

The result of the costs and returns to yam production is presented in Table 2. The result shows that, an average total cost of ₦308,157.27 was invested in the yam production by the farmers in 2020 production season. The variable costs of ₦291,084.27 accounted for 94.46% of the total cost of production in the study area. This implies that variable costs constituted larger share of the cost of yam production in the study area. This result is similar to the findings of ugwumba *et al.*, (2014) who reported that variable cost items accounted for 96.48% of the total cost of yam production in Southwest,

Nigeria. The cost composition also reveals that labour cost, comprising of costs of land clearing, planting, agrochemical applications, weeding, staking and harvesting constituted the lion share of the variable costs, representing 56.85% of the total cost of yam production. This is an indication that the yam farmers spent a huge sum of money on labour in the study area. This is consistent with the findings of Ariyo *et al.*, (2020) that cost of labour was the major important single cost item associated with yam production in Ekiti State, Nigeria. The total fixed cost was ₦17,073.00 representing 5.54% of the total cost of production. Furthermore, a total revenue of ₦399,868.5 was realised from the sales of harvested yam while gross margin of ₦108,784.23 and net farm income of ₦91,711.23 were realised. This implies that yam production was a profitable enterprise in the study area.

Table 1: Selected Socio-economic Characteristics of the Yam Farmers ($n = 120$)

Variable	Frequency	Percentage (%)	Mean
Sex			
Female	4	3.3	
Male	116	96.7	
Age (years)			
≤40	22	18.3	51.43 (±10.813)
41-60	69	57.5	
> 60	29	24.2	
Educational Qualification			
No Formal Education	8	6.7	
Formal Education	112	93.3	
Household Size (no)			
1-5	54	45.0	6 (±2.792)
>5	66	55.0	
Farm size (ha)			
0.1-0.6	69	57.5	1.2 (±0.855)
>0.6	51	42.5	
Cooperative Membership			
Yes	79	84.0	
Access to Bank Loan			
Yes	23	24.5	
Extension Contact			
Yes	18	19.1	
Yam Output			
≤5,000	98	81.7	3,646
>5,000	22	18.3	

Source: Field survey, 2022

Table 2: Average Costs and Return to Yam Production in the Study Area.

Cost items	Amount	% of TC
Variable costs		
Planting material	52,708.33	17.10
Land clearing	80,708.30	26.19
Cost of planting	17,026.21	5.53
Transportation cost	8,848.33	2.87
Cost of agrochemicals	53,233.33	17.27
Cost of weeding	32,250.00	10.46
Cost of staking	23,912.50	7.76
Cost agrochemical application	7,684.77	2.49
Cost of harvesting	11,595.83	3.76
Miscellaneous	3,116.67	1.01
Total Variable Cost (TVC)	291,084.27	94.46
Fixed Costs (depreciated)		
Rent on land	5,573.25	1.81
Cutlass	977.61	0.32
Hoe	1,227.45	0.40
Boot	3,565.25	1.16
Basket	621.55	0.20
Bowl	936.42	0.30
Wheel barrow	2,085.22	0.68
Yam ban	1,865.45	0.61
Others	220.80	0.07
Total Fixed Cost (TFC)	17,073.00	5.54
Total Cost	308,157.27	
Returns		
Total Revenue (TR)	399,868.5	48063.106
Gross Margin (TR - TVC)	108,784.23	
Net Farm Income (GM - TFC)	91,711.23	

Source: Field survey data, 2022

Economic Performance of the Yam Farmers in the Study Area

Table 3 presents the results of the profitability ratios used to measure the economic performance of the yam farmers in the study area. Return per naira invested in yam production was 0.30. This implies that, for every ₦1 spent during the production process, a return of 30K was realised. Results of the rate of return on variable cost (RRVC) and fixed cost (RRFC) were 131.51% and 637.17% respectively. This shows that, every ₦1 invested in variable and fixed inputs generates ₦1.31 and ₦6.37 respectively in the study area. This is an

indication that the yam farmers need to efficiently use variable inputs to boost production in the study area. Furthermore, the gross ratio that measures the overall success of the yam enterprise shows that the total cost of production accounted for 77% of the total revenue realised from the enterprise. The value of the fixed ratio of 0.04 implies that 4% of the total revenue was spent to procure the fixed input while 73% of the total revenue accounted for the operating expenses incurred in yam production in the study area. The results of the profitability ratios indicate that yam production is an economically viable enterprise capable of generating employment opportunities and

improving the standard of living of the yam farmers in the study area.

Table 3: Economic Performance of the Yam Farmers in the Study Area

Performance Measures	Ratios
Return per naira spent	0.30
Rate of return on variable cost (RRVC)	131.51
Rate of return on fixed cost (RRFC)	637.17
Gross ratio (GR)	0.77
Fixed ratio (FR)	0.04
Operating ratio (OR)	0.73

Source: Field survey data, 2022

Factors Influencing Economic Performance of Yam Production in the Study Area.

Table 4 presents the result of the multiple regression analysis. The linear function was chosen as a lead equation because it best fits the model in terms of the value of the highest coefficient of multiple determination, significance of parameters, significant F value and conformity with *a priori* expectations. The model had a coefficient of multiple determination of 0.896. This shows that about 90% of variation observed in the quantity of yam yield was jointly explained by the independent variables included in the model. The model revealed that education ($p < 0.05$), household size ($p < 0.10$), farm size ($p < 0.01$) and access to loan ($p < 0.05$) were the socio-economic factors influencing yield of yam in the study area.

The coefficient of educational status of the respondents was positive and significant at 5% alpha levels.

This implies that yield of yam increases with educational status of the farmers. This result corroborates the finding of Toluwase and Sekumade (2017) that positive influence of education on yam output could be due to increased technical knowhow, accessibility to new innovation and marketing information by the educated farmers. Household size of the farmers was also positive and significant at 5% level of probability. This implies that yam farmers with large household size have higher yield than the small household sized farmers. This could be as a result of the availability of the household members as labour in the study area. The area of farmland cultivated to yam production was found to increase yam yield as it was positive and significant at 1% alpha levels. A hectare increase in the farm size will increase yield by 43,821.24 units. This result is in tandem with the findings of Ariyo *et al.*, (2021) that farm size is a crucial variable for increased yam output. Furthermore, farmer's access to loan was positive and significant at 5% levels. This implies that yam yield increases with farmers' accessibility to formal loan facilities in the study area. This result concurs with the findings of Zakaria *et al.*, (2014) that farmers who borrowed from formal sources to invest on their farm operations stand high chance of increasing the yield of their farms.

Table 4: Factors Influencing Economic Returns of Yam Production in the Study Area

Variables	Coefficient	t-ratio	Sig.
(Constant)	-18485.899	-2.143	0.034
Educational Status	3253.884**	2.151	0.034
Household Size	1263.842*	1.736	0.085
Farming Experience	264.423	0.759	0.449
Farm size	43831.240***	20.065	0.000
Type of Labour Used	853.386	0.297	0.767
Access to Loan	8320.382**	2.136	0.032
Cooperative Membership	2216.599	0.726	0.470
Extension contact	-1033.321	-0.317	0.752
R ²	0.896		
Adj. R ²	0.888		
F value	116.360		

Source: Field survey data, 2022

*** and ** indicate significance at 1% and 5%

CONCLUSION AND RECOMMENDATIONS

Findings from the study revealed that yam production is dominated by aged, literate, married, large household sized, smallholder male farmers whose production were mainly influenced by educational status, family size, farm size and access to loan facilities. Yam production was also found to be an economically viable enterprise in the study area with a net return of 0.30. Therefore, Government at all tiers should make yam production attractive and appealing to the youths in the state, being a high yam producing state, through the provision of machineries, technologies and information that will ensure efficient yam production in the study area. In addition, loan facilities should be made available and accessible to the farmers at no or low interest rates to expand their business and increase their income in the study area.

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EXTENSION SERVICE NEEDS AMONGST WOMEN GINGER (*Zingiber Officinale*) FARMERS IN KAGARKO LOCAL GOVERNMENT AREA OF KADUNA STATE, NIGERIA

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ABSTRACT

This study `Extension service needs amongst women ginger (*Zingiber officinale*) farmers in Kagarko Local Government Area of Kaduna state. Was conducted in 2023, with the aim of evaluating the socioeconomics characteristics, the extension service needs and constraints to accessing extension services by the women ginger farmers of Kagarko in Kaduna of Nigeria.

A multi-stage sampling technique was used to select 120 women ginger farmers. Primary data were collected from the respondents with the aid of a structured questionnaire and the data collected were analyzed using both descriptive (frequency, percent and mean) and inferential (regression analysis) statistics. Results of the study show that the mean age of the respondents was 33.3years with a greater percentage (85%) of them being married, half (50%) of them had acquired primary education and on the average, women ginger farmers in the study area had farming experience of at least 9.75years with mean household size of 6 people who cultivated an average of 1.138 hectares of land with an annual income of ₦138, 641.64 kobo. The findings of the study indicated a need for marketing services by the respondents who were faced with the constraint of no much extension contacts. Results of the regression analysis indicated a significant relationship ($P<0.10$) between age and extension needs, educational level and household size of the respondents and their extension needs ($P<0.05$). Based on the findings of the study, it's concluded that the women ginger farmers had no appreciable extension contacts and hence recommended the needs for extension services for the women farmers.

Keywords: Extension service; needs; Women ginger farmers; Kagarko Local Government Area; Kaduna state; Nigeria

INTRODUCTION

Ginger (*Zingiber officinale*) is a flowering plant whose rhizome and root or ginger, is widely used as a spice and a folk medicine. Ginger is among the family of Zingiberaceae, which also

includes turmeric (*Curcuma longa*), cardamom (*Elettaria cardamomum*) and galangal. Ginger is an herbaceous perennial crop which grows an annual pseudo stems (false stems made of the rolled bases of leaves) about one-meter-tall bearing narrow blade leaves. The leafy stems of

ginger grow about a metre high. The leaves are 6-12 inches long, elongate, alternate in two vertical rows and arise from sheaths enwrapping the stem. The flowers of the plant are in dense cone-like spikes about 1- inch thick and 2-3 inches long that are composed of overlapping green bracts, which may be edged with yellow tip. The inflorescences of the plant bear flowers having pale yellow petals with purple edges, and arise directly from the rhizome on separate shoots (Haiping, 2020).

The consumed part of the ginger plant is the rhizome, often called “ginger root”, although it is not an actual root. A mature ginger rhizome is fibrous and has a striated texture. The outer skin of the rhizome is brownish in colour while the inner flesh depending on the variety may be yellow, red or white (*Thrive Africa*, 2020).

Ginger is believed to have originated from Southeastern Asia where it was first cultivated. Ginger was introduced to Africa and the Caribbean by the colonial masters. Cultivation of the crop in Nigeria dates back to 1927. Ginger is cultivated in the 36 states of Nigeria but with five states in the lead and these states include Kaduna, Bauchi, Benue, Gombe and Nasarawa states (Yusuf, 2017 and *Thrive Africa*, 2020).

In 2018, global production of ginger was 2.8 million tonnes, led by India with 32% of the world total. China, Nigeria and Nepal also had substantial production of the crop. The average annual production of ginger crop in Nigeria is about 400,000 tonnes making it the 3rd largest producer in the world after India and China. The average yield of ginger in Nigeria is 13-27 tonnes/hectare compared to the global average of 35-40 tonnes/hectare. Globally, Nigeria has the 2nd largest production share of about 16% after India with a production share of 33.9% (*ThriveAgric*, 2024).

With the estimated global ginger market as \$3 billion, Nigeria farmers can tap into this potential to earn foreign exchange as the country explores opportunities to grow its non-oil exports. In 2019, \$10.4 million was realized as revenue from ginger exports in Nigeria which makes the percentage of Nigeria’s Gross Domestic Product (GDP) that came from ginger crop exports in 2016 was 23% (Statista, 2023) Data gleaned from the National Bureau of Statistics show that the country’s export value of the crop has been increasing steadily. Ginger exports increased from N1.13 billion in quota 2 of 2018 to N1.24 billion in the same period of 2019. It increased in quota 2 of 2020 from N1.57 billion to N3.75 billion in 2021. The growth was maintained in 2022 as export earnings from the crop grew to N4.6 billion. In quota 2 of 2023, it doubled to N10 billion (Business day, 2024).

However, Nigeria, the largest producer of ginger in Africa, and the second largest in the world after India, is reaping only a modest fragment of the \$3 billion global ginger market, despite its record of N10 billion export values in quota 2, which becomes the highest in six years.

Ginger is a very popular spice used worldwide and it’s being used to spice up meals, or as a food, for medicinal purpose and could be used in forms of vegetables, candy, soda, pickles and alcoholic beverages and its demand all over the world has been consistent throughout history (Ravindran, 2016; Nair, 2019). Oils are also extracted from the crops which may be used for perfumes and medicine. Historically, ginger has been used for centuries for medicinal purposes, often as a digestive aid, but also for other ailments. In addition, the plant has ornamental value for landscaping (Nair, 2019).

According to *ThriveAgric* (2024) the ginger commodity is so popular owing to its number of uses. Some of them are herbal medicines, spices

of bread in bakeries, and its uses in breweries to produce drinks among others. Going by official statistics, Nigeria is currently the third largest exporter of Ginger in the world after China and India. Experts were of the opinion that the Nigerian ginger is highly regarded in the international market for its quality and highly medicinal value. Specifically, its aroma, pungency and high oil and oleoresin content are other distinct features of ginger products from Nigeria (ThriveAgric, 2024).

Kaduna State is the largest producer of ginger in Nigeria and Africa. The state accounts for more than 60% of Nigeria total harvest of the crop. Ginger crop produced in Kaduna is known in the international market for its quality and highly medicinal value. Specifically, its aroma, pungency, high oil and oleoresin contents are other distinct features.

Many women ginger farmers in kagarko, lack consistent access to agricultural extension services, including training, information dissemination, and on-farm support compared to their male counterparts. Therefore, it means that the women will not have access to production, processing and market information; which has to do with modern production system, availability of credit facility, pricing trends in selling their ginger and buyer connections. This is crucial for women to optimize their income from ginger production. Therefore, the objective of this study was to assess the socioeconomics characteristics, the extension service needs and constraints to accessing extension services by the women ginger farmers of Kagarko in Kaduna of Nigeria,

RESEARCH METHODOLOGY

Study Area

This study was conducted in Kagarko Local Government Area of Kaduna state. The Local

Government Area lies between latitude 9°45'N and 7°68' E and longitude 9°27'0" N and 7°41'0" E covering an area of 2,356 Km², and a projected population of 353,200 people (National Population Commission).

It has its headquarters in Kagarko town and shares boundaries with Kachia Local Government Area to the North, Jaba Local Government Area to the East and Niger State to the West and the FCT to the South, respectively. The climate of the area is generally characterized by two climatic seasons, dry season (November-March) and rainy season (April-October), with maximum rainfall of 1536mm and minimum rainfall of 800mm and an average annual rainfall of 1125mm. The area has a maximum temperature of 38°C and a minimum temperature of 28°C, with an average temperature of 34°C.

The soil in the area is generally deep, well drained and varies from sandy loam to clay sandy loam.

Sampling Procedure

Multistage sampling technique was used to arrive at the sample size of the study. In the first stage, Samaru zone of Kaduna state ADP was purposively selected due to the high number of female ginger farmers in the area. In the second stage, Kagarko Local Government Area- LGA was randomly selected from the Samaru ADP zone of Kaduna State. The third stage included random selection of two chiefdoms (Kagarko chiefdom and Koro chiefdom) out of the three chiefdoms in the LGA.

The fourth stage involved the random selection (balloting method) of six villages; four villages (Dogon Kurmi, Kasabere, Kubacha and Icce) from the Koro chiefdom and two villages (Kagarko and Kudiri) from the Kagarko chiefdom. The fifth stage was the random selection of farmers from each of these villages based on the population of ginger farmers.

Eighteen (18) farmers from Dogon Kurmi, thirty (30) farmers from Kudiri, seventeen (17) farmers from Kubacha, thirteen (13) farmers from Kasabere, seventeen (17) farmers from Icce and twenty-five (25) farmers from Kagarko, which constituted the sample size of the study totaling a hundred and twenty (120) women ginger farmers.

Analytical Technical

Data obtained for this study was analyzed using both descriptive (frequency, mean and percentage) and inferential statistical analyses. Descriptive statistics was used to achieve objectives (identify the extension needs of the women ginger farmers; determine the types of extension services needed by the women ginger farmers; and determine the constraints faced by the women ginger farmers in extension service delivery).

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Respondents

Age of the respondents

Results in Table 2 show that 35.83% of the respondents were 36 years and above, 27.5% of them were within the age range of 24-29 years and few (13.3%) of them were between the ages of 18-23 years with a mean age of 33.3 years. The findings imply that majority of the farmers were within their active and productive ages and hence could cope with rigors associated with ginger farming activities. This is in accordance with the findings of Bala (2016) who reported that majority of women ginger farmers in Kaduna state were less than 50 years of age.

Marital Status

Table 2 further reveals that majority (85%) of the respondents were married, with a few (3.3%)

of them being divorced. The implication is that more married women were engaged in ginger farming which could be due to their having more responsibilities and more people to cater for in their households. This finding is in line with Adegboye (2011), who reported that majority of ginger farmers in Kagarko Local Government Area of Kaduna state were married.

Educational Attainment

As reported in the Table, half (50%) of the respondents attained primary education, 31.7% attained secondary education, 2.5% of them attained adult education and few (1.7%) of them attained Qur'anic education. The findings imply that majority of the respondents had one form of education or the other and hence could be able to understand the technologies disseminated by the extension agents. This finding is in line with Kachiro *et al.* (2016) who reported that majority of women ginger farmers in Samaru zone of Kaduna state ADP had one form of formal education or the other (Table 2).

Household Size

Results in Table 2 revealed that majority (72.5%) of the respondents had a household size of 2-7 people, 25% of them had a household size of 8-13 people and a few (0.83%) of them had a household size of 20 people and above, with an average household size of 6 people. This finding suggests that the respondents in the study area had moderate household size.

This is important to the respondents as it helps in providing available and cheaper family labour for their ginger farming activities. This finding is in contrast with Kachiro *et al.* (2016) who reported that the majority of women ginger farmers in Samaru zone of Kaduna state had a household size of 6-10 persons.

Table 2: Distribution of the respondents according to their age, marital status, educational attainment and household size (n=120)

Variables	Frequency	Percent	Mean
Age (years)			
18-23	16	13.3	33.30years
24-29	33	27.5	
30-35	28	23.3	
36 years and above	43	35.83	
Marital status			
Single	7	5.8	
Married	102	85.0	
Divorced	4	3.3	
Widowed	7	5.8	
Educ. Attainment			
Informal Educ.	22	18.3	
Primary	60	50.0	
Secondary	38	31.7	
Household size			
2-7	87	72.5	6people
8-13	30	25.0	
14-19	2	1.66	
20 people and above	1	0.83	

Source: Field survey, 2023

Farming Experience

Table 3 further shows that 38.3% of the respondents had farming experience of 1-6 years, 37.5% of them had farming experience of 7-12 years and few (11.66%) of the respondents had farming experience of 13-18 years, with a mean farming experience of 9.75 years. This implies that respondents had been into the business for a while and hence are expected to have ample experience to adopt ginger farming technologies disseminated to them by the extension workers. This finding is in contrast with Nmadu and Marcus (2011) who reported that the average farming experience of ginger farmers in Kaduna state is 27 years.

Land Acquisition

A greater percentage (84.2%) of the respondents inherited their farmlands used for ginger

production either from their parents or husbands. This implies that the main source of getting farmland for agricultural activities in the study was mainly through inheritance and purchasing. This finding is in line with Ganiyu *et al.* (2021) who reported that land acquisition for yellow ginger farming in Jaba Local Government Area of Kaduna state was mainly through inheritance (Table 3).

Farm Size

Table 3 also shows that about half (49.2%) of the respondents had a farm size of 1hectare used for ginger production, 25% of them had a farm size of 1.5 hectares, 16.7% of the respondents had a farm size of 0.5 hectares and a few (0.8%) of them had a farm size of 2.5 hectares for ginger production with a mean farm size of 1.14 hectares. This finding indicates that the respondents were able to cultivate appreciable of

hectareage for ginger production and hence with extension service support, they expected to achieve appreciable income. This finding is in contrast with Nmadu and Marcus (2011) who reported that the average farm size for ginger producers in Kaduna state was 3.09 hectares.

Annual Income

Findings in the Table revealed that about half (49.16%) of the respondents had an annual income of ₦101,000 - ₦200,000, 35.83% of them had an income within the range of ₦100,000 - ₦200,000, with a few (2.5%) of them having ₦301,000 and above with a mean income of ₦138,641.67k. This implies that the respondents need more assistance from government, nongovernmental organizations and the financial institutions for loan that improve their capital source for ginger production. This finding is in contrast with Mazza *et al.* (2019) who reported that the average annual income of ginger farmers in Abia and Imo states was ₦72,487.5k. Extension Needs of the Women Ginger Farmers This objective of this study discusses the extension needs of the farmers and their contact with extension workers.

Extension Services Needed

Results in Table 4 further revealed that 24.2% of the respondents needed the services of the extension agents for only ginger production services, 14.2% of them expressed the need for extension services on processing and marketing of ginger crop. These findings imply that the ginger famers in the study area were in serious need of extension services especially on production management and marketing of the ginger crop produced. This finding is in accordance with the findings of Adegboye (2011) who reported that one of the major problems of ginger farmers in Kagarko Local

Government Area of Kaduna state was marketing of the ginger crop produced by them. Constraints to Extension Services by the Women Ginger Farmers

The results in Table 5 clearly show that all the respondents had faced one constraint or the other as regards to extension service delivery and majority (98.3%) of the respondents were faced with the constraint of not having any contact with extension workers. This is in accordance with the study of Bala, (2016) which reported that majority of women ginger farmers in Kaduna state have never had contact with extension workers.

CONCLUSION AND RECOMMENDATIONS

Based on the findings of this study, it is concluded that majority of the ginger famers in the study area were married and in their active productive ages with minimum income for ginger production with majority not having contact with extension agents. Based on the findings it evident that there is a need for extension services amongst the women ginger farming communities in Kagarko LGA of Kaduna state especially ginger production management and marketing.

Based on the findings of this study, it deems necessary to draw the under listed recommendations:

1. Needs to mobilize unmarried females to engage in ginger production in the study area and beyond.
2. Needs to provide available credit facilities and or grants that could boost ginger production capital amongst the famers.
3. The state government should also provide ginger marketing outlets and also provide enabling policies in place to regulate the activities of the middlemen.
4. Needs to employ and train adequate extension workers that help to disseminate and teach women ginger farmers on science based ginger production management practices.

Table 3: Distribution of the respondents according to their farming experience, land acquisition, farm size and annual income (n=120)

Variables	Frequency	Percent	Mean
Farming experience (years)			
1-6	46	38.3	9.75years
7-12	45	37.5	
13-18	14	11.66	
19 and above	15	12.5	
Land acquisition			
Inherited	101	84.2	
Purchased	16	13.3	
Rented	1	0.8	
Borrowed	2	1.7	
Farm size (ha)			
0.5	20	16.7	1.138 hectares
1	59	49.2	
1.5	30	25.0	
2	10	8.3	
2.5	1	0.8	
Annual income(₦)			
~~₦~~ 50,000– ~~₦~~ 100,000	43	35.83	₦138,641.67
~~₦~~ 101,000– ~~₦~~ 200,000	59	49.16	
~~₦~~ 201,000– ~~₦~~ 300,000	15	12.5	
~~₦~~ 301,000 and above	3	2.5	

Source: Field survey, 202

Table 4: Extension service needs of the women ginger farmers (n=120)

Extension Needs	Frequency	Percent
None	1	0.8
Production services	29	24.2
Production and processing services	10	8.3
Production, processing and marketing services	14	11.7
Production and marketing services	12	10.0
Processing services	11	9.2
Processing and marketing services	17	14.2
Marketing services	26	21.7

Source: Field survey, 2023

Table 5: Distribution of Respondents Based on Constraints to extension service (n=120)

Variables	Frequency	Percent
inappreciable number of contacts with extension workers	2	1.7
No contact with extension worker	118	98.3

Source: Field survey, 202

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LEVEL OF ADOPTION OF IMPROVED MAIZE PRODUCTION TECHNOLOGIES AMONG MAIZE FARMERS IN KOKONA LOCAL GOVERNMENT AREA OF NASARAWA STATE, NIGERIA.

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ABSTRACT

The study assessed the adoption level of improved maize production technologies among farmers in Kokona L.G.A of Nasarawa State, Nigeria. Multi-stage sampling procedure was employed in selecting 60 farmers for the study. Data were collected using structured questionnaire and analyzed using both descriptive and inferential statistics. The results from the study revealed that Majority (90.00%) of the respondents were males, 86.66% were married, 83.33% had one form of education or the other, with the mean farming experience of 23 years. Majority (76.66%) of the respondents adopted improved technologies on a medium level. The multiple linear regression analysis showed farm size and annual income were significant at 1% level. All the respondents (100%) indicated poor access to credit, inadequate extension contacts, inadequate capital, and inadequate farm machinery as the most severed constraints, followed by pest and diseases infestation (98.30%), effect of climate change (96.70%), among others. The study concluded that adoption of improved maize production technologies in the study area was on a medium level, and recommended that the state government through the ADP in the state should prioritize on the need for extension workers to visit farmers across all the LGAs in the state to enable farmers have access to extension; also, the farmers should be encouraged by the extension workers to form cooperative association, in order to have easy access to credit to help increase their purchasing power of farm inputs necessary to promote adoption of improve maize production technologies.

Keywords: Adoption, Improved technologies, Maize production

INTRODUCTION

Maize (*Zea Mays*) is a cereal crop of the grass family Gramineae. It is also commonly known as corn, and was domesticated more than 9000 years ago in Southern Mexico and Central America (Kenett *et al*, 2021). Maize plays an important and diverse role in a global agri-food systems; owing to its multiple end uses as

human food, livestock feed, and serves as an important component for many industrial products (Shiferaw *et al*. 2011; Erestein *et al*. 2022). Along with rice and wheat, maize provides about 30 % of the food calories to more than 4.5 billion people in many developing Countries of the World including Nigeria. (Shiferaw *et al*. 2011).

Nigeria was Africans second largest producer of maize in 2019 after South Africa and the 14th largest producer globally. Africa had a total maize production volume of about 90 million metric tonnes (MMT), South Africa had 16 MMT, and Nigeria averaged production volume was about 11 MMT; yet the country's local demand continues to surpass supply thus creating an annual demand gap of about 4million tones annually (Ntiedo, 2022).

Maize is one of the most popular food crops in Nigeria, which is widely consumed by millions of Nigerians. It is perhaps, the most important cereal crop of significant economic importance in African countries that has replaced sorghum and millet. It is grown in diverse environment and consumed by people with different preference and socioeconomic background in Africa, most especially Nigeria (Olaniyan, 2015).

However, local production has for years lagged consumption, a situation that has fueled importation with implication for Nigerians currency and job creation (Ntiedo, 2022). The crop is the first most cultivated in Nigeria in terms of area (12,403,330 ha) (NAERLS 2020). The top producing states in Nigeria include Kaduna, Adamawa, Taraba, Bauch, Benue, Nasarawa, Ogun, among others. Corn is Consume in different forms in Nigeria. It is ground, fermented and locally processed into pap; it is industrially processed into custard, corn syrup, corn oil, corn flour and corn flakes; and also as raw material for brewery and livestock manufacturing industry. The local demand for maize in Nigeria is as high as 12MMT excluding exports, leaving a deficit of over 2million metric tons (Thrive Agric, 2020). Hence, the need to increase local maize production to meet the countries ever increasing population through application of improved technologies such as the use of improved seed varieties, adequate fertile application, herbicides, good management practices, among others.

Adoption is a decision of “full use of an innovation as the best course of action available Adoption is a choice to utilize technology to its fullest extent as the most advantageous course of action (Rogers, 2003). Adoption of improved technologies such as fertilizer, herbicides and improved seeds has leads to increase in agricultural production and also increased income of the farmers. Transformation of agriculture can be achieved by exposing small-scale farmers to improve agricultural production technologies. Generally, the use of modern farming technologies such as improved inputs (e.g seeds, fertilizers), has enhanced crop yield and income of the farmers (Bamire, 2002).

Most farmers in Nigeria are small-scale farmers whom are classified as resource poor. This is due to the poor resources available at their disposal; especially capital resource, which has made them stick to traditional method of production using primitive tools and inputs. This method of production leads to low productivity and does not always meet the ever-increasing demand for domestic and industrial use. Adoption of improved technologies which is considered to be the most important factor that has brought about increased productivity in crop production is not often used by most farmers (Oyewole and Sennuga, 2020). If there must be increase in the efficiency of agricultural production through agricultural modernization, farmers must to a large extent adopt improved agricultural technologies into their farming operations (Sasore, 2005). Even though some breakthroughs have been made worldwide in the area of improved technologies, many farmers in Nigerian still rely so much on traditional methods of production which may lead to inefficiency in production. This research therefore aimed to assess the level of adoption of improved maize production technologies in Kokona L.G.A of Nasarawa State, Nasarawa State.

The specific objectives are to:

- i Identify the socio-economic characteristics of the maize farmers in the study area;
- ii Ascertain the level of awareness of improved maize production technologies by the respondents;
- iii Identify the improved maize production technologies in the study area;
- iv Assess the level of adoption of improved maize production technologies by the respondents;
- v Determine factors influencing the adoption of improved maize production technologies in the study area; and
- vi Identify constraints to maize production by farmers in the study area.

METHODOLOGY

Kokona Local Government Area is situated in Nasarawa State, North Central Geopolitical Zone of Nigeria. The LGA is made up of a number of towns and villages such as Garaku, Doma, Pam-baraue, Endo, Angwansira, Kama, Agwada, Amba, Marke, Shabu, etc. The estimated population of Kokona LGA is estimated at 183,776 inhabitants. Majority of the inhabitants belongs to the Mada ethnic group. Kokona LGA sits on a total area of 1,844 square kilometers and has an average temperature of 29°C, annual rainfall of 1450mm annually and average wind speed of 10km/h. Farming is an important economic activity undertaken by dwellers of Kokona LGA. Crops grown in the area include yams, maize, groundnuts, cowpea, and sorghum among others.

A multi-stage random sampling technique was used in the selection of the respondents. Firstly, three (3) districts were randomly selected out of the six (6) districts in Kokona Local Government Area. Secondly, two (2) villages were also randomly selected from each of the three districts selected, making six (6) villages.

Finally, 10 maize farmers were randomly selected from the six (6) villages selected, making a total of 60 sample size for the study. Primary data was used for this study.

The data was collected with the aid of a structured questionnaire which was administered to the respondents. Both descriptive and inferential statistics were used to analyse data for the study. Simple descriptive statistics such as frequency, percentage and mean score were used for objectives i, ii, iii and v; and multiple linear regression model was used to achieve objective iv. The hypothesis of the study was tested using F-statistic.

The multiple linear regression model is expressed as:

$$Y = a + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + e$$

Where:

Y = Level of adoption of improved maize technologies

= Number of improved technology adopted by individual respondent / Total number of improved technologies multiply by 100

a = Constant term

$\beta_1, \beta_2, \dots, \beta_9$ = Regression coefficients

X_1 = Age (Years)

X_2 = Sex (Male = 1, Female = 0),

X_3 = Level of education (No. of years spent in formal schooling),

X_4 = Years of experience in maize production (number of years)

X_5 = Annual income (in naira)

X_6 = Membership of Association/Cooperative (Number of years spent in the association)

X_7 = Access to credit (dummy)

X_8 = Extension contact (Number of visits per year)

X_9 = Farm size (ha)

E = Error term

RESULT AND DISCUSSION

Socio-Economic Characteristics of Maize Farmers in the Study Area

Age: Table 1 shows that many (43.33%) of the respondents were between the age of 35- 44 years, followed by 41.66% who were between 45 to 54 years, and 15.00% were between the age range of 25- 34 years. The mean age of the respondents was 42.3 years. This implies that maize farmers in the study area are in their active and productive age to practice improved maize production technologies. This result is in line with Ademiluyi, (2014) who revealed a mean age value of maize farmers in Plateau State Nigeria to be 40years.

Sex: The study revealed that majority (90.00%) of maize farmers in the area were male, and only 10.00% were female. The result implies that men are more into maize production in the area. This could be due to men access to productive resources such as land and labour than women. This is in agreement with Chiroma *et al.* (2020) who reported majority (72.0%) of maize farmers in western agricultural zone of Bauchi State to be males.

Level of Education: The results further show that a large proportion (43.33%) of the maize farmers had secondary education, 26.66% had tertiary education and 13.33% had primary education, while 16.00% had no formal education.

This implies that majority of the respondents had one form of education or the other. This could bring about easier adoption of improved maize production technologies as a result of their educational exposure. This is in line with the study of Chiroma *et al.* (2020) who revealed that majority (80.3%) of maize farmers in western agricultural zone of Bauchi State had one form of education of the other.

Marital Status: The result on marital status of the respondents shows that majority (86.66%) were married while 13.33% were single. This could have a positive influence on maize technology adoption. The study agrees with that of Ezekiel (2016) who reported that majority (87.5%) of the maize farmers in Yewa North LGA of Ogun state are male.

Farming Experience: The respondents had a minimum farming experience of 5 years, maximum of 30 years and a mean farming experience of 23.2 years. This implies that respondents have been into maize farming for a long period of time. The more the farming experience of the farmer, the more their likelihood to adopt maize technological packages, as he/she already have ideas that can enable him/her to predict practices that could yield positive result. This is in line with Ademiluyi (2014) who revealed a mean farm experience of the maize farmers in Bassa LGA of Plateau State to be 16.4 years; meaning they are experienced farmers.

Membership of Cooperative: The results reveal that all (100.00%) of the respondents were non members of cooperative society. This implies that maize farmers in the any do not belong to any cooperative group which could be a barrier to farmers getting information about improved technologies. This is unfortunate on the side of the farmers because information on agricultural technology is often made more available to farmers in group than individual. According to Lawi *et al.* (2020), some of the potential benefits of cooperative associations include provision of easy access to loan, improving farmers welfare, providing avenue for exchange of ideas/knowledge, providing access to information on best crop production practices and marketing, as well as buying of inputs at subsidizes rate. Their non-membership of cooperative societies by the respondents will

likely affect their adoption of improved technologies negatively.

This agrees with Ademiluyi (2014) who reported that majority (81.08%) of maize farmers in Bassa LGA of Plateau State are non-members of cooperative societies.

It also agrees with the findings of Babuga *et al.* (2020) who revealed that majority (75.72%) of maize farmers in Bauchi State, Nigeria are nonmembers of cooperative societies.

Extension Contact: The result for extension contact shows that all 100.00% of the respondents had no access to extension contact. This implies that the farmers are lagging behind in term of getting information on agricultural innovations that will boost their agricultural production.

The extension agents who serve as promoters of the adoption of improved maize varieties and other practices are lacking in the area.

This could bring about knowledge gap on the side of the farmer and therefore, may result in low adoption of the technologies as the farmers are not aware of the benefits attached to adopting the technologies.

The result is contrary to that of Babuga *et al.* (2020) who reported that 52.86% of maize farmers in Bauchi State, Nigeria had contact with extension.

Access To Credit: All the respondents (100%) had no access to credit. This could be due to their non participation in cooperative societies and lack of extension contact, which would have created an avenue to source for credit from financial institutions.

However, their inability to access credit may greatly affect their decision to adopt improved maize production technology; as the capital required to purchase farm inputs like fertilizers, herbicides, pesticides, improved seed etc may not be available at their disposal.

Income: About 51.61% of farmers had an annual income of between ₦251,000 – ₦451,000, 22.58% had ₦652,000 annual income and above, 16.12% had between ₦50,000 – ₦250,000 and only 6.45% had between ₦452,000 – ₦652,000 with an average annual income of ₦175,500. This implies that farmers in the area had low annual income as regards the result of the annual income. This could be as a result of poor extension contact which would have enlightened farmers on new innovations that will boost production and bring about increased income.

Sources of Information: Half (50.00%) of the respondents got their information on improved maize technological packages from other farmers, 40.00% from friends and only 10.00% from the media. Farmer to farmer diffusion of information may not be adequate and reliable as information from the extension agents who are trained to disseminate information on innovations to farmers. This could hinder farmers adoption of improved maize technology in the area.

Level of awareness of improved maize production technologies by the respondents.

Table 2 presents the level of awareness of improved maize production technologies by the respondents.

The analysis revealed that farmers were well informed about the following maize production technology; Use of fertilizer (2.20), herbicides and pesticides application (2.00), and appropriate plant spacing (2.00).

On the other hand respondents have little or no awareness on improved seed varieties, use of seed dressing and appropriate harvesting techniques as evident by mean scores which were less than the cut off score of 2.0.

This implies that maize farmers in the area are aware of some maize production technologies

despite not having contact with extension agents, which the farmers must have gone out of their own effort obtain information on improved farming practices. This findings is in line with the result of Abiodun and Damilola, (2018) who reported the need for an increase in awareness of maize production due to the low level of

awareness of farmers at Oyo state. The result is not in line with that of Issa *et al.* (2016) who reported land preparation (97.5%), use of manure (89.2%) and seed dressing to be the improved maize technologies with the highest level of awareness among the respondents.

Table 1: Distribution of the socioeconomic characteristics of the respondents

Variables	Frequency	Percentage	Max.	Min.	Mean
Age (years)			54	25	42.3
25 - 34	09	15.00			
35 - 44	26	43.33			
45-54	25	41.67			
Gender					
Male	54	90.00			
Female	06	10.00			
Education level					
No formal education	10	16.67			
Primary education	08	13.33			
Secondary education	26	43.33			
Tertiary education	16	26.66			
Marital Status					
Married	52	86.67			
Single	08	13.33			
Farm experience			30	5	23.2
1 – 10 years	08	13.33			
11 – 20 years	18	30.00			
21 – 30 years	34	56.67			
Member of Co-operative society					
Members	00	0.00			
Non members	60	100.00			
Access to credit					
Yes	00	0.00			
No	60	100.00			
Access to extension agents					
Yes	00	0.00			
No	60	100.00			
Farm size			10	1	4.1
1 – 5 hectares	54	90.00			
6 – 10 hectares	06	10.00			
Annual income			₦1,000,000	₦50,000	₦175,500
₦50,000 – ₦250,000	10	16.67			
₦251,000 – ₦451,000	32	53.33			
₦452,000 – ₦652,000	04	6.67			
>₦652,000	14	23.33			
Source of improved tech. info					
Friends	24	40.00			
Media	06	10.00			
Other farmers	30	50.00			

Table 2: Level of awareness of improved maize production technologies by the respondents.

Improved Maize Production Technologies	Mean	Standard Deviation	Remark
Improved seed varieties	1.48	0.56	Unaware
Use of fertilizer	2.20	0.54	Aware
Herbicides and pesticides application	2.00	0.21	Aware
Appropriate plant spacing	2.00	0.43	Aware
Use of seed dressing	1.00	0.00	Unaware
Appropriate harvesting techniques	1.00	0.00	Unaware

Source: Field survey, (2023) Cut-off score = 2.0; ≥ 2.0 = Aware; < 2.0 = Not aware

Identification of improved maize production technologies in the study area

Table 3 shows the improved maize production technologies identified by the respondents in the study area. It was revealed that most (97%) of the respondents identified use of fertilizer as the most improved maize production technologies highly aware of and practiced by the farmers in the area, followed by 95% of the respondents

who identified herbicides and pesticides application, 67% indicated appropriate planting spacing, 53% identified appropriate harvesting techniques, 28% identified improved seed varieties and 17% indicated use of seed dressing in the area. From the result, it can be deduced that farmers in the area had ideas about maize production technologies. This could be as the result of information gotten from other farmers/friends and families.

Table 3: Identified improved maize production technologies in the study area.

Improved technologies	Frequency	Percentage
Use of fertilizer	58	97.00
Herbicides and pesticides application	57	95.00
Appropriate plant spacing (7cm by 50)	40	67.00
Appropriate harvesting techniques	32	53
Improved seed varieties	17	28
Use of seed dressing	10	17

Source: Field survey, (2023)

*Multiple responses

Level of adoption of improved maize production technologies by the respondents

The result on the level of adoption of improved maize production shows that majority (76.66%) adopted moderately, followed by 11.67% who adopted on both low and high level. This implies that the maize farmers in the area practiced improved maize production technologies moderately to an extent, despite not having contact with extension. This could be due to their level of education in one form or the other which may have exposed them on the benefits associated with the practice of improved technologies. Also it could be that they results of

yields obtained from other farmers and friends who had adopted improved technologies motivated the respondent to adopt the technologies even with their lack of access to extension workers, who are supposed to equip them with such knowledge.

Furthermore, the moderate adoption may be as a result of the respondents' efforts in getting information on improved technologies from other farmers and friends; as none of the farmers belonged to any cooperative group whom they are supposed to share ideas about their farm production, and pool their resources together towards purchasing recommended farm inputs at a subsidized rate.

Table 4: Distribution of the respondents on their level of adoption of improved maize production technologies.

Adoption index	Frequency	Percentage	Level of Adoption
10 – 39%	7	11.67	Low
40 – 69%	46	76.66	Medium
70% and above	7	11.67	High
Total	60	100.0	

Source: Field survey, (2023)

Factors influencing the adoption of improved maize production technologies in the study area.

The result of the multiple linear regression analysis in Table 4 shows the factors that influenced the adoption of improved maize production technologies in the study area. The result revealed a coefficient of determination (R^2) with the value of 0.51. This implies that 51% of the changes in the dependent variable (level of adoption of improved maize technologies) were caused by the independent variables that were included in the model. The Table revealed that two variables were significant; these were farm size and farmers' annual income.

The coefficient of farm size (-14.606) was negative and highly significant at 1% probability level. This means that, an increase in a unit of farm holding might be responsible for farmer's non adoption. This could be due to the fact that larger farm size(s) requires more inputs and the farmers may not be financially buoyant enough to acquire the inputs needed for larger farm holding; more so that the respondents do not

have access to credit as captured in their socioeconomic characteristics. The result agrees with Kadafur *et al.* (2020) who reported farm size among other variables to positively influence the adoption of improved maize variety in northern Guinea Savanna of Borno State, Nigeria.

Also, annual income of farmers was significant at 1% probability level with positive coefficient (0.000). This implies that there is a positive relationship between annual income and adoption of improved maize production technologies. This means that increase in annual income would give rise to an increase in the likelihood of the farmers to adopt improved maize production technologies, because it is only farmer with higher income that would be able to purchase farm inputs needed to adopt improved technologies. This finding is in line with the study of Etoundi and Dia (2008) on the determinants of the adoption of improved maize in Cameroon. They reported that annual income of the farmers had positive influence on the rate of adoption of maize technological packages in the area.

Table 5: Factors influencing the adoption of improved maize production technologies in the study area

Independent variables	B	Std. error	T	Sig
Age	0.365	0.533	0.684	0.501
Gender	2.004	9.702	0.033	0.207
Level of education	-0.2551	2.132	-1.197	0.244
Farm experience	-0.038	0.456	-0.084	0.934
Farm size	-14.606	3.953	-3.695	0.001***
Annual income	0.000	0.000	4.643	0.000***
Constant	40.508	14.234	2.845	0.009
R square	0.51			

Source: Field survey, (2023)

*** = At 1% level of significant

Constraints to maize production by farmers in the study area

Table 6 presents the results of constraints limiting maize production by farmers in the study area. All the respondents (100.00%) reported poor access to credit, inadequate extension contacts, inadequate finance/capital, and inadequate machinery ranked first as the most serious constraints to maize production in the area. These were followed by problem of pests and diseases infestation (98.3%) ranking second, effect of climate change (96.7%) ranking third, inadequate manpower supply (91.7%) ranking fourth and inadequate storage facilities (86.7%) ranking fifth. This implies that all the respondents are faced with one serious problem

or the other in their maize production. This could be due to farmers' lack of extension contact. Extension agents who are supposed to help farmers solve their farm problems and proffer solutions are not available in the area. These findings are consistent with the result of Okonji and Awolu, (2020) who reported that inadequate credit, inadequate extension services, and inadequate storage facilities were the major challenges of maize farmers in Ekiti State, Nigeria. It is also in line with the findings of Issa *et al.* (2016), who reported high cost of inputs (96.7%), inadequate capital (95%) and high cost of labour (88.3%) as the major constraints to adoption of improved maize production practices in Ikara Local Government Area of Kaduna State, Nigeria.

Table 6: Distribution of the Constraints to maize production by the respondents in the study area

Constraints	Frequency	Percentage (%)	Rank
Poor access to credit	60	100.0	1st
Inadequate extension contacts	60	100.0	1st
Inadequate finance/capital	60	100.0	1st
Inadequate farm machinery	60	100.0	1st
High cost of inputs	60	100.0	1st
Pests and diseases Infestation	59	98.3	2nd
Climate condition	58	96.7	3rd
Inadequate manpower supply	55	91.7	4th
Inadequate storage facilities	52	86.7	5th

Source: Field survey, (2023)

*Multiple responses

CONCLUSION

Based on the findings of this study, it can be concluded that maize farmers in Kokona Local Government Area of Nasarawa State adopted maize production technologies on a medium scale. The farmers' level of adoption was influenced by annual income and farm size of the respondents. The major constraints to maize production in the study area were poor access to credit, inadequate extension contacts, inadequate

finance/capital, inadequate machinery, pests and diseases infestation, among others.

RECOMMENDATIONS

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

1. The extension organization in the state should ensure that extension workers visit farmers across all the LGAs of the State including the study area.

2. Farmers should form cooperative society in order to have access to credit from financial institution so as to increase their financial power to purchase farm inputs such as agrochemicals, machineries, among others to increase their production.
3. Farmers should be provided with timely and adequate information on weather forecast and guided on ways to adapt and mitigate its effects on their farm production.

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MARKET ORIENTATION AND PARTICIPATION OF SMALLHOLDER CASSAVA-BASED AGRIPRENEURS IN ABIA STATE, NIGERIA

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ABSTRACT

This study examined the market orientation and participation of smallholder cassava-based agripreneurs in Abia State, Nigeria. Data were collected from 120 respondents through a structured questionnaire and analyzed with both descriptive and inferential statistics (market orientation and participation index, multiple regression, net return analysis, and mean count). The results on market participation index showed that 97.78% of the cassava-based products were highly commercialized, while the market orientation index of 0.82 indicates that the agripreneurs had high level of market orientation. The regression result showed that labor, education, credit, and market information were all directly related to market participation and significant at 1% while experience, selling price and capital were positively signed, and significant at 5%. The regression result showed income, experience, labor, technology, and credit were all directly related to market orientation and significant at 1%, while education, and market information were positively signed and both significant at 5%. The net-return analysis result showed that on the average, a cassava-based agripreneur makes ₦997,158.63 profit for a production season. The study concluded that a market-oriented approach and active participation will empower smallholder cassava-based agripreneurs to unlock their full potentials and recommends that youths and rural households to participate in the business.

Keywords: market orientation, participation, cassava-based agripreneurs

INTRODUCTION

Market orientation is an agribusiness marketing strategy that focuses on recognizing consumer requirements and preferences and meeting them (Shim, Kim & Altmann 2018). Market orientation is a business philosophy that emphasizes on identifying and meeting consumer needs and desires. Recent research shows that agripreneurs should pursue market orientation to gain long-term competitive advantages through market participation (Saleh, Azmin & Saraih 2021). An agripreneurs' capacity to participate in a market successfully

and efficiently is referred to as "market participation." By participating in the market, agripreneurs becomes an active actor in the value chain of any agricultural product (Adino 2021).

It has been estimated that about 90% of smallholder farmers in West Africa cultivate cassava (*Manihot esculenta* Crantz) as a staple crop, making it a critical product for agripreneurs (Ikuemonisan, Mafimisebi, Ajibefun & Adenegan 2020). There are numerous ways in which agripreneurs can utilize cassava as a source of food, feed, and raw

material. Cassava is grown by 98% of smallholder crop farmers in Abia State, which means that most of the state's agripreneurs relies heavily on the crop (Ikueomonisana et al., 2020). The socio-economic conditions of the cassava-based agripreneurs are significantly dependent on their market orientation and ability to participate in the market actively (Onya, Oriala, Ejiba, and Okoronkwo, 2018).

Cassava-based agripreneurs in Abia State face conditions that limit their socio-economic well-being; for example, most cannot afford to hire professional labour, sufficient experience and lack the basic infrastructure that will improve their market orientation and participation for increased wealth creation (Ukeje, Ogbonna, Okonkwo & Adiele-Ezekiel 2017; Osuji, 2019). In addition, most agripreneurs in the study area are resource-poor because of their limited access to technical education, income, land, equipment, which has disadvantaged them from going into commercial farming and industrial processing (Ikueomonisana et al., 2020; Obayelu *et al.*, 2021; Agbeze, Ohunyeye, Obamen & Ibe 2020). Critically, cassava-based agripreneurs face the challenge of credit access, utilization, and repayment (Abasilim, Balogun & Adeyemi 2019). Therefore, the interest rate and credit worthiness of agripreneurs and other socio-economic concerns affect the ability of cassava-based agripreneurs to improve their market orientation and participate actively in the market (Achoja, 2020).

The majority of cassava-based agripreneurs are active participants in the cassava value chain and market (Madu, Okoro, Ikpan & Okoye 2018). Agripreneurs are involved in cassava farming, seedling and stem production, root processing and value addition, distribution, and supply. Agripreneurs ensure that there is enough production to meet market demand. Some agripreneurs, particularly in developed

economies, engage in contract cassava production. Cassava-based agripreneurs aggregate smallholder cassava farmers' output, thereby creating a market for them. Agripreneurs bridge the market gap between farmers, manufacturers, and end-users. Agripreneurs must have a fully developed market orientation to explore their potential in the cassava value chain. The development of market orientation and participation of cassava-based agripreneurs are critical for their sustainability and profitability.

The issue of limited access to credit and production inputs is a significant challenge for cassava-based agripreneurs, as they struggle to find adequate capital to finance their investments and maintain healthy working capital to improve their market orientation (Christopher, Mary & Mohammed 2019). Other researchers have reported that other socio-economic variables such as income, location, cooperative membership, marital status, and gender have influenced the industrial growth of cassava-based agripreneurs in order to meet market demands for food, feed, and raw materials (Okoruwa, Abass, Akin-Olagunju & Akinola 2020; Otunba-Pyne, 2020).

Researchers have been fascinated by the critical question of whether factors from the external environment or within the firm influence market orientation and participation (Choeng *et al.*, 2021; Tirra *et al.*, 2019). As a result, understanding key firm and market-specific factors up the value chain are required to sustain cassava-based agripreneurs market participation. The demand for value-added cassava products, consumer acceptance, transportation costs, the product type, the efficiency of the transport and marketing sector, travel distance as well as small volumes, poor price information, commodity perishability, differences in storage and retailing are the primary marketing factors influencing the

market orientation and participation of cassava-based agripreneurs (Oteh, 2017).

According to some researchers, lack of infrastructure, insufficient land preparation or land tenure system, lack of suitable planting materials and equipment, lack of mechanization and power, soil infertility, and land pressure are among the most commonly reported constraints to the production of cassava products for the market (Okoruwa *et al.*, 2020; Otunba-Pyne, 2020). Based on the previously identified socio-economic, market, and firm-specific factors and other constraints that limit market participation and orientation of cassava-based agripreneurs, it is critical to analyze the market orientation of cassava-based agripreneurs in Abia State, Nigeria.

Specific Objectives

1. examine cassava-based agripreneurs' market orientation and participation;
2. estimate the determinants of cassava-based agripreneurs market orientation and participation;
3. examine the performance of cassava-based agripreneurs; and
4. examine the challenges faced by the cassava-based agripreneurs.

METHODOLOGY

The study was carried out in Abia State Nigeria. Abia State is one of the thirty-six (36) states of the Federal Republic of Nigeria which was created on 27th August, 1991 and is located in the South-east geo-political zone of Nigeria. It is between longitude 7° 23' and 8° 02'E and latitudes 5° 47' and 6° 12'N. The state has an estimated population of 4,143,100 people, (NPC, 2022) It covers a land area of 776,270 square kilometres.

The study made use of multi-stage sampling procedure in selecting the 120 respondents needed for the study. The first stage, involved all the three (3) Agricultural zones in Abia State. They are Umuahia, Ohafia and Aba agricultural zones. In the second stage, two (2) Local Government Areas (LGAs) were purposively selected from each of the agricultural zones. The Local Governments selected were Ikwuano and Umuahia South for Umuahia agricultural zone, Ohafia and Isiukwuato for Ohafia agricultural zone and Osisioma Ngwa and Ugwuababo for Aba agricultural zone giving a total of six (6) LGAs. These LGAs were selected because of cassava farming and processing activities in the area. In the third stage, two (2) communities were randomly selected from each of the LGA giving a total twelve (12) communities. Finally, ten (10) cassava-based agribusiness were purposively selected from each community and this gave a total of one hundred and twenty (120) respondents which constituted the sample size for the study. Data for this study was collected from primary sources. The primary data was collected by the use of structured questionnaire, interview schedule and direct observations of the cassava-based agripreneurs. Objective 1 was achieved using market orientation and commercialization indexes. Objective 2 was analyzed using OLS multiple regression analysis, objective 3 was analyzed using net returns analysis, while objective 4 will be analyzed using mean rating from the 4 point likert scale.

Model Specifications

Market Participation

$$CI = \frac{\text{Gross value of sales by each agripreneur}}{\text{Gross value of crop produce by each agripreneur}} * 100$$

CI= commercialization index

Market Orientation

$$MOI = \sum \frac{\alpha_i L_i}{L_t}$$

Where, MOI is market orientation index of an agriprenneur,

L_i is amount of land allocated to each agriprenneur,

L_t is the total crop land operated by all the agriprenneur,

α is the proportion i of cassava sold (marketability index, α) as;

$$\alpha_i = \frac{\sum_{i=1}^N Q_i}{\sum_{i=1}^N Q_i}$$

$$Q_i \geq S_i \text{ and } 0 \leq \alpha_i \leq 1$$

Where, S = the proportion of cassava sold

Q = total amount produced aggregated over the total i sample enterprises.

α takes a value between 0 and 1, inclusive. Crops mainly produced for markets usually have α value closer to 1. The higher proportion of land an enterprise allocates to the more marketable crop, the more the enterprise is market oriented. (Iheke Onu, and Egem, 2021).

OLS Multiple Regression Model

This model is specified implicitly as:

$$Y_i = (X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, \dots, X_{12})$$

Where $i = 1, 2$

Y_1 * = market participation index

Y_2 * = Market orientation index

X_1 = income (in Naira)

X_2 = experience (in years)

X_3 = labour (number of workers)

X_4 = education (number of skills)

X_5 = Technology (modern =1, traditional= 0)

X_6 = gender (male=1. Female= 0)

X_7 = Age (in years)

X_8 = selling price (Naira)

X_9 = Distance to market (km)

X_{10} Credit (Amount in Naira)

X_{11} = Market Information (Yes=1, No=0)

X_{12} = Capital (naira)

β_i = the parameter

μ_i = the error term

Net Returns Analysis

This is specified as;

$$NR = TR - TC \dots \dots \dots (3.5)$$

Where;

NR = Net Returns

TR = Total Revenue

TC = Total Costs (Total variable cost + Total fixed cost)

Four-point rating scale:

Cassava-based agriprenneurs' rated the responses of their respondents in response to the challenges they face in market participation using a four point rating scale and categorized as follows;

Not a Challenge.....1

Moderate Challenge.....2

Severe Challenge.....3

Extremely Severe Challenge.....4

The Mean (cut off) score of 2.50 obtained by dividing 10 by 4 forms the basis for decision making. Any mean score from 2.50 and above is accepted as a challenge, while below 2.50 is rejected as not a challenge.

RESULTS AND DISCUSSION

Level of Cassava-Based Agriprenneurs' Market Orientation and Participation

Level of market participation

In measuring agriprenneurs' level of participation, the agriprenneurs' commercialization index which is a ratio of gross value of sales by each agriprenneur to the gross value of crop produce by each agriprenneur was used. This index has been used in the past by Strasberg *et al.* (1999). The market participation of the cassava-based agriprenneurs as derived from equation 3.1 in

respect to their commercialization index was 97.78%. The 97.78% implies that there is a high level of cassava-based product towards commercialization in the study area. According to Strasberg *et al.* (1999), the closer the index is to 100, the higher the degree of commercialization. The result shows that cassava has moved from subsistence to a commercial crop or it is majorly produced for sale in the market.

Level of market orientation

The market orientation index of the cassava-based agripreneurs as derived from equation 3.2 and 3.3 in Iheke *et al.* (2021) was 0.82. Iheke *et al.* (2021) stated that crops mainly produced for market usually have α value closer to 1, the higher proportion of land an agripreneur allocates to the more marketable crop, the more the agripreneur is market oriented. The market orientation index coefficient of 0.82 implied that the agripreneurs' had high market orientation. This is an indication that the cassava-based agripreneurs were commercially inclined and market oriented. With improved market share in cassava production, the agripreneurs are expected to experience improved income and enhanced economic well-being, (Akinwale *et al.*, 2022).

Determinants of Market Participation and Orientation

Determinants of Market Participation

The regression estimates of the determinants of market participation is summarized and presented in Table 1: The linear functional form was chosen as the lead equation based on statistical criteria such as the magnitude of the coefficient of multiple determination (R^2), number of significant variables, conformity with a priori expectation of the signs in the coefficients of the variables, and overall

significance of the functional form (F-ratio). The F-ratio (31.18) was significant at 1% which attests to the overall significance of the regression result. The R^2 value (0.761) of the lead equation shows that 76.1% of the variations observed in market participation were accounted for by the explanatory variables included in the model.

Income was significant at 10% and negatively related to market participation. This implies that as the income of the agripreneurs increases, market participation decreases. This is not in line with a priori expectation, it could be as a result of the agripreneurs engaging or investing in other forms of businesses, thereby decreasing their participation in the market. This result is in contrast with the findings of Iheke *et al.* (2021) that increase in income would enable farmers purchase improved inputs and modern farm tools that are energy-saving, leading to increased productivity and hence commercialization.

Experience was significant at 5% and positively related to market participation. This indicates that there is a direct relationship existing, and as such with an increase in experience, there is an increase in market participation. This is in agreement with the findings of Onu and Echebiri (2019) that the more the agripreneur stays long in farming, the more he tend to be more efficient, have better knowledge of the market, better knowledge of efficient allocation of resources and market situation and thus expected to participate more in the market.

Labor was significant at 1% and positively related to market participation. This implies that an increase in the number of laborers results to an increase in market participation. The result also showed that the coefficient of education (28.641) was positive signed and highly significant at 1%. This indicates that an increase in the level of education of the farmers can result

in an increased market participation of the agripreneurs. This is in line with a priori expectation as educated farmers are flexible and can adopt good changes and new improved technologies that can enhance their efficiency and productivity leading to high level of participation.

Technology was significant at 5% and positively related to market participation. This implies that an increase in improved technology will result in more participation in the market. Cassava is an important crop in the study area and around the world, and leveraging technology can improve various aspects of its production, processing and marketing. This result is in line with Onu and Echebiri (2019) who noted that Technology and innovation adoption boosts production and productivity and hence leads to increase level of market participation.

The coefficient of gender was significant at 5%, and negatively related to market participation. This implies that the females participate more in the market than the males, a result in contrast to the expected outcome, but possibly because women are better at bargaining power. This result is in line with Okoye, *et al.* (2018) that women are more inclined to sell their cassava than men, having a female head increases a households' chances of selling its cassava by a greater amount than the male. Some past studies had also indicated that women are more involved in the processing and marketing of cassava products, (Yusuf and Opeyemi, 2020);

The selling price coefficient was significant at 5% and positively related to market participation. This implies that an increase in the selling price of the cassava-based product will result in a corresponding increase in the market participation. Note that increase in selling price leading to increased market participation is in line with a priori expectation. The law of supply

states that increase in price of goods leads to a corresponding increase in the quantity supplied. Following this, increase in the selling price definitely will lead to increased market participation of cassava-based agripreneurs since it is believed that more profit will be made. This result is in line with Yusuf *et al.* (2020) who noted that lower prices kill marketing incentives leading to low participation.

Credit was significant at 1%, and directly related to market participation. This indicates that an increase in the credit of the agripreneur, will lead to an increase in market participation. This Increase in credit would enable the agripreneurs to purchase improved inputs and modern farm tools that are energy saving, leading to increased productivity and hence more participation.

The market information coefficient was directly related to market participation and significant at 1%. This implies that an increase in market information would result in an increase in market participation. It is expected that as the cassava-based agripreneurs' have adequate information in respect to the market, it would influence the farmers' efficiency, hence market participation.

The result also showed that the coefficient of capital was positively signed and significant at 5%. This implies that an increase in the capital of the agripreneur, will result in a corresponding increase in market participation. With more capital, the cassava-based agripreneur can invest in modern machinery, equipment, and inputs to boost cassava production, leading to higher yields and a larger quantity of cassava available for sale in the market. This result is in agreement with Iheke et al (2021) who noted that a farmers increase in capital elevates its production capacity, marketing efforts, and reach, which will contribute to increased market participation and potential success in the agricultural sector.

Table 1: Determinants of market participation

Variable	Linear (+)	Exponential	Double Log	Semi-Log
Intercept	2.288 (4.30)***	12.934 (10.56)***	-9.384 (-1.19)	-1.250 (-3.26)***
Income (X₁)	-613.419 (-1.68)*	-0.013 (-1.57)	-0.785 (-1.07)	-2675000 (-0.75)
Experience (X₂)	9.921 (2.31)**	0.020 (2.05)**	0.174 (1.36)	1175384 (1.89)*
Labor (X₃)	20.958 (5.86)***	5.210 (6.33)***	0.672 (5.65)***	2661962 (4.61)***
Education (X₄)	28.641 (3.53)***	-0.011 (-0.61)	0.074 (0.28)	2331996 (1.85)*
Technology (X₅)	15.040 (3.43)***	0.268 (2.65)***	0.231 (0.83)	-1499920 (-1.11)
Gender (X₆)	-64.453 (-2.12)**	-0.091 (-1.05)	-0.105 (-1.34)	-1134251 (-3.00)***
Age (X₇)	229.409 (0.62)	0.011 (1.25)	0.404 (1.07)	1710752 (0.93)
Selling Price (X₈)	309.059 (2.24)**	0.000 (2.27)**	1.755 (2.54)**	8393020 (2.50)**
Distance to market (X₉)	7.411 (0.41)	-6.410 (-0.02)	0.053 (0.46)	775147.5 (1.38)
Credit (X₁₀)	0.517 (5.77)***	-3.280 (-1.59)	-0.010 (-1.62)	-75566.44 (-2.47)**
Market information (X₁₁)	3.601 (2.66)***	0.284 (5.51)***	0.165 (1.33)	-26.495 (-1.98)*
Capital (X₁₂)	4.863 (2.46)**	-5.550 (-0.12)	-0.004 (-0.06)	528353.8 (1.49)
R²	0.761	0.688	0.668	0.682
Adjusted R²	0.736	0.656	0.634	0.649
F-Ratio	31.18***	21.62***	19.77***	21.01***

Source: Field Survey, 2023. *Significant at 10%, **Significant at 5%, ***Significant at 1%
 Note: Figures in parenthesis are t-values. + Lead Equation

Determinants of Market Orientation

The regression estimates of the determinants of market orientation is summarized and presented in Table ii. The linear functional form was chosen as the lead equation based on statistical and econometric criteria such as the magnitude of the coefficient of multiple determinations (R^2), number of significant variables, conformity with a priori expectation of the signs in the coefficients of the variables, and overall significance of the functional form (F-ratio). The F-ratio (120.28) was significant at 1% which attests to the overall significance of the regression result. The R^2 value (0.761) of the lead equation showed that 92.8% of the variations observed in market orientation were

accounted for by the explanatory variables included in the model.

The coefficient of income was positive and highly significant at 1%. This implies that it has a direct relationship with market orientation. An increase in income of the agripreneur will lead to more orientation of the market. Experience was positively signed and significant at 1%. This indicates that there is a direct relationship existing, and as such with an increase in experience, there is an increase in the knowledge of the market.

Labor was 1% significant and directly related to market orientation. This implies that an increase in the number of laborers will result in the agripreneurs' being more market oriented. The

coefficient of education was significant at 5% and positively related to market orientation. This indicates that the higher the level of education, the more the agriprenneur is more informed of the market, (i.e. will have more knowledge of the market).

Technology was positively signed and significant at 1%. This means that it is directly related to market orientation. As better technology is adopted for easy farming and production, the more the agriprenneur will have more knowledge of what the consumer needs, and works towards meeting them. The coefficient of gender was significant at 1%, and positively related to market orientation. This implies that male farmers tend to be more informed of the market more relative to their female counterparts. This result is in line with Iheke and Nwaru (2018).

Age was 10% significant and indirectly related to market orientation. This implies that an increase in the age of the agriprenneur, will lead to a decrease in his orientation of the market. This result is in line with Iheke et al; (2021) that the older the agriprenneur, the less his orientation level. The distance to market was negatively signed and significant at 1%. This implies that the farther the agripreneurs' distance to market, the less he is oriented of the market (i.e., have lesser knowledge of the market).

Credit was significant at 1%, and directly related to market orientation. This indicates that an increase in the credit of the agriprenneur, will lead to an increase in market orientation. This Increase in credit would enable the agripreneurs' to adopt all possible means of getting information in relation to the market. This result is in tandem with (Osuji, 2019) that accessibility of credit by the farmers would influence the farmers' orientation towards commercialization. More so, market information coefficient (0.274) was positively signed and significant at 5%.

This implies that an increase in market information will result in increase in market orientation. It is expected that adequate access to market information by the cassava-based agripreneurs in the study area would enlighten them more on the knowledge of the market in respect to what the consumers' needs.

Performance of the Cassava-Based Agripreneurs

The performance of the cassava-based agripreneurs as shown by the net returns analysis is presented in Table iii. The result of the net return analysis of cassava-based agripreneurs shows that they incurred an average total cost of ₦1,002,341.37 out of which ₦715,716.31 was variable cost, while ₦286 625.06 was fixed cost for the production season. The agripreneurs' sold an average quantity of 93 bags at a unit cost of ₦21,500. The average total revenue realized from sales of bags of cassava was ₦1,999,500 for the production season. The average net return for the production season was ₦997,158.63. On the average, a cassava-based agriprenneur makes ₦83,096.55 profits per month. The above analysis is a confirmation that cassava-based production is a viable and profitable business in the study-area. In the light of the agripreneurs net profit, youths and households are encouraged to participate in the business. This is because; cassava is a high-yielding crop, which obviously generates profit for farmers. Its versatility and demand in various industries such as food processing, animal feed, and bioenergy also contributes to its potential for generating more income. This result is in line with Adino, (2021) that a farm household will choose to participate in the cassava market if the net present value of the expected benefits from participation is greater than the net present value of remaining autarkic-net of costs. Costs here include all transaction costs the household faces in the process of market participation.

Table 4.3: Determinants of market orientation

Variable	Linear (+)	Exponential	Double Log	Semi-Log
Intercept	14.459 (4.78)***	2.738 (6.29)***	-3.888 (-1.21)	-805.081 (-2.32)**
Income (X₁)	4.570 (5.88)***	3.390 (3.04)***	0.158 (3.69)***	19.715 (4.27)***
Experience (X₂)	1.250 (3.58)***	0.015 (2.99)***	0.161 (2.88)***	17.508 (2.90)***
Labor (X₃)	0.000 (9.70)***	3.980 (8.33)***	0.593 (9.80)***	40.512 (6.22)***
Education (X₄)	1.353 (2.08)**	0.016 (1.77)*	0.274 (2.40)**	33.147 (2.70)***
Technology (X₅)	3.601 (2.66)***	0.284 (5.51)***	0.165 (1.33)	-26.495 (-1.98)*
Gender (X₆)	9.659 (3.12)***	0.176 (3.96)***	0.097 (2.77)*** _s	-0.586 (-0.16)
Age (X₇)	-0.524 (-1.77)*	-0.002 (-0.57)	-0.099 (-0.60)	-15.783 (-0.88)
Selling Price (X₈)	-0.001 (-0.88)	-0.000 (-0.87)	-0.228 (-0.72)	-2.985 (-0.09)
Distance to market (X₉)	-0.040 (-3.31)***	-2.820 (-1.35)	-0.017 (-0.34)	3.277 (0.60)
Credit (X₁₀)	1.293 (4.26)***	1.280 (1.21)	0.001 (0.38)	-0.296 (-0.96)
Market information (X₁₁)	0.274 (2.40)**	33.147 (2.70)***	0.016 (1.77)*	1.353 (2.08)**
Capital (X₁₂)	-0.000 (-0.87)	-3.620 (-1.52)	0.025 (0.76)	5.937 (1.69)*
R²	0.928	0.903	0.920	0.859
Adjusted R²	0.921	0.893	0.912	0.844
F-Ratio	126.28***	90.85***	113.36***	59.68***

Source: Field Survey, 2023. *Significant at 10%, **Significant at 5%,

***Significant at 1%

Note: Figures in parenthesis are t-values.

+ Lead Equation

Table iii. Net Return Analysis of Cassava-Based Agripreneurs

Item	Amount (₦)
Variable costs	
Fuel	112500
Planting material	19550
Labor	285500
Transportation	59033.34
Fertilizer	45000
Herbicide	16080
Storage	80968.75
Processing	49184.22
machine maintenance	47900
Total variable cost	715716.31
Fixed costs	
Rent	98157.89
Levies	14575
Capital consumption allowance	173892.17
Total fixed cost	286625.06
Total cost	1002341.37
Revenue	
Bags of cassava	1999500
Net return	997158.63

Source: Field Survey, 2023

Table 4.5 Challenges faced by the cassava-based agripreneurs

Challenges	Mean score
lack of infrastructure	2.58
Insufficient land preparation	2.41
Lack of suitable planting equipment	2.68
Low capital base	2.65
Lack of technical expertise	2.71
Lack of mechanization/power	2.63
Soil infertility	1.93

Source: Computations from field survey, 2023

Challenges Faced by the Cassava-Based Agripreneurs

The challenges faced by the cassava-based agripreneurs are presented in Table iv. From the result, it is observed that lack of technical expertise was a challenge experienced most by the cassava-based agripreneurs with a mean score of 2.71, followed by lack of suitable planting equipment with a mean score of 2.68, low capital base (2.65), lack of mechanization and power (2.63), and finally lack of infrastructure, with a mean score of 2.58. These variables were accepted as a major challenge faced by the cassava-based agripreneurs'. Some studies have reported that availability of basic infrastructure such as good road networks play a vital role in increasing commercialization (Sawicka 2019). This result agrees to that.

CONCLUSION AND RECOMMENDATIONS

Market orientation and active participation are critical for the success and sustainability of smallholder cassava-based agripreneurs. By focusing on market demands, understanding consumer preferences, and adapting production strategies accordingly, smallholder agripreneurs can enhance the marketability of their cassava products and increase their profitability. Engaging in the market actively enables smallholder agripreneurs to establish valuable networks with various stakeholders, including processors, distributors, and policymakers. Collaboration and knowledge exchange with

these entities foster innovation, enhance product development, and open up opportunities for value addition, thereby improving the competitiveness of their cassava-based enterprises.

Based on the findings of this work, the following recommendations were made:

1. With the high level of cassava-based products towards commercialization as well as high market inclination in the study area, engaging in cassava production can create employment opportunities and generate income for individuals and communities. Also, cassava and its derivative have a growing export market; hence, participating in the market can be a pathway to international trade and global exposure.
2. Market orientation and participation in the cassava market can be influenced by several factors, including experience, labor, education, technology, market information, among others.
3. The average net return of the cassava-based agripreneurs' indicates that cassava is a viable and profitable business in the study-area. Its versatility and demand in various industries such as food processing, animal feed, and bioenergy also contributes to its potential for generating more income, hence youths and households are encouraged to participate in the business. This is because; cassava is a high-yielding crop, which obviously generates profit for farmers.

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PERCEPTION AND WILLINGNESS TO PAY FOR IMPROVED SANITATION FACILITIES AMONG URBAN SLUM HOUSEHOLDS IN LAGOS STATE, NIGERIA

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ABSTRACT

The study investigated the perception and willingness to pay for improved sanitation facilities among urban slum households in Lagos state, Nigeria. Data from 120 respondents were gathered through multistage sampling techniques and a well-structured questionnaire. Analysis employed descriptive statistics, contingent valuation method, binary logistic regression model, and double-hurdle regression model. Findings indicated a predominance of female respondents (53.3%), with mean ages and household sizes of 43 years and 5 persons, respectively. The average monthly income for respondents and their spouses was ₦46,749.58 and ₦13,812.50, while monthly expenditure averaged ₦39,370.83. A significant majority of respondents perceived a link between poor sanitation and disease transmission, with 85.8% supporting the provision of improved sanitation facilities and 55.8% expressing willingness to contribute financially to their maintenance. The binary logistic regression model revealed a mean willingness to pay (WTP) of ₦1,031.36 monthly for improved sanitation facilities. Additionally, the double-hurdle regression model revealed that factors such as age, monthly expenditure, toilet type, landlord status, and distance to current toilet facility significantly influenced the decision to pay for improved sanitation, while factors such as sex, household size, education, income, and toilet type influenced the amount respondents were willing to pay. The study concluded that unimproved sanitation facilities were prevalent, with some residents resorting to uncovered pit latrines and water bodies for defecation. Therefore, increasing toilet proximity, raising incomes, and improving access to education could enhance the utilization of improved sanitation facilities in the area.

Keywords: Improved sanitation, perception, urban slum, willingness, double-hurdle

INTRODUCTION

Improved sanitation, as defined by the United Nations International Children's Emergency Fund/World Health Organization (UNICEF/WHO, 2015), refers to a system that facilitates the proper disposal of human and

animal waste to enhance and safeguard public and environmental health. Such facilities hygienically separate excreta from human contact and are utilized exclusively by members of a single household. Examples include toilets connected to sewer systems or septic tanks, ventilated improved pit (VIP) latrines, pit

latrines with a slab, and composting toilets. Access to basic sanitation is crucial for promoting hygienic waste disposal and maintaining a healthy environment both at home and in the community. Despite global efforts, approximately 2 billion people lacked access to safe drinking water, and an estimated 4.2 billion lacked access to adequate sanitation facilities in 2020 (Sustainable Development Goals, 2021). In less developed countries, reliance on unimproved sanitation facilities such as pit latrines without a slab, flush to pit latrines or elsewhere, bucket and hanging toilets, shared facilities, or open defecation was common, exposing populations to various health risks. Additionally, over a billion people lacked access to potable water (UNICEF/WHO, 2015; Owolabi, 2017).

In Nigeria, inadequate access to water and poor sanitation management have contributed to water and sanitation crisis, with millions lacking access to safe water and sanitation. Despite significant investments totalling US\$188.3 million in sanitation projects between 2014 and 2017 in sanitation projects (UNICEF, 2020), Nigeria continues to face challenges, with a large portion of households lacking access to safe water and improved sanitation facilities. According to the World Bank (2022), approximately 57.4% of Nigerian households lack access to improved sanitation facilities, and the number of Nigerians practicing open defecation increased from 47 to 48 million between 2018 and 2021. The consequences of poor sanitation extend beyond health risks to include environmental degradation and socioeconomic implications; pollution of drinking water sources, malnutrition, and disruption in children's school attendance (WHO, 2016; Abubakar, 2017).

The United Nations Human Settlements Programme (UN-HABITAT, 2003) defines a

slum as low-income settlements characterized by poor living conditions. Housing quality within these settlements ranges from makeshift shanties to more permanent structures, often with limited access to essential services such as water, electricity, and sanitation (Akinwale *et al.*, 2013). Numerous studies (Akinwale *et al.*, 2013; Ayeni, 2014; Yussuf *et al.*, 2014; Abiodun, 2021) have highlighted the crowded nature of urban slums in Lagos, with more than five people typically residing in a single room. These areas are characterized by poor personal hygiene practices, widespread open defecation, inadequate access to toilets, limited water and electricity supplies, insufficient waste disposal facilities, and poor drainage systems, all of which increase residents' susceptibility to waterborne diseases. Given that fishing is a primary occupation among urban slum dwellers, the prevalence of waterborne diseases poses a significant threat to their health and productivity (Ayinde *et al.*, 2015). This study therefore aimed to investigate the perception and willingness of urban slum households in Lagos State, Nigeria, to invest in improved sanitation facilities. Key objectives included describing the socioeconomic characteristics of these households, identifying available sanitation facilities, assessing perceptions of sanitation facilities, estimating willingness to pay for improved sanitation, and identifying factors influencing decision to, and willingness to pay for improved sanitation.

Concept of Willingness to Pay (WTP)

Willingness to Pay (WTP) serves as an indicator of the monetary value individuals are willing to spend to reduce the likelihood of encountering environmental or health risks (Aboki *et al.*, 2019). It represents the maximum amount of money someone is willing to give up to enhance the quality or quantity of a product (Akhtar *et al.*, 2017). An individual's WTP for a good or

service reflects the satisfaction derived from that specific product or service, and it involves predicting what individuals will be willing and able to pay for the proposed improvement, such as an improved sanitation facility (Singh, 2020). WTP for a good or service can be determined through direct methods, where consumers are directly questioned using carefully crafted elicitation techniques, or indirectly by examining market prices (Dare et al., 2018). This study employs the contingent valuation method (CVM) to evaluate consumer WTP for improved sanitation facility within the study area. CVM, a stated preference evaluation method, involves survey-based techniques to elicit respondents' preferences expressed in terms of monetary values for goods not typically traded in conventional markets. It employs a well-structured questionnaire to solicit households' bids regarding changes in the value of an environmental good and their willingness to pay to maintain or enhance its value (Moffat et al., 2011; Zvobgo, 2021).

Empirical Review of Previous Studies on WTP for Improved Sanitation Facilities

Previous research findings on the willingness to pay (WTP) for improved sanitation facilities indicate that various factors such as gender, age, education, household size, income, household expenses, quality of existing sanitation facilities, and distance play a role in determining individuals' readiness to invest in improved sanitation. For instance, Minh et al., (2013) investigated the WTP for improved sanitation in rural Vietnam using the contingent valuation method. They found that the average and median maximum WTP amounts were 15.6 million Viet Nam Dong (\$631.58) and 13.0 million Viet Nam Dong (\$526.32), respectively. Significant factors influencing the WTP rate included the gender of the household head, age, household economic status, current toilet type, satisfaction with the

existing toilet, and awareness of the health implications of poor sanitation. The geographic location and economic status of the household were significant determinants of the WTP amount.

Similarly, Dare et al., (2018) explored the factors influencing rural households' willingness to pay for improved sanitation among rural households in Oyo State, Nigeria. They found that the mean WTP for improved sanitation (public toilet) was N658.80k. Factors such as age, gender, household size, income, distance to the toilet, and the use of covered latrines significantly influenced the WTP for improved toilet services. Additionally, Mulatya et al., (2021) examined the WTP for sanitation improvement in three rural counties in Kenya. Their study revealed that the mean WTP per household was \$153.39, \$11.49, and \$14.77 for SAFI, SATO pans, and SATO stools, respectively. Key determinants of household willingness to pay for these sanitation products were proximity to the toilet, household income, type of sanitation product, socioeconomic status, and satisfaction level with the current toilet facilities.

METHODOLOGY

Study Area

The research took place in Lagos State, Nigeria, situated along the southwestern coastline of the country, approximately between latitudes 6°22'N and 6°52'N, and longitudes 2°42'E and 3°42'E. Geographically, Lagos State is surrounded by bodies of water, with nearly one-quarter of its area comprising lagoons, creeks, and rivers. It spans a total area of 3,577 km² and is estimated to have a population of 12,777,884 (NBS, 2019). The rapid population growth of Lagos is primarily attributed to rural-urban migration, accounting for up to 75% of the population increase (Abumere, 2004). Consequently, it is

common to witness rural immigrants occupying undeveloped land to fulfill their urban land requirements, often leading to unregulated development of slum communities characterized by inadequate basic infrastructure and extremely poor environmental conditions (Akinwale *et al.*, 2013).

Sample and Sampling Techniques

The study employed a multi-stage sampling technique to select respondents. In the first stage, 2 Local Government Areas (LGAs) – Ajeromi-Ifelodun and Eti-osa – were purposively chosen in the state. Subsequently, 2 communities were purposively selected from each LGA – Ajegunle, Ayetoro, Ilaje, and Sangotedo – in the second stage. These communities were selected due to their classification as slums and their lack of access to safe water, sanitation, and hygiene practices. In the third stage, 30 respondents were randomly selected from each community, resulting in a total of 120 respondents for the study.

Qualitative data on the socio-economic characteristics of urban slum households, types of available sanitation facilities, perceptions of these facilities among urban slum households, and factors influencing decisions to, as well as amount to pay for improved sanitation facilities were collected using a questionnaire.

Analytical Technique

Descriptive statistics, including frequency, percentages, mean, and standard deviation, were utilized to describe the socio-economic characteristics of respondents, types of sanitation facilities currently in use, and perceptions regarding sanitation facilities in the study area.

Mean Willingness to Pay (WTP)

The Contingent Valuation Method (CVM) was employed to evaluate the willingness of urban

slum households to pay for improved sanitation facilities within the study area. This method was deemed suitable for estimating the value of goods that are not typically traded in conventional markets. To determine the mean willingness to pay of households for improved sanitation services, the responses to the willingness-to-pay question were regressed against the prices they were presented with for the improved service (bid). The analysis was conducted using the logit regression model, similar to the approach adopted by Akeju *et al.*, (2018) and Aminu and Nyor, (2021).

$$Y = \frac{1}{1 + \exp - (\beta_0 + \beta_1 X)} \dots\dots\dots (1)$$

Y represents the response of households to the willingness-to-pay question, denoting 1 if affirmative and 0 otherwise.

X stands for the price (in ₦) proposed to the household for the improved service (bid).

The coefficient estimates derived from the regression were then utilized to compute the mean willingness to pay of the households, employing the formula established by Hanemann (1989), as applied by Akeju *et al.* (2018) and Aminu and Nyor (2021). This involved determining the mean willingness to pay as negative and the ratio of the regressed constant to the bid price coefficient.

Double-hurdle regression model

This model was employed to identify the factors influencing the willingness to pay for improved sanitation facilities within the study area. The double-hurdle model, initially introduced by Cragg in 1971 and later refined by Ogunmola and Adekanmbi (2020), integrates both the willingness-to-pay decision and the amount an individual is willing to pay into its framework. The Cragg Model posits that for a consumer to demonstrate a positive desire to pay (expenditure) for a good or service, two hurdles must be surpassed. As outlined in the willingness-to-pay choice equation:

Willingness-to-pay decision (probit) equation:
 $P_i^* = Q_i\delta + u_i$ (2)

Whether a respondent would be willing to pay for improved sanitation facility or not is determined by a latent variable P_i ; Q_i : list of external factors; δ : coefficients associated with the repressors (Q), including the constant term; u_i : error term assumed to be normally distributed (which means a zero mean and a unit variance). The latent willingness to pay P^* is connected to the observable willingness to pay (P) in the following way

$$P = \begin{cases} 1 & \text{if } y^* > 0 \\ 0 & \text{otherwise} \end{cases} \dots\dots\dots (3)$$

The second equation (the amount willing to pay) is stated as:

$$Z_i^* = X_i\beta + \varepsilon_i \dots\dots\dots (4)$$

Where; Z_i^* represents latent willingness to pay for improved sanitation facility; X_i : vector of explanatory variables determining the price willing to pay (which could be the same as P_i); β : coefficients related with the repressors' (X), including the constant term; ε_i : error term which is supposed to have a normal distribution (with zero mean and constant variance). The following equation describes the link between latent willingness to pay (P^*), the latent amount to pay (Z^*) and the observed amount to pay for organic leafy vegetable (Z):

$$Z = \begin{cases} Z^* & \text{if } Z^* > 0 \text{ and } P = 1 \\ 0 & \text{otherwise} \end{cases} \dots\dots\dots (5)$$

The model is specified explicitly as:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \dots\dots\dots + \beta_{16} X_{16} \dots\dots\dots (6)$$

Where: Y = Households WTP (1 if yes, 0 otherwise). X_s are the explanatory variables which include: X_1 = Age of household head (years), X_2 = Sex (1- male, 0 otherwise), X_3 = Level of education (years), X_4 = Household size (number of people), X_5 = Occupation (1 if

Fishing, 0 otherwise), X_6 = Monthly income (₦), X_7 = Spouses' income (₦), X_8 = Other income sources (1 if yes, 0 otherwise), X_9 = Monthly expenditure (₦), X_{10} = Residential status (1- landlord/landlady, 0 otherwise), X_{11} = Distance of toilet to the house (km), X_{12} = Sharing toilet facilities (1 if yes, 0 otherwise), X_{13} = Defecating in water closet (1-defecating in water closet, 0 otherwise). X_{14} = Defecating in water body (1-defecating in water body, 0 otherwise). X_{15} = Defecating in covered latrine (1-defecating in covered latrine, 0 otherwise), X_{16} = Defecating in uncovered latrine (1- defecating in uncovered latrine, 0 otherwise)

RESULTS AND DISCUSSION

Socio-economic Characteristics of the Respondents

Table 1 displays the socio-economic profile of urban slum households. The findings indicate that the majority (53.3%) of respondents were female and under 40 years old. With a mean age of approximately 43 years, respondents were predominantly in their productive age range, potentially influencing their willingness to invest in improved sanitation within the study area. This aligns with Aminu and Udeze's (2023) findings, suggesting that a significant portion of urban slum households in Lagos State falls within economically active age brackets. Moreover, a majority (56.7%) of respondents had received formal education, while 43.3% had informal education. Formal education is likely to enhance respondents' understanding of the repercussions of inadequate sanitation facilities, thereby potentially increasing their willingness to pay for improved sanitation services. This finding resonates with Dare et al.'s (2018) observations that the prevalence of formal education may augment respondents' awareness of the significance of adopting proper sanitation

practices to mitigate the risk of waterborne diseases, particularly in Oyo State, Nigeria.

Half of the respondents were married, with an average household size of 5 persons, indicating that the majority of respondents were married with relatively small households. This suggests that they may have fewer dependents to support and lower monthly expenses, potentially enabling them to afford improved sanitation facilities. However, the mean monthly income of the respondents (₦46,749.58) and their spouses (₦13,812.50) indicates that they were low-income earners, who may face challenges in allocating part of their limited income towards improved sanitation. This is further evidenced by the mean monthly expenditure of ₦39,370.83, which consumes a significant portion of the total household income. Fishing emerged as the predominant occupation among a substantial percentage (40.8%) of respondents, while the majority (75%) were tenants.

Distribution of Respondents by Sources of Water

Regarding water sources, as presented in Table 2, the majority (51.7%) of respondents accessed water from public taps, with 25.8% relying on tanker services, 16.7% on wells, and only 4.2% on boreholes. This highlights the unreliable nature of water sources in the study area, as respondents reported irregular public water supply.

Distribution of Respondents by Sanitation Activities in the Study Area

Results on the sanitation activities of the respondents presented in Table 3 show that, only 40.8% of respondents used improved toilet facilities, such as pour flush into septic tanks (3.3%) or pit latrines with slabs (37.5%), while

29.2% used pit latrines without slabs, and 34.2% practiced open defecation in nearby water bodies. This indicates that a majority of respondents used inadequate sanitation facilities, posing potential health risks. Additionally, 84.2% of respondents shared toilet facilities with other occupants, increasing the risk of exposure to diseases, as shared toilets in urban slums are often poorly maintained. Furthermore, 65% of respondents expressed dissatisfaction with their current toilet facilities, with many having to travel considerable distances to access them, potentially contributing to open defecation. Leaking toilets were reported by 70.8% of respondents, while 10.8% indicated that their pit latrines had never been emptied, 80% claimed that it was emptied between 1 and 3 years ago while 9.2% said their pit latrine was emptied more than 3 years ago. Moreover, 30% said the contents of their pit latrine was removed by service provider, while the contents of the pit latrine of 45.8% of the respondents was emptied in an uncovered pit or water body, contents of 7.5% was buried or emptied into a covered pit and 16.7% did not know where the contents of their pit latrine was emptied into. This implies that the majority of pit latrine contents were emptied in an unhygienic manner, with implications for environmental pollution and waterborne diseases.

Handwashing facilities were lacking in the majority (75.8%) of residences, often due to the constraints imposed by building types prevalent in the area. The result agrees with the findings of Aminu and Udeze (2023) that absence of hand washing facility in residential dwelling can be attributed to the predominant architectural styles (Brazilian “face me and face you”) or rooming condos which often lack space to accommodate fixed handwashing facilities in the study area.

Table 1: Selected Socio-economic Characteristics of the Respondents (n = 120)

Variable	Frequency	Percentage (%)	Mean
Sex			
Female	64	53.3	
Male	56	46.7	
Age			
≤40	64	53.3	42.85±5.121
41-60	39	32.5	
> 60	17	14.2	
Education			
Primary Education	21	17.5	
Secondary Education	41	34.2	
Tertiary Education	6	5.0	
Informal education	52	43.3	
Marital Status			
Single	31	25.8	
Married	60	50.0	
Divorced	9	7.3	
Widowed	20	16.7	
Household Size			
1-5	76	63.3	5±2.750
6-10	41	34.2	
>10	3	2.5	
Occupation			
Farming/fishing/poultry	49	40.8	
Trading	36	30.0	
Artisan	27	22.5	
Paid employment	8	6.7	
Monthly Income			
≤50,000	72	60.0	46,749.58± 11458.42
51,000-70,000	42	35.0	
>70,000	6	5.0	
Spouse's Income			
None	69	57.5	13,812.50±2513.047
≤50,000	44	36.7	
51,000-70,000	4	3.3	
>70,000	3	2.5	
Monthly Expenditure			
≤50,000	70	58.3	39,370.83±2812.765
41,000-60,000	30	25.0	
>60,000	20	16.7	
Residential Status			
Landlord	30	25.0	
Tenant	90	75.0	

Source: Field survey, 2023

Table 2: Distribution of Respondents by Sources of Water

Water source	Frequency	Percentage
Well	20	16.7
Borehole	7	4.9
Public tap	62	51.7
Tanker services	31	25.8

Source: Field Survey Data, 2023

Table 3: Distribution of Respondents by Sanitation Activities in the Study Area

Types of toilet facilities	Frequency	Percentage
Water closet	4	3.3
Pit latrine with slab	45	37.5
Pit latrine without slab	35	29.2
Water body	41	34.2
Share toilet facility		
No	19	15.8
Yes	101	84.2
Satisfy with current toilet facility		
No	78	65.0
Yes	42	35.0
Distance to toilet facility		
In-dwelling	4	3.3
<20m	31	25.8
21-40m	49	40.8
41-60m	24	20.0
>60m	12	10.0
Toilet leakage		
No	85	70.8
Yes, frequently	7	5.8
Yes, sometimes	18	15.0
Don't know	10	8.3
Frequency of emptying pit latrine		
None	13	10.8
1-3yrs ago	96	80.0
>3yrs ago	11	9.2
Place where the content of toilet is emptied into		
Removed by service provider	36	30.0
Buried/covered pit	9	7.5
Uncovered pit/water body	55	45.8
Don't know	20	16.7
Hand Washing Facility		
Fixed facility	2	1.7
Mobile object	27	22.5
No hand washing place in-dwelling	91	75.8

Source: Field Survey Data, 2023

Distribution of respondents by solid waste disposal methods

Table 4 depicts the findings regarding methods of solid waste disposal in the study area. The results indicate that 40% of respondents disposed of their waste in open dumpsites, 27.5% dumped waste into surrounding water bodies, 8.3% burned their solid waste, and 24.2% utilized Private Sector Participation/Lagos State Waste Management Authority (PSP/LAWMA) services. This suggests that a majority of respondents disposed of their solid waste in unsafe and unhealthy manners. This supports Foday et al.'s (2013) assertion that dumping waste in water or open dumpsites not only pollutes the environment and increases infectious disease incidence but also subjects passersby and residents to offensive odors. Additionally, Aminu et al. (2020) reported that air and water pollution from open dumpsites worsens during the rainy season due to offensive odors and groundwater pollution, while incineration smoke contributes to air pollution for nearby residents, during the dry season.

Table 4: Distribution of Respondents by Solid Waste Disposal Methods

Method	Frequency	Percentage
PSP/LAWMA	29	24.2
Open dumpsite	48	40.0
Burning	10	8.3
Water body	33	27.5

Source: Field Survey Data, 2023

Perceptions of Households on Sanitation Facilities

Table 5 illustrates the responses regarding household perceptions of sanitation facilities. The findings were derived from a 5-point Likert scale analysis with a weighted mean of 3.0.

Responses below 3.0 were deemed negative (disagree), while those equal to or above 3.0 were considered positive. The results indicate unanimous agreement among sampled urban slum households on several key perceptions: solid waste serving as a breeding ground for disease vectors, the preventability of many diseases through proper waste management, and the emission of offensive odors due to poor sanitation, all scoring a mean of 5 each and ranking first. Additionally, a vast majority (99.2%) strongly agreed that poor sanitation contributes to the transmission of diarrheal diseases, with a mean of 4.98, ranking fourth. Furthermore, 97.5% and 96.7% of respondents strongly agreed that poor sanitation practices can contaminate water sources and degrade the environment, respectively, both scoring a mean of 4.97 and ranking fifth. Moreover, 95.8% strongly agreed that poor sanitation poses dangers to human and community health, with a mean of 4.93, ranking seventh. However, only 46.7% of respondents strongly agreed/agreed that infection can easily be contracted through the use of public toilets,

with a mean of 4.35, ranking eighth. Conversely, respondents disagreed that defecating in water bodies nourishes fishes or that open defecation is more hygienic than using toilets, scoring means of 1.93 and 1.55, and ranking ninth and tenth, respectively. This indicates strong agreement among urban slum households with the positive aspects of improved sanitation facilities examined in this study, echoing the findings of Jenkins and Scott (2007) as cited by Safari et al. (2020), which emphasized attributes such as cleanliness, convenience, health promotion, safety, and pride as crucial for toilet adoption. Such positive attributes may foster a sense of pride, further promoting the adoption of improved sanitation facilities

Table 5: Distribution of respondents' perception on sanitation facilities

Perceptions	SA	A	U	D	SD	Mean	Rank
Poor sanitation is linked to transmission of diarrhea diseases	119 (99.2)	0 (0.0)	1 (0.8)	0 (0.0)	0 (0.0)	4.98	4 th
Solid waste is a breeding ground for disease vectors	120 (100)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5.00	1 st
Many diseases can be prevented if wastes are properly managed	120 (100)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5.00	1 st
Poor sanitation can lead to emission of offensive odour	120 (100)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5.00	1 st
Poor sanitation practices can contaminate/pollute water sources	117 (97.5)	3 (2.5)	0 (0.0)	0 (0.0)	0 (0.0)	4.97	5 th
Poor sanitation can degrade the environment	116 (96.7)	4 (3.3)	0 (0.0)	0 (0.0)	0 (0.0)	4.97	5 th
Poor sanitation is dangerous to human and community health	115 (95.8)	4 (3.3)	0 (0.0)	0 (0.0)	1 (0.8)	4.93	7 th
Open defecation is more hygienic than defecating in the toilet	2 (1.7)	4 (3.3)	2 (1.7)	41 (34.2)	70 (58.3)	1.55	10 th
Infection can easily be contacted through the use of public toilet	56 (46.7)	56 (46.7)	4 (3.3)	2 (1.7)	2 (1.7)	4.35	8 th
Defecating in water bodies help provide food and nourish fishes in the water	0 (0.0)	3 (2.5)	14 (11.7)	51 (42.5)	52 (43.3)	1.73	9 th

Source: Field survey data, 2023

Households Willingness to Pay (WTP) for Improved Sanitation Facilities (ISF)

In developing nations, households' willingness to pay (WTP) for improved sanitation facilities (ISF) constitutes a significant social and behavioral process with far-reaching implications for public health, sanitation policy formulation, planning, and the improvement of sanitation services by public utility companies. Existing literature (Minh *et al.*, 2013). indicates a lack of comprehension among planners and policymakers in developing countries regarding the WTP for quality sanitation services. Nevertheless, the provision of safe, secure, and hygienic sanitation services is considered a fundamental right for every citizen (Hutton, 2012). Improved sanitation services not only contribute to increased household income generation and poverty reduction but also serve

as a prerequisite for sustainable development (Howard and Bartram, 2015).

As depicted in Table 6, the majority (85.8%) of respondents expressed support for the ISF project, while 14.2% were opposed to it. This suggests that most sampled respondents recognized the necessity and significance of improved toilet facilities within the study area. Furthermore, Table 6 indicates that a majority (55.8%) of urban slum households were willing to contribute financially to the maintenance of the ISF, while 44.2%, although supporting the project, were unwilling to bear any maintenance costs. The reasons for this reluctance, as outlined in Table 6, include a significant proportion (39.2%) believing that it is the government's responsibility to provide ISF in their communities, 35% expressing satisfaction with their current toilet facilities, 10.8% citing

financial constraints, 8.3% expressing distrust in the government, and 6.7% providing no specific reason for their unwillingness to pay for ISF in the study area. These findings align with previous studies conducted in Manikganj Municipality, Lahore, Pakistan; Kwara and Benue States, Nigeria, which found that respondents often consider it unnecessary to pay for improved water supply due to beliefs that the government should provide such services free of charge, financial constraints, and uncertainties regarding the program (Akhtar *et al.*, 2017; Rahman *et al.*, 2017; Aminu and Nyor, 2021)

Mean willingness to pay

Table 7 displays the findings regarding the mean willingness to pay (WTP) for improved sanitation facilities within the study area. Parameter estimates were derived using the logit regression model as outlined in the methodology section. The estimated mean WTP for improved sanitation facilities was calculated as $-(66.007/-0.064) = \text{₹}1,031.36$ per month. Given that a significant portion of urban slum households reside in rented accommodations and share the cost of public utilities like electricity and water, they should feasibly be able to afford this amount, considering it is relatively low compared to other utility expenses. This outcome is in agreement with the conclusions drawn by Mulatya *et al.*, (2021), who found that willingness to pay for sanitation improvements in rural areas of Kenya exhibits price elasticity.

Factors influencing respondents' Willingness to Pay (WTP) for improved sanitation

Table 8 illustrates the outcomes of the double-hurdle regression model concerning the determinants influencing households' decision to pay and the amount they are willing to pay for improved sanitation facilities within the study area. The estimated sigma value of 35.2993 is

statistically significant at a 1% level, indicating a good fit for the model and suggesting a high correlation between the residuals of the first and second hurdles.

Hurdle 1: Decision to Pay (WTP)

At the first hurdle, factors such as age, monthly expenditure, homeownership, use of uncovered pit latrine, sharing toilet facilities, and distance to the current toilet significantly influence the decision to pay for improved sanitation facilities in the study area.

The coefficient of respondents' age exhibits a negative significant relationship with WTP for improved sanitation facilities at a 5% significance level. This suggests that as the age of the household head increases, the probability of WTP for improved sanitation decreases. A year increase in the household head's age corresponds to a 5.6% decrease in the likelihood of WTP. This is in consonance with the findings of Zvobgo, (2021) that active group (20–54 years) had a relatively higher WTP odds ratio compared to the elderly group in Chitungwiza, Zimbabwe. The result also agrees with the findings of Aboaba *et al.*, (2020); Aminu and Nyor, (2021) that increase in age of respondents reduces the likelihood of respondent's willingness to pay for greenhouse cucumber in Lagos State and improved water supply in Benue State, Nigeria.

Additionally, the coefficient of monthly expenditure displays a negative and significant relationship at a 1% level, indicating that WTP for improved sanitation decreases as monthly expenditure increases. A higher monthly expenditure reduces the likelihood of WTP for improved sanitation by 21%, potentially due to the low-income status of the respondents in the study area

Table 6: Distribution of Respondents Based on their support and WTP for the Project

Support the ISF project	Frequency	Percentage
No	17	14.2
Yes	103	85.8
WTP	Frequency	Percentage
No	53	44.2
Yes	67	55.8
Reasons	Frequency	Percentage
Do not trust government	10	8.3
Its government responsibility	47	39.2
Satisfied with current toilet facility	42	35.0
Cannot afford the fees	13	10.8
None	8	6.7

Source: Field survey data, 2023

Table 7: Estimates of the Bivariate Logit Model for Mean WTP

Bid	Coefficients	Std. Err.	Z	P> z
Constant	16.007	1.010	9.885	0.000
Price	-0.064	0.014	-5.335	0.002***
Mean WTP	250.11			

***Statistically significant at 1%, degree of freedom -2 Log likelihood 16.977, Chi-squared 147.741

Table 9: Double Hurdle Estimates of Household's Willingness to Pay for Improved Sanitation Facility

Variable	Hurdle 1: Decision to pay			Hurdle 2: amount willing to pay		
	Coeff.	Std. Err.	p> z 	Coeff.	Std. Err.	p> z
Sex	-0.135	0.479	0.778	-121.4**	59.128	0.042
Age	-0.056**	0.024	0.018	-3.368	2.993	0.263
Education	0.129	0.174	0.458	39.559*	22.537	0.082
Household size	0.044	0.117	0.706	-13.28**	14.448	0.029
Occupation	-0.145	0.172	0.400	-1.958	21.103	0.510
Monthly income	0.000	0.000	0.508	0.001**	0.002	0.011
Spouse's income	0.000	0.000	0.352	0.000	0.001	0.774
Monthly expenditure	-0.210***	-0.00	0.052	0.101	0.001	0.426
Landlord	0.191**	0.889	0.015	-0.799	105.354	0.994
Water closet	0.541	0.072	0.322	-0.041**	0.031	0.021
Water body	0.569	0.225	0.211	-0.514**	-0.241	0.021
Uncovered pit latrine	0.551**	0.226	0.030	69.863**	27.182	0.012
Covered pit latrine	-0.619	0.425	0.145	-16.5**	54.696	0.035
Sharing toilet	0.025**	0.777	0.014	126.188	93.514	0.180
Distance	0.103**	0.049	0.028	24.768	44.965	0.583
Constant	1.960	2.247	0.383	-16.573	9.012	0.572
Sigma	35.2993***	8.117	0.000			
Wald χ^2	46.136***		0.001			
Prob>chi2	0.000***					
Log Likelihood	-132.437					

*, **, *** significant at 10, 5 and 1%, respectively.

Source: Field survey data, 2023

Conversely, factors such as homeownership, the presence of an uncovered pit latrine, sharing toilet facilities, and greater distance to the current toilet positively influence the decision to pay for improved sanitation facilities at a 5% significance level, suggesting a higher likelihood of WTP in these cases. This is in tandem with the findings of Dare *et al.*, (2018) that respondents living in their own buildings had higher willingness to pay for improved toilet services. This result also agrees with the findings of Mulatya *et al.*, (2021) that distance to the current toilet increased overall willingness to pay for improvement in rural sanitation in Kenya.

Amount Willing to Pay

At the second hurdle, factors such as gender, education level, household size, monthly income, presence of water closet, proximity to water body, and utilization of covered and uncovered pit latrines influenced the amount respondents were willing to pay for improved sanitation facilities in the study area.

The coefficient of gender exhibited an inverse relationship with the amount respondents were willing to pay, significant at a 5% level. This indicates that the amount respondents were willing to pay decreased based on their gender, with female respondents demonstrating a higher likelihood of paying a higher price than their male counterparts. This trend could be attributed to the higher vulnerability of female residents to infections when using poor sanitation facilities compared to males. This result contradicts the findings of Ayanshola *et al.*, (2013) that men were more willing to pay for improved sanitation facilities in Ilorin, Kwara State, Nigeria. Minh *et al.*, (2013) also reported that women in rural Vietnam seemed to exhibit less concern regarding sanitation. Similarly, the coefficient of household size displayed a negative significant relationship with the amount

willing to pay at a 5% level. This suggests that as household size increases, the amount respondents were willing to pay for improved sanitation facilities decreases. For every additional person in the household, the amount willing to pay decreased by approximately ₦13.28. This result agrees with the findings of Aminu and Adebajo, (2023) that as the size of the household increases, the household head's WTP for organic leafy vegetables decreases in Ogun State, Nigeria. In the same vein, factors such as access to water closet toilet systems, proximity to water bodies, and use of covered pit latrines also exhibited negative and significant coefficients at a 5% level. This implies that the likelihood of paying a higher price for improved sanitation facilities decreased among respondents with access to these sanitation amenities, possibly because they were content with their current sanitation arrangements. This is in line with Dare *et al.*'s (2018) findings, indicating that rural households in Oyo State, Nigeria, held the belief that defecation should not incur monetary cost due to the ample expanse of land covered with water in the vicinity.

Conversely, the coefficient of education displayed a positive significant relationship with the amount respondents were willing to pay at a 10% level, indicating that the probability of paying a higher amount for improved sanitation facilities increased with the educational level of the respondents. This finding aligns with previous studies by Mezgebo and Ewnetu (2015) who reported that residents with higher levels of education are more likely to pay more for improved services.

Furthermore, the coefficient of monthly income was positive and significant, suggesting that the amount respondents were willing to pay increased with their income levels. This supports economic theory, which posits that individual or household demand for specific commodities is

influenced by income. This is in line with the findings of Francis (2013) and Minh *et al.*, (2013) who reported that higher income increases WTP for sanitation in Uganda and rural Vietnam respectively.

Finally, the coefficient of uncovered pit latrines exhibited a positive and significant relationship with the amount respondents were willing to pay at a 5% level.

This suggests that a higher prevalence of urban slum households using uncovered latrines was associated with a greater willingness to pay for improved sanitation facilities, consistent with findings of Dare *et al.*, (2018) that WTP for improved sanitation services increases with number of rural households using uncovered latrines.

CONCLUSION AND RECOMMENDATIONS

The study concluded that the prevalence of unimproved sanitation facilities, including defecation in uncovered pit latrines and water bodies, was notable in the study area. Although 85.8% of respondents supported the improved sanitation facility project, only 55.8% were willing to contribute to its maintenance. The mean WTP for improved sanitation facilities was estimated at ₦1,031.36 monthly. Regarding factors influencing respondents' decisions and the amount they were willing to pay for improved sanitation facilities, age, monthly expenditure, landlord status, toilet-sharing arrangements, and distance significantly affected the decision to pay. On the other hand, factors such as gender, education, household size, monthly income, access to water closet facilities, proximity to water bodies, and the use of covered and uncovered pit latrines significantly influenced the amount respondents were willing to pay.

The findings suggest that increased proximity of households to toilets, higher incomes, and access

to education could enhance the utilization of improved sanitation facilities in the study area. Additionally, the study recommends that government and other stakeholders implement public enlightenment and sanitation education programs focused on raising awareness about the consequences of poor sanitation and the benefits of using improved sanitation facilities among urban slum dwellers.

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PERFORMANCE AND APPLICATION OF STOCHASTIC PRODUCTION FRONTIER IN ORANGE-
FLESHED SWEET-POTATO PRODUCTION IN ABIA
STATE, NIGERIA

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ABSTRACT

The importance of orange-fleshed sweet potato as a food security crop cannot be over-emphasized. Hence, this study examined the performance and application of stochastic production frontier in orange-fleshed sweet-potato (OFSP) production in Abia State, Nigeria. A multi-stage random sampling procedure was used to select 40 OFSP producers. Primary data were collected with aid of structured questionnaire and scheduled interview. Data collected were analyzed using descriptive statistics, budgetary technique, ordinary least square regression and stochastic production frontier. The results from the study revealed that the mean age, household size, farming experience and income of the respondents were 47.55years, 6persons, 10.75years and ₦163157.50 respectively. Also, 57.5%, 97.5%, 65.0, 60% and 52.5% of the respondents were male, married, cooperative membership, had secondary education and access to credit respectively. The net farm income, the rate of return on investment and the benefit-cost ratio of OFSP production were ₦71,260.72, 0.78 and 1.78 respectively. Planting material, cultivated farmland and labour as well as inefficiency variables such as household size, experience and education that were included in the model were statistically significant and positively related to total output of OFSP. Level of education, marketing experience, sex and labour cost were significant and positively related to the net farm income of OFSP production. Also, high cost of input, poor extension agent- farmers' contact, poor access to farm and low credit facilities were the major constraints to OFSP production in the study area. The study therefore recommends that the farmers should be encouraged to adopt agricultural insurance schemes as a way to protect them against risks of crop failures in OFSP production. In addition, incentives in the form of improved farm inputs, adequate capital and other social infrastructures should be provided to rural farmers as a means of boosting their OFSP output

Keywords: Orange-fleshed sweet-potato, Stochastic production-frontier, Performance

INTRODUCTION

The agricultural sector needs a boost to become the mainstay of the Nigerian economy again. The rapid development of the sector which is dominated by subsistence farmers in Nigeria

cannot be over-emphasized. So an increase in the production of food crops such as maize, rice, orange-fleshed sweet potato (OFSP) and wheat would go a long way in curbing food insecurity. OFSP is one of the bio-fortified crops developed as part of the global effort to control vitamin A

deficiency (HarvestPlus, 2009). It is one of the starchy staple crops which contain appreciable amounts of β -carotene, ascorbic acid and the amino acid lysine, deficient in cereal-based diets like rice. It also contains soluble fiber needed in reducing cholesterol concentration and anti-oxidant nutrients that can inhibit the development of coronary heart disease. The leaves of OFSP contain considerably higher amounts of minerals such as phosphorus, nitrogen, potassium, magnesium, copper, iron and zinc than what is found in commonly cultivated vegetables in addition to chlorogenic acids, a phenolic compound responsible for suppressing obesity in humans (Shi, *et al.*, 2008).

orange-fleshed Sweet potato (OFSP) is an improved breed of sweet potato (*Ipomea batatas* [L.] Lam.) cultivated in the world today for food and source of income especially among the rural dwellers (Padmaja, 2009; Mitra, 2012). It can be grown in wide range of agro-ecologies and soil types. OFSP is a crop with immense ability to grow in marginal fields (Afuape, 2014). As an excellent food security crop in Sub-Saharan Africa (Low, *et al.*, 2007), OFSP has a fairly drought resistant ability once established, short maturity period compared to other root/tuber crops and can be propagated using vegetative parts.

The first and second varieties of the crop were released in December 2012 and June 2013 respectively in Nigeria, by “Reaching Agents of Change Organization” (Njoku and Umoh, 2013), while over 20,000 farmers have received at least one bundle of OFSP vines for production and consumption purposes by 2015 (Olafeju, 2015). Enhancing orange-fleshed sweet potato competitiveness will improve the efficiency with which farmers use the available resources in increasing production, productivity, household income, food security, and overall economic growth.

The drawbacks in OFSP production were mainly centered on inadequate planting materials. Just as seen in sweet potato, cost of planting material takes 40.1% of the total production followed by labour (24.9%) and fertilizer (18.5%) respectively. Also, unavailability and untimely supply of quality vines (seed) has been cited as one of the major constraints to the realization of the full potentials of OFSP production in Sub-Saharan African (Coomes *et al.*, 2015; McGuire & Sterling, 2016; McEwan *et al.*, 2015). This ugly situation is compounded by the failure of the formal seed delivery system and the perishable, bulky nature of the OFSP vines. However, the limited role played by the institutional seed sector in providing timely and quality vines to farmers has given birth to a flourishing informal decentralized and local vine multiplication system (Kimenye and McEwan, 2014; McEwan *et al.*, 2017).

In light of the reviewed information, this study therefore, examined the performance and application of stochastic production frontier in Orange-Fleshed Sweet-Potato (OFSP) production in Abia State, Nigeria. Specifically, the study determined the profitability of OFSP production; estimated the factors that influence OFSP performance and production; and identified the constraints militating against orange-fleshed sweet potato production in the study area.

METHODOLOGY

Study area

The study was conducted in Abia State, it has a land mass of 700 square km with 17 local government areas. The state lies between longitudes $7^{\circ} 23^1$ and $8^{\circ} 02^1$ East of Greenwich meridian and latitudes $5^{\circ} 49^1$ and $6^{\circ} 12^1$ North of the equator. Abia State is bounded on the northeast by the states of Anambra, Enugu and Ebonyi, to the west by Imo state, Cross River

State to the east and Akwa Ibom State to the southeast, and on the South by Rivers State. Abia consists of three agricultural zones, namely; Aba, Umuahia and Ohafia. The estimated population of Abia State is 3,720,000 people (NPC, 2016). The annual rainfall ranges from 200-250mm while the temperature ranges from 22°C to 35°C. Abia state is made up of three agricultural zones namely: Umuahia, Aba and Ohafia Agricultural zone. Farming is done at subsistence level. The state is endowed with a rich fertile soil that supports the growth of the crops; Yam, cassava, cocoyam, melon, maize, oil palm, garden egg, cocoa, to mention but a few. Poultry, goat, pigs and sheep are the major livestock kept. Abia state is divided into 17 local government areas. These are group into three agricultural zones namely, Aba, Umuahia, and Ohafia zone.

Sampling Procedure

The study adopted a multistage sampling procedure. In the first stage, two agricultural zones (Ohafia and Umuahia) were purposively selected. In the second stage, two Local Government Areas (LGAs) were randomly selected from each of the zones. Third stage involved a random selection of two communities each from the selected 4 LGAs. In the final stage, ten (10) producers were randomly selected from a list compiled with the assistance of the Extension officers of the ADPs, research institute and state's Ministry Agriculture giving a sample size of forty (80) producers. The data for this study were obtained from primary sources using a structured questionnaire and through oral interview and personal observations.

Analytical Techniques

The data were analyzed using econometric models and descriptive statistical tools such as mean, percentage and frequency distribution. The socio-economic characteristics of the

respondents in the study area were analyzed using descriptive tools. The cost items, revenue and factors influencing OFSP production were analyzed using budgetary techniques, stochastic production function and multiple regression model respectively. Also, the constraints militating against OFSP production in the study area were analyzed using mean likert scale.

Models Specification

The budgetary analysis adopted for the cost and return of OFSP production is specified as:

TC = TVC + TFC	-	-	1
TR = P x Q	-	-	2
GM = TR – TVC	--	-	3
NR = GM – TFC	-		4

Where:

TC = Total cost of marketing (₦)

TVC = Total Variable Cost

TFC = Total Fixed Cost (₦)

TR = Total Revenue (₦)

P = Price of OFSP (₦)

Q = Quantity of OFSP (kg)

GM = Gross Margin (₦)

NR = Net Return (₦)

Rate of Return on Investment (RRI)

$$RRI = \frac{\text{Net Return per annum}}{\text{Total cost incurred per annum}} - -5$$

Return per naira invested

$$BCR = \frac{\sum B}{\sum C} - -6$$

Where:

$\sum B$ = summation of benefit

$\sum C$ = summation of cost

BCR = Benefit cost ratio

Ordinary Least Square (OLS) Regression

OLS regression for factor influencing the performance (net return) of OFSP production is specified as: $Y = f(X_1, X_2, X_3, \dots, X_8)$ - 7

Where:

Y = Net Return (₦) from i^{th} OFSP Producers (as defined in equation 4)

X_1 = Age of farmer,
 X_2 = Educational level of farmer,
 X_3 = Sex of farmer (Male =1, female =0)
 X_4 = Quantity of OFSP (Bags)
 X_5 = Amount of Credit granted (₦)
 X_6 = Experience (years)
 X_7 = Cost of labour (₦)
 X_8 = Fixed inputs (₦)

Stochastic Production Frontier

The stochastic production frontier was used to analyze the factor influencing of OFSP production

The stochastic efficiency frontier production function is defined by:

$$Y_i = f(X_i, \beta) \exp(V_i - U_i) \quad - \quad 8$$

$$Y_i = \text{Yield of the OFSP (kg)}$$

X_i = corresponding vector of inputs

$$Y_i = f(X_1 \dots X_n) \quad - \quad - \quad - \quad 9$$

$$Y_i = \beta_0 + \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_n X_n + e_{i-}$$

-10

Where $e_i = V_i - U_i$,

$$Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 \dots + \beta_n X_n + V_i - U_i \quad 11$$

V_i = is independently and identically distributed random errors, having $N(0, \sigma^2)$ distribution.

U_i = technical inefficiency

e_i = error term

Where:

$$Y_i = \text{Yield of the OFSP (Kg)}$$
 $X_1 = \text{Number of Vine (in Kg)}$
$$X_2 = \text{Cultivated farmland (hectares) or } M^2$$

X_3 = Quantity of fertilizer used (in Kg)

 $X_4 = \text{Labour (manday)}$
$$X_5 = \text{Pesticides/herbicides (litres)}$$

X_6 = Capital (Depreciation, insurance, tax, interest and rent on land)

In the frontier model specified, to estimate β , which is the vector of the regression parameter, the stochastic production model is linearized thus:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 \quad - \quad - \quad - \quad 12$$

The technical inefficiency is outlined by the equation

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \dots + \delta_n Z_n -$$

Equation 11 outlines the technical inefficiency effect and it also indicates that these effects in a stochastic frontier are expressed in terms of various explanatory variables, which include the following:

 $Z_1 = \text{age of respondent (years)}$ $Z_2 = \text{household size (Number)}$ $Z_3 = \text{OFSP farming experience (years)}$ Z_4 = Formal education of the farmer (years) Z_5 = value of off-farm income (naira) $Z_6 = \text{sex of respondent (1=male, 0=female)}$

Z_7 = marital status of respondent (1=married, 0=otherwise)

$\delta_0, \delta_1, \delta_2 \dots \delta_7$ are parameters to be estimated.

For the constraints to OFSP production in the study area, the Likert scale mean count was used.

5-point rating scale of Strongly Agree (5), Agree (4), Undecided (3), Disagree (2), Strongly Disagree (1) was used to achieve the mean ($\bar{X}$). Variables with mean score of 3.0 (which is the average mean score of the rating level) and above imply that they are positive and in affirmative to the objective being measured while factors with mean score less than 3.0 have no influence on the variable being measured.

To determine the mean likert scale $[\sum X/N]$, mean of each item will be computed by multiplying the frequency of each response with it's appropriate nominal value and dividing the sum with the number of respondents to the item. This can be given thus:

$$\text{Mean} = \sum fn/N$$

Where, Mean = Likert mean score

E = Summation

f = frequency

n = Likert nominal scale

N = Number of respondents

N = Number of respondents

$$\text{Mean} = \frac{1+2+3+4+5}{5} = 3.0$$

RESULTS AND DISCUSSION

Socio-economic characteristics of OFSP producers in the Abia state, Nigeria

The results of socio-economic characteristics of OFSP producers in the Abia state, Nigeria is presented in Table 1.

The results in Table 1 showed the mean age of OFSP producers was 48 years. This represents an active stage in life. This has direct bearing on the availability of able-bodied manpower for primary production. Moreover, age influences the ability to seek and obtain off-farm jobs and income, which could increase agribusiness household' income and ultimately their production capacity. Also Sunday *et al.*, (2014) described this age range as "working age". Majority of the producers represented by 57.5%, 97.5%, 65.0 and 52.5% were male, married, cooperative membership and had access to credit respectively. This result for sex is expected because OFSP production involves tedious pre-planting operation such as heap or ridge preparation. The implication of marital status on livelihood strategy can be explained in terms of the supply of family labour. The supply of family labour would be more where the household heads are married. This is in consonance with the findings of Zalkuwi *et al.*, (2014). The result of the cooperative membership implied that most of the farmers can pool resources to achieve their production goal. Access to credit has the capacity to transform the poor through acquiring productive capital, which improves their capacity to generate income, savings and investment for better welfare (Diagne & Zeller, 2011). The mean household size was 6 persons. The economic implication is that it will provide the OFSP producers household with family labour and reduce cost of production and increase their revenue. This is desirable, consistence and of

great importance. This corroborates with the findings of Ayuya *et al.*, (2011) who made an argument that the large household have the capacity to relax the labour constraints required during introduction of new technology. Most (60%) of the respondents had secondary education. The result implies that the household are highly literate having acquired one level of education or the other. This means that they can be easily convinced to accept better practices of their business operations. Undoubtedly, the high level of literacy predisposes some level of managerial ability in the farm business (Afolabi, 2010; Acquah & Addo, 2011). Furthermore, this study agreed with previous findings that education provides a favorable atmosphere for awareness, adoption of innovation and utilization of financial service (Siyanbola, 2013). The average farming experience of the OFSP producers was 10.75years. This implies that most of the respondents are experienced in the production of OFSP. Nwaru (2004), noted that the number of years spent in business may give an indication of the practical knowledge he has acquired on how he can overcome certain inherent farm production problems. The average income of the respondents was ₦163157.50. The relatively high income status of the farming household has implication for household welfare as is reflected in their expenditures.

Budgetary analysis of OFSP production in Abia State, Nigeria

The budgetary analysis was also carried out for OFSP production and is presented in Table 2.

The result in the Table 2 showed the total value of production was ₦163,157.50. Total variable cost and total fixed cost of production were ₦91,896.78 and ₦25,086.78 respectively. The net farm income (profit), the rate of return on investment (RRI) and the benefit-cost ratio were ₦71,260.72. 0.78 and 1.78 respectively. These imply that OFSP production was a

profitable agribusiness in the study area, hence the call for unemployed youth to venture into the production of OFSP. The high proportion of labour cost to the total variable cost confirms the assertion that cost of agriculture labour is high (Akintobi, *et al.*, 2021). This is due to numerous farming operations involved in the production of agricultural products. For instance, in the production of OFSP, labour use is composed of land preparation, cultivation, planting, fertilizer application, weeding, harvesting, sorting and bagging. These operations are paid for as labour cost in man-hours.

Determinants of net farm income (NFI) of OFSP production in Abia State, Nigeria

The results of the factors that influence the net farm income (NFI) of OFSP production in Abia State, Nigeria is presented in Table 3.

From Table 3, the Linear functional form was chosen as the lead equation based on the number of significant variables, the coefficient of multiple determinations (R^2), the conformity of variables to a priori expectation as well as the significance F-ratio. The coefficient of multiple determination (R^2) was 0.618 which implies that 61.8% variability in the net farm income (NFI) of the production of OFSP was explained by the explanatory variables included in the model.

The level of education of the respondent was significant at 1% and positively related to the NFI indicating that, as the level of education increases, profit increases which may be as a result of increase in knowledge of reducing cost of production in the area. This study agreed with previous findings that education provides a favorable atmosphere for awareness, adoption of innovation and utilization of financial service (Siyanbola, 2013).

The coefficient of production experience and labour cost were positive and significant at 1%, implying that increase in any of these variables lead to a significant increase in the NFI of OFSP

producers. The positive sign of the coefficients shows that as the production experience and labour cost increases, the NFI of the OFSP producers also increase and vice versa. This is because the OFSP producers use their previous experiences to factor their cost of production into their selling price, thus making more profit. Sex is statistically significant at 5% and was inversely related to NFI which implies that female OFSP producers have significant effect on the NFI. This result is expected because female have good bargaining power than male.

Determinants of OFSP Production in Abia State, Nigeria

The result of the maximum likelihood estimate of stochastic production frontier function for OFSP production in Abia State, Nigeria is presented in Table 4.

From Table 4, the estimated variance (σ^2), gamma (γ) and Log likelihood function indicate goodness of fit with the stochastic frontier model. For production factors the coefficient of planting material, cultivated farmland and labour were statistically significant and positively related to total output of OFSP. This implies that increase in any of these variables will lead to increase in output of OFSP and vice versa. This is expected and in accordance with a priori expectations. This result is in agreement with the findings of Ataboh *et al.*, (2014). On determinants of technical efficiency, planting material, cultivated farmland and capital had a direct relationship with production output. Also the coefficient of capital was negative and significant at 1% level of probability. This indicates that the more farm assets depreciate, the more the decrease in output

Furthermore, the result shows that there is a positive relationship between the inefficiency variables such as household size, experience and education which were included in the model.

This shows that increase in these variables increases the output of OFSP. These results imply that, the more the number of person per household coupled with increase in years spent in farming and school, the greater the output of OFSP. While a negative relationship exists between age and marital status with output of OFSP. This implies that as OFSP producers advance in age, their output decreases. The

implication is that the older the farms become the lesser the output. Also, OFSP producers who are not married, have low output level.

Constraints Militating against OFSP Production
The result of the problems influencing the production of orange-fleshed sweet potato among the farmers in the study area is presented below.

Table 1: Distributions of Respondents according to socioeconomic characteristics

Variables	Frequency	Percentage
Age		
25-34	3	7.5
35-44	9	22.5
45-54	21	52.5
55-64	7	17.5
Mean	47.55	
Sex		
Male	23	57.5
Female	17	42.5
Marital status		
Married	39	97.5
Single	1	2.5
Education		
Primary	4	10.0
Secondary	24	60.0
Tertiary	12	30.0
Household Size		
1-4	16	40.0
5-8	11	27.5
9-12	13	32.5
Mean	6.00	
Access to credit		
No	14	35.0
Yes	26	65.0
Farming Experience		
1-5	15	37.5
6-10	8	20.0
11-15	17	42.5
Mean	10.75	
Cooperatives		
No	19	47.5
Yes	21	52.5
Income		
10000-100000	12	30
110000-200000	24	60
210000-300000	3	7.5
310000-400000	1	2.5
Mean	163157.50	
Total	40	100.0

Source: field survey, 2021

Table 2: Cost and Returns of OFSP production in Abia State

Budget Items	Units	Unit Price	Average value (₦)
Revenue	50kg/Bag	7300.8	163,157.50
Variable Costs			
- Cost of planting materials	Kg	180	3,960
- Fertilizers	Bags	8000	8,000
- Agrochemicals	-	1500	4500
- Land preparation	(Man-day)	5000	25000
- Planting	(Man-day)	800	4000
- Weeding	(Man-day)	600	3000
-Fertilizer Application	(Man-day)	500	1500
- Harvesting	(Man-day)	5000	15000
- sorting and bagging	-	-	1850
Total variable Cost (TVC)			66,810
Fixed Costs			
Land Rent			18,500
Depreciation of farm equipment			6586.78
Total Fixed cost (TFC)			25,086.78
Total Cost	TVC+TFC		91,896.78
Net farm Income (NFI)	TR-TC		71,260.72
RRI			0.78
BCR			1.78

Source: Field survey (2021).

Table 3: Determinants of net farm income (NFI) of OFSP production

Variables	Linear (+)	Semi log	Exponential	Double log
Constant	6090.749 (1.081)	-132847.211 (-3.062)***	8.911 (43.582)***	3.848 (2.011)**
Age (X ₁)	6075.286 (0.282)	7620.299 (1.236)	0.382 (0.511)	0.555 (5.345)***
Education (X ₂)	3.985 (2.943)***	26092.946 (2.674)***	0.000 (2.667)**	1.029 (2.391)**
Sex (X ₃)	-9.301 (-2.028)**	-1427.516 (-.784)	0.004 (0.0)	-.052 (-.641)
Quantity (X ₄)	0.135 (0.201)	623.783 (0.567)	4.007E-6 (1.428)	0.024 (0.497)
Amount of credit use (X ₅)	.066 (.914)	9032.135 (0.954)***	-1.933E-6 (-.588)	0.293 (0.907)
Production experience (X ₆)	4.303 (2.877)***	190.577 (1.376)	0.000 (1.482)	.736 (0.990)
Labour cost (X ₇)	0.235 (4.07)***	0.06 (2.56)**	1.05 (9.95)***	23.54 (2.90)***
Fixed cost (X ₈)	-0.89 (-1.03)	-023 (0.94)	-3.45 (-0.05)	-1.65 (-1.32)
R ²	0.618	0.419	0.369	0.499
F-ratio	4.124***	6.256***	000***	8.644***

Source: Field Survey, 2021. + lead equation, *** Significant at 1%, ** Significant at 5%, *significant at 10%

Table 4.3: Maximum likelihood estimate of stochastic production frontier function

Variables	Coefficient	Standard error	t-ratio
Production factor			
Constant	8.0834	0.3930	20.57
Planting materials (X_1)	0.0000	6.10e-06	5.95***
Cultivated farmland (X_2)	0.0013	0.0004	3.38***
Fertilizer (X_3)	-0.0022	0.0035	-0.63
Labour (X_4)	0.1305	0.0666	1.96*
Pesticides/herbicides (X_5)	-0.0000	0.0000	-1.08
Capital (X_6)	-0.0003	0.0001	-4.48***
Inefficiency Factors			
Age of respondent (Z_1)	-0.5385	0.7101	-7.62***
Household size (Z_2)	0.0004	0.0007	6.01***
Years of experience (Z_3)	0.0414	0.8601	4.87***
Years of formal education (Z_4)	0.4413	0.6074	7.33***
Value of off-farm income (Z_5)	-0.2790	0.6846	-0.41
Sex of respondent (Z_6)	-0.5892	0.7680	-0.77
Marital status (Z_7)	-0.5968	0.3164	-1.89*
Sigma squared(δ)	0.6678	0.4817	0.96
Gamma(γ)	0.8914	0.0929	
Log likelihood function	-66.2183		
LR test	155.28***		

Source: Field Survey, 2021. *** and * are Significant at 1% and 10% respectively

Table 5: Constraints militating against orange-fleshed Sweet Potato Production

Problems faced	Mean	Standard deviation
High cost of Input	3.983	0.1352
Land tenure system	3.083	0.1071
Unfavourable government policy	3.783	0.1011
Poor access to farm	3.233	0.1352
Inadequate technical knowledge in the use of technology	2.583	0.2308
High interest rate on loan	2.667	0.1658
High cost of improved varieties	2.967	0.1594
Poor extension agent- farmers contact	3.933	0.0784
Low credit facilities	3.233	0.1816
High cost of agrochemicals	3.200	0.1184
High cost of labour to carry out farming Activities	1.733	0.0853
High incidence of pests and disease	3.033	0.1465
Low yield	2.583	0.2308
Unavailability/insufficient planting materials	2.633	0.1629
Low investment/ start-up capital	2.867	0.1603
Grand mean	3.03	

Source: Field survey, 2021

The result in Table 5 showed the distribution of the respondents based on the problems faced in the production of OFSP in the study area. The result shows that High cost of Input ($\bar{x}$ = 3.983), Poor extension agent-farmers contact ($\bar{x}$ = 3.933), Poor access to farm ($\bar{x}$ = 3.233), Low credit facilities ($\bar{x}$ = 3.233), were the major problems affecting respondent in the study area. The result for cost of inputs was expected because of the current inflation in Nigeria couple with poor supply chain due to poor road network that connect farm inputs manufacturing industries in the country to farmers. The high cost incurred from inputs supply also inflates the cost of farm inputs in the country. The results of extension agent-farmers contact and poor credit facilities were also expected because both of them serve as tools for enhancing the production capacity of the farmers, however due to the location of OFSP farm especially in wetland, the possibility of farmers having extension agent visit to their farms is low, also access to credit facilities has been a major issue in agricultural production in Nigeria. The result equally showed a grand mean of score of 3.03 indicating that the problems listed above actually affected the OFSP production in the study area.

CONCLUSION

Based on the findings, the study therefore concludes that OFSP production in the study area was profitable and females are more involved its production than males. Planting material, cultivated farmland and labour as well as inefficiency variables such as household size, experience and education were statistically significant and positively related to total output of OFSP. Level of education, marketing experience, sex and labour cost were significant and positively related to the net farm income of OFSP production. High cost of input, poor extension agent- farmers' contact, poor access to farm and low credit facilities were the major

factors that constrained the production of OFSP in the study area. Based on the findings, it was recommended that farmers should be encouraged to adopt the agricultural insurance schemes as a way to protect them against risks of crop failures in OFSP production. In addition, incentives in the form of improved farm inputs should be provided to rural farmers as a means of boosting their OFSP output. Lastly, adequate capital and other social infrastructures should also be provided.

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SOURCES OF INFORMATION ON SOIL HEALTH MANAGEMENT STRATEGIES FOR
CONTROLLING BLACKLEG DISEASE OF POTATOES AMONG FARMERS IN JOS SOUTH
LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

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ABSTRACT

This study investigates the sources of information on soil health management strategies for controlling blackleg disease in potatoes among farmers in Jos South Local Government Area, Plateau State, Nigeria. The research examines the socio-economic characteristics of farmers, identifies primary information sources, and explores commonly adopted soil health management strategies. A purposive sampling method was used to select 160 respondents from four districts, and the data was analysed using descriptive statistical tools. The findings indicate that the majority of farmers are predominantly female, young, married, and have basic education. Agricultural NGOs, Key informants, and workshops are valued sources of information. Crop rotation, cover cropping, and organic mulching are widely adopted, reflecting a preference for natural approaches. The study emphasizes the need for targeted education and support to enhance the adoption of additional soil health management strategies, which can boost productivity and sustainability in potato farming. References to relevant literature on sustainable potato production and soil health management support the study's findings and recommendations. The study's conclusions also align with policy implications for enhanced soil management in Africa.

Key Words: Soil health management, Blackleg disease, Potato farming, Sustainable agriculture

INTRODUCTION

Globally, potatoes (*Solanum tuberosum* L.) play a crucial role in ensuring food security and generating income for millions of people (Dolničar, 2021). Nigeria, with its favourable climate, has become a significant potato-producing country in Africa (International Potato Centre [CIP], 2019). However, potato production in Nigeria faces significant challenges, including blackleg disease

(*Pectobacterium atrosepticum*), which causes substantial yield losses (Okorie et al., 2017). Moreover, blackleg disease poses a considerable threat to global potato production, potentially resulting in losses of up to 50% (CIP, 2019). Effective management requires understanding soil health management strategies (SHMS) (Larkin et al., 2011). Yet, limited information exists on sources used by Nigerian potato farmers for implementing SHMS to control blackleg disease.

The limited understanding of effective information dissemination among farmers highlights the need for research on optimal communication channels and sources to enhance soil health management strategies (SHMS) knowledge. Insights into farmers' experiences with information dissemination could facilitate targeted educational programs (Adeleke, Adeoye and Agbaje, 2020). Collaborative efforts among agricultural extension services, research institutions, and farmer organizations are crucial for creating a comprehensive support system (Ogunleye et al., 2021). Evaluating current practices employed by farmers in combating blackleg disease is essential. This involves investigating cultural practices like crop rotation, resistant cultivar selection, and proper irrigation techniques. Integrating these strategies can build resilience against disease outbreaks, improving yield stability (Huang et al., 2018).

As Nigeria boosts its potato production, tackling blackleg disease will be crucial for food security and farmer prosperity. This is because potato production faces significant disease-related challenges, potentially compromising global food supplies. A comprehensive approach that includes education, resource availability, and a sustainable practice is essential to overcome these challenges. This study investigates sources of information on soil health management strategies for controlling blackleg disease in potatoes among farmers in Jos South Local Government Area, Plateau State, Nigeria.

In specific terms, the study seeks to:

- i. Describe socio-economic characteristics of potato farmers in Jos South Local Government Area.
- ii. Identify the main sources of information utilised by potato farmers for managing soil health Strategies against blackleg disease

- iii. Identify the common soil health management strategies adopted by potato farmers.

MATERIAL AND METHODS

The study was conducted in Jos South Local Government Area, Plateau State, Nigeria, characterized by a cold climate (14°C – 31°C) and mild altitude (1,500m above sea level). The area has a near-temperate climate with two marked seasons: wet and dry. A purposive sampling technique was employed to select the farmers since they are not registered with any recognised organization. Four districts (Kuru, Vwang, Gyel, and Du) were purposively selected based on their potato cultivation significance. 40 potato farmers from each district were selected through referrals from local agricultural extension agents and farmer organizations. A total of 160 potato farmers participated in the study. Primary data was collected using structured questionnaires and an interview schedule designed to capture information on demographics, sources of information on SHMS, and blackleg disease management practices. Descriptive statistics (frequency, percentages and mean) were used to analyse objectives.

RESULTS AND DISCUSSIONS

The findings in Table 1 revealed that a higher percentage (61.9%) of the potato farmers were female, whereas only 38.1% were male. These findings suggest females dominate potato farming activities in this area. This can be attributed to potato production being labour-intensive, requiring meticulous attention often provided by women (Adeoye, Ayanwale and Odebode, 2017; Li, et al., 2019). Furthermore, sustainable potato production practices, which emphasize careful resource management and attention to detail, may also contribute to

women's participation in this sector (Schüler et al., 2020).

The participants' average age of 37 suggests a vibrant and industrious group, characterized by substantial productive potential, physical capability for rigorous farming tasks, and openness to technological innovations in potato disease management. This age profile mirrors findings from Momoh, Mbube, and Silas (2024), where 37-year-old poultry farmers demonstrated eagerness to adopt innovative strategies for improved productivity.

A slight majority (52.5%) of respondents are married, indicating stable household conditions and potentially greater agricultural resources. This status allows married farmers to involve family in soil health management, encouraging better practices. Furthermore, dual incomes or shared resources can improve financial stability, facilitating investments in advanced farming equipment and techniques that best enhance soil quality. This finding supports Mbube, Elenwa, and Nnodim (2019), who observed that married farmers have greater adoption capacity due to shared responsibilities and access to additional resources.

The educational background of respondents reveals a significant discrepancy, with 48.1% possessing primary education, 30% secondary, 11.3% tertiary, and 10.6% lacking formal education. This predominantly basic education level may limit farmers' understanding and adoption of advanced soil health management strategies for controlling blackleg disease in potatoes. Consistent with previous studies on agricultural education and development, the low tertiary education rate (11.3%) may reflect socioeconomic constraints or restricted opportunities for higher education (Momoh, Mbube and Silas, 2024). The 10.6% lacking

formal education highlights the need for alternative information channels, such as extension services (Almeida and Morais, 2024).

The mean household size of potato farmers in the study area was 6 persons, indicating a household size slightly above average. Potato farmers with slightly above-average households may have additional labour available for farming activities, potentially enhancing adoption efforts, but may also face slightly increased pressure on resources, potentially diverting resources, limiting investment in advanced practices. This finding is consistent with a study by Bryan et al. (2013), which found that households with slightly above-average sizes in rural Africa had increased labour availability for farming, but also faced higher resource demands, affecting their ability to adapt to climate change.

The mean years of farming experience (7 years) among respondents indicates a seasoned group of individuals possessing extensive knowledge and skills in agricultural practices. This experience level suggests that farmers have likely encountered various challenges, adapting their methods over time to enhance yield and sustainability (Kayanika, Kanzoni and Mwangi, 2016).

The study highlights a significant disparity in formal training among potato farmers, with only 20% having received formal education in potato farming, while 80% rely on informal knowledge. This insufficient training in agricultural practices may impede the adoption of effective soil health management strategies and best practices, particularly in managing blackleg disease. These findings align with Ayanwale, Adeyemo and Oyeade, (2017), who similarly observed that limited formal education and reliance on informal knowledge

hinder the adoption of improved agricultural practices among farmers.

The finding reveals a mean farm size of 6 hectares, which indicates the vast majority of farmers operate on a relatively small scale, which may limit their ability to invest in modern technologies and best practices (Kayanula and Wale, 2017). Small farm sizes often correlate with limited access to resources such as credit, markets, and extension services, which may lead to heavy reliance on manual labour, impacting productivity and efficiency.

The study's findings indicate that the average farm-based income was ₦ 121,778, significantly lower than Nigeria's national poverty line of ₦ 137,430, according to the NBS (2020). This low income may have restricted farmers' financial flexibility for agricultural development, hindering productivity growth and making them vulnerable to economic shocks, climate change, and market fluctuations. Only 5% of potato farmers access credit, highlighting a significant obstacle to agricultural growth. This is consistent with the Central Bank of Nigeria CBN (2020) report that just 12% of community-based farmers in Nigeria can obtain credit, limiting their investment in productivity-enhancing practices.

Potato farmers' main information sources for managing soil health and blackleg disease include formal and informal options, print media, and Key informants. Results show a preference for agricultural NGOs as the top formal source ($\bar{x} = 2.93$), while government agencies, agricultural universities, and extension agents are rated lower (mean scores of 1.77, 2.09, and 2.09, respectively). This indicates a

trust in NGOs for their relevant and accessible approaches, particularly due to their practical training methods. Additionally, the effectiveness of government outreach appears lacking, as farmers find these sources less responsive to their needs, highlighting a demand for applicable, research-backed information in their specific context. Klerkx et al. (2015) similarly observed that farmers value NGOs for their context-specific advice and practical support.

The findings indicate a low-rating for mass media (Radio and Television $\bar{x} = 1.96$, Newspapers and Magazines $\bar{x} = 1.99$, and Online Forums $\bar{x} = 1.31$), and print materials (booklets, pamphlets, brochures, and posters), with a mean score of 1.91. In contrast, informal sources, such as fellow farmers ($\bar{x} = 3.41$) and community leaders ($\bar{x} = 3.38$), were rated more useful than traditional media. This indicates a preference for community knowledge sharing in agriculture, as farmers find advice from peers and local leaders more relatable and applicable to their needs.

Key informants (Agricultural Experts, Soil Scientists, Plant Pathologists, and Agronomists) rated their usefulness high, with a mean score of 2.93, while other sources like workshops, seminars, and conferences scored even higher at 3.4. This discrepancy highlights a significant divergence in perceptions regarding the efficacy of different knowledge dissemination methods within the agricultural community. The low rating for print suggests it may not effectively engage the audience, whereas higher scores for expert input and interactive methods indicate a preference for dynamic learning. Ogundari and Ojo (2020) also noted that farmers favoured expert assessments and interactive platforms over print materials.

Table 1: Distribution of Respondents according to Socioeconomic Characteristics

	Variable	Frequency	Percentage	Mean ($\bar{x}$)
Sex	Male	61	38.1	
	Female	99	61.9	
	Total	160	100	
Age(years)	18-38 Years	87	54.4	37 years
	39-58 Years	59	36.9	
	59 and above	14	8.8	
	Total	160	100	
Marital Status	Single	43	26.9	
	Married	84	52.5	
	Separated (Divorced)	33	20.6	
	Widow/Widower			
	Total	160	100	
Educational Level	Primary	77	48.1	
	Secondary	48	30	
	Tertiary	18	11.3	
	No normal education	17	10.6	
	Total	160	100.0	
Household size	1-5 persons	76	47.5	6 persons
	6-10 persons	75	46.9	
	11 persons and above	9	5.6	
	Total	160	100.0	
Farming experience(yrs)	1-5 years	55		7 years
	6-10 years	77		
	11-15 and above	28		
	Total	160	100.0	
Formal Training in Potato Farming	Yes	128	80	
	No	32	20	
	Total	160		
Farm size (acres)	1-5 ha	81	50.6	6 hectares
	6-10 ha	40	25	
	11ha and above	19	11.9	
	Total	160	100.0	
Annual income (₦)	₦50,000 - 100,000	45	32.1	₦121,778
	₦101,000-150,000	37	26.4	
	₦151,000-200,000	32	22.9	
	₦201,000 and above	26	18.6	
	Total	160	100.0	
Access to Credit Facilities for Farming Purposes	a) Yes	247	95	
	b) No	13	5	
	Total	160	100.0	

Field Survey, 2024

Mean score ≥ 2.50 = Agreed

Table 2: Main Information Sources Utilized by Potato Farmers for managing soil health strategies against blackleg disease

Agreement Levels with Information Sources	Strongly Agree (4)	Agree (3)	Strongly Disagree (2)	Disagree (1)	Mean Score
Formal Sources	F (%)	F (%)	F (%)	F (%)	($\bar{x}$)
Agricultural Extension Agents	63(39.4)	45(28.1)	30(18.75)	22(13.75)	2.93
Research Institutions (International Potato Centre, National Agricultural Research Institutes)	19(11.9)	21(13.1)	80(50)	40(25)	2.12
Government Agencies (Ministry of Agriculture, Agricultural Departments)	12(7.5)	20 (12.5)	47(29.38)	81(50.63)	1.77
Universities and Colleges of Agriculture	11(6.9)	10(6.3)	122(76.25)	17(10.63)	2.09
Non-Governmental Organizations (NGOs) focused on agriculture	19(11.9)	21(13.1)	80(50)	40(25)	2.09
Informal Sources					
Fellow Farmers/Family Members	112(70)		10(6.25)	18(11.25)	3.41
Community Leaders / Local Farming Groups	101(63.1)		21(13.13)	10(6.25)	3.38
Mass Media					
Radio and Television	19(11.9)	20(12.5)	63(39.38)	61(38.13)	1.96
Newspapers and Magazines	-	28(17.5)	152(95)	5(3.13)	1.99
Online Forums (social media, online discussion groups)	3(1.9)	17(10.6)	3(1.9)	135(84.38)	1.31
Print Materials					
Booklets, Pamphlets Brochures and Posters	25(15.6)	3(1.9)	89(55.63)	88(55)	1.91
Key Informants					17
Agricultural Experts, Soil Scientists, Plant Pathologists, and Agronomists	63(39)	3(1.9)	30(18.75)	22(13.75)	2.93
Other Sources					
Field Days and Farmer Field Schools	3(1.9)	19(11.9)	17(10.6)	3(1.9)	2.23
Workshops, Seminars and Conferences	88(55)	18(11.3)	10(6.25)	7(4.38)	3.4

Sources: Field Survey, 2024.

Mean score ≥ 2.50 = Agreed

Table 3: Common Soil Health Management Strategies used by Potato Farmers

Soil Health Management Strategies used	Strongly Agreed (4)	Agreed (3)	Disagreed (2)	Strongly Disagreed (1)	Mean Score
	F (%)	F (%)	F (%)	F (%)	($\bar{x}$)
Crop rotation and diversity	112(70)	20(12.5)	10(6.25)	18 (11.25)	3.4
Organic amendments (e.g., compost)	19(11.89)	21(13.13)	31(19.38)	81(50.63)	2.2
Integrated Pest Management (IPM) practices	8(5)	12(7.5)	17(10.6)	123(76.9)	1.41
Soil testing for nutrient deficiencies	0	11(6.9)	27(16.9)	122(76.3)	1.31
Conservation tillage	19(11.9)	21(13.1)	80(50)	40(25)	2.12
Cover cropping	101(63.1)	38(23.8)	11(6.9)	10(6.3)	3.44
Biological control methods (e.g., beneficial microorganisms)	3(1.9)	19(11.9)	3(1.9)	135(84.4)	1.31
Chemical control methods (e.g., fungicides)	10(6.25)	21(13.1)	101(63.1)	28(17.5)	2.08
Organic mulching	81(50.6)	47(29.4)	20(12.5)	12(7.5)	3.23

Sources: Field Survey, 2024

Table 3 presents soil health management strategies favoured by potato farmers in the study area. The results show the most crop rotation and diversity, cover cropping, and organic mulching were widely adopted, with mean scores of 3.4, 3.44, and 3.23, respectively. In contrast, practices like organic amendments (e.g., compost), holistic pest control strategies, soil nutrient testing, conservation tillage, biological control, and chemical methods, which scored below 2.5, were less commonly utilized. These findings reflect potato farmers' preference for natural and holistic approaches to enhancing soil health. As noted by Lal (2015), crop rotation and cover cropping enhance soil fertility and reduce erosion, explaining their high adoption rates. Farmers' continued recognition of sustainable agriculture's advantages, including enhanced soil health, pest management, and climate resilience, highlights their adherence to environmentally sustainable principles. Cover cropping, with a mean score of 3.44, indicates an increasing recognition of its benefits in preventing soil erosion, suppressing weeds, and enhancing nutrient cycling. This aligns with Snapp et al.'s (2010) assertion that it improves soil organic matter and reduces erosion.

Conversely, the lower adoption rates for organic amendments and soil nutrient testing suggest a knowledge deficit or accessibility barrier. Research emphasizes the crucial role of information access in sustainable agriculture adoption (Ajewole, 2019). Moreover, the lower scores for integrated pest management and biological and chemical control methods reflect reduced reliance on regulated approaches, likely driven by environmental concerns or economic limitations. Maredda et al. (2017) noted that smallholder farmers often favour IPM practices that minimize chemical use and promote sustainability. Overall, while there is a

strong inclination towards sustainable practices like crop rotation, there is also a need for education and support to enhance the adoption of additional soil health management strategies, boosting productivity and sustainability in potato farming.

CONCLUSION

This study highlights the socioeconomic characteristics, main sources of information and soil health management strategies of potato farmers in Jos South Local Government Area, Plateau State, Nigeria. The findings indicate farmers are predominantly female, young, and married, with a basic education level. Agricultural NGOs are the top formal source of information, while Key informants and workshops are also highly valued. Crop rotation, cover cropping, and organic mulching are widely adopted, reflecting a preference for natural and holistic approaches. The study underscores the need for education and support to enhance the adoption of additional soil health management strategies, boosting productivity and sustainability in potato farming. The low adoption rates of organic amendments, integrated pest management, and soil nutrient testing suggest limited knowledge or access to these practices. Addressing these gaps through targeted extension services and training programmes can improve soil health and reduce environmental degradation. Notably, the study reveals a preference for community-based knowledge sharing and dynamic learning approaches in agricultural extension services. Farmers rely heavily on fellow farmers, community leaders, and Key informants, such as agricultural experts and soil scientists, for information on managing soil health and blackleg disease. Workshops, seminars, and conferences are also highly valued, indicating a desire for interactive and expert-driven learning.

RECOMMENDATIONS:

1. Farmers should adopt high-yield crops, enhance farming practices, build direct buyer relationships, engage in farmers' markets, cooperatives, and online platforms, create value-added products, negotiate better prices through collective bargaining, and maintain accurate records and budgets to boost their income.
2. Government agencies, agricultural education institutions, NGOs focused on sustainable agriculture, and farmer organizations/cooperatives should collaborate to enhance access to education and training on sustainable agricultural practices, emphasizing soil health management.
3. To promote alternative information channels, Government agencies, NGOs, farmer organizations, agricultural institutions, private companies, and community organizations should collaborate to increase awareness of sustainable agricultural practices, improve knowledge sharing, and enhance agricultural productivity and sustainability.
4. Farmer organizations and cooperatives should promote sustainable practices to combat blackleg disease by encouraging organic soil amendments, conservation tillage, and biological pest control. These actions will enhance soil health, boost biodiversity, increase crop yields, and mitigate blackleg impacts.
5. Government agencies, agricultural institutions, farmer organizations, and community groups should collaborate to foster farmer-to-farmer networks and engage community leaders in agricultural extension. This will enhance knowledge sharing, increase participation, promote

sustainable practices, improve yields, and strengthen resilience.

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SOIL SCIENCE AND CROP PRODUCTION

EFFECT OF TILLAGE AND SOWING DATE ON YIELD OF PEARL MILLET [*Pennisetum glaucum* (L.) R.Br.] VARIETIES IN SUDANO-SAHELIAN ECOLOGICAL ZONE OF NIGERIA

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ABSTRACT

Field trials were carried out at Gambawa village, Gumel Local Government Area, Jigawa State of the Sudano-Sahelian ecological zone (lat. 12°60'N; long. 9°43'E) during the 2018 and 2019 rainy seasons to compare and identify appropriate tillage method for high millet yield and to compare the effects of different sowing dates on millet varieties. The experiment consisted of six tillage methods, three sowing dates and two millet varieties. The experiment was laid out in a split-split-plot arrangement in a Randomized Complete Block Design (RCBD) with four replications. Tillage methods [T₁: Zero Tillage (ZT) (Paraquat at 1.0 kg a.i.ha⁻¹ followed by Primextra at 1.0 kg a.i.ha⁻¹ pre-emergence followed by 2,4-D at 1.5 kg a.i.ha⁻¹ post emergence), T₂: Minimum Tillage (MT) (Light hoe weeding followed by atrazine at 1.0 kg a.i.ha⁻¹ pre-emergence followed by 2,4-D at 1.5 kg a.i.ha⁻¹ post emergence), T₃: MT (Paraquat at 1.0 kg a.i.ha⁻¹ followed by Primextra at 1.0 kg a.i.ha⁻¹ pre-emergence followed by light hoe weeding at 4 WAS), T₄: MT (Ridging followed by supplementary hoe weeding), T₅: Conventional Tillage (CT) (Single harrowing followed by ridging followed by Primextra at 1.0 kg a.i.ha⁻¹ pre-emergence followed by supplementary hoe weeding), T₆: CT (Double harrowing followed by ridging followed by Primextra at 1.0 kg a.i.ha⁻¹ pre-emergence followed by supplementary hoe weeding)] were assigned to the main plot. Sowing Dates [Early June (1st - 10th), Mid June (11th - 20th) and Late June (21st - 30th)] were assigned to the sub-plot. Millet varieties (LCICMV-1 and LCICMV-3) occupied the sub-sub plot. The result of the trials indicated significant effect ($p \leq 0.05$) of tillage methods and sowing dates on yield characters and yield in both years. Varieties also differed significantly in yield characters and yield in both years. T₄ had significant effect and scored highest on more yield characters. LCICMV-3 sown within early June significantly recorded highest yield variables. It could be concluded that farmers in the study areas should sow LCICMV-3 early in June after T₄.

Keywords: Tillage, sowing dates, varieties, pre-emergence herbicides, number of panicles, 1000 seed weight, grain yield, Stover yield, harvest index, threshing percentage, Genstat

INTRODUCTION

Cereals are universally important food crops, among which Millet is one of the most important in the world (Siddig *et al.*, 2013). Pearl

millet [*Pennisetum glaucum* (L.) R. Br.] belongs to the family Poaceae. It is believed to have originated in West Africa (Van Oosterm *et al.*, 2002). It is planted as grain and fodder crop across a wide range of environments around the

world (Raemaeker, 2001). Pearl millet is an important drought-hardy coarse grain crop that provides staple food for the poor in a short period. It flourishes satisfactorily and can be cultivated under rainfall as low as 200 to 250 mm (Bidinger and Hash, 2003), which makes it one of the most reliable cereals in the rainfed regions of arid and semi-arid tropics although average yields are usually very low. Generally, soils are tilled to provide a more suitable structure for plant growth and development. At any level of field management, different pearl millet varieties have different performance level. Lal (1989) asserted that emphasis in crop production should be placed on appropriate and efficient tillage method, for higher productivity. Sowing is an important factor influencing growth and yield of crops (Nafziger, 1994). The sowing date plays vital role in improving its growth and increasing the yield (Farrell *et al.*, 2003). Timely sowing of millet ensures sufficient time for root development and vegetative growth for optimum harvesting (Amodu *et al.*, 2005). Timely sowing ensures sufficient time for optimum harvesting of available soil nutrients and radiant energy (Soler *et al.*, 2007). In sahelian locations, manipulation of sowing dates in millet cultivation offers flexibility owing to the narrowness of the optimum time of sowing as conditioned by erratic onset of the rains and shorter raining season. Millet is grown in over 40 countries, predominantly in Africa and Asia, as a staple food grain and source of feed, fodder, fuel and construction material in the hottest, driest, semi-arid and arid regions where rainfed agriculture is practiced. In Africa, its uses are diverse and range from baby food to bread. In Nigeria, the grain is used primarily for human consumption. It is processed into “tuwo” “kunu” and “akamu” (Remison, 2005). The culm is used for fencing, thatching, roofing and fodder for livestock (Uzoma *et al.*, 2010). Millet grains may be cooked as rice, or may be ground into flour to

make cake and bread. The grains are also used to produce malt, and in Nigeria the malted seed is an important source of beer (Remison, 2005). It is proving to be superior feed for poultry, pigs, cattle, fish and other livestock. As a food source, it is non-glutinous and non-acid forming so it is smoothing and easy to digest (Oelke *et al.*, 2011).

There has been no sustainable rise in productivity of rainfed pearl millet mainly because of soil-moisture deficiency, usually at critical stages of growth. There is a need to focus our research efforts on how the productivity potential can be best achieved to overcome the effect of moisture stress, which is mainly responsible for reduction in the productivity of rainfed pearl millet. The average national grain yield of millet stood at 0.85 t ha⁻¹ in 2016 as against 1.3 t ha⁻¹ in 2012 (FAOSTAT, 2017; 2018). Nema *et al.* (2008) reported beneficial effect of various tillage practices on the moisture conservation and crop yields under dryland condition. Among several agronomic advantages that tillage operations offer to a crop, moisture conservation is of utmost importance.

The soils of the pearl millet growing regions being mostly light in texture embody low moisture holding capacity. Efforts have been made to augment the soil-moisture retentivity by adopting various tillage practices (Sinha, 2015). Although for most situations conventional tillage methods have been the major tillage operations for crop production, they are now expensive operations in terms of work rate and fuel consumption (Ecclestone, 2004). The costs, as well as the environmental concerns have led farmers and researchers to adopt alternative tillage methods (Ecclestone, 2001). For these reasons, there is a considerable attention and emphasis on the shift to the conservation tillage methods, i.e., reduced tillage, minimum tillage and no-tillage methods.

Time of sowing is an important agronomic factor which causes substantial increase or decrease in yield. To date, the challenge for cereal growers is to find the most suitable date between sowing too early and sowing too late (Nielson *et al.*, 2002). In Niger Republic, the length of the growing period is mainly a function of the date of the first rains (Sivakumar 1988) and varies widely from year to year. However, due to the erratic rainfall pattern in the Sahelian regions, the first rain suitable for planting is often followed by several dry days that cause high seedling mortality and require the farmers to replant.

The optimum planting date range for pearl millet is only 10–14 days, which is a major constraint to using soil tillage with animal traction (Grema and Odo, 1998). The fact that pearl millet has a large early season root-to-shoot ratio, tolerates high soil temperatures (Bidinger and Hash, 2004), and tolerates sand blasting (Buerkert and Stern, 1995; Buerkert *et al.*, 2000; Michels *et al.*, 1995a,b) makes early planting a viable option. A significant reduction in grain yield has been shown to occur with delayed sowing for a wide range of climatic conditions (Dahlke *et al.*, 1993). With the fluctuation of rainfall pattern in the savannah agro ecological zone of Nigeria caused by climate change, the traditional or long period when rain is believed to have established have been fluctuating and the period when rainfall is received is becoming shortened and cannot be predicted.

In view of the above, this study was designed to evaluate the yield of millet varieties to different tillage practices and sowing date in semi-arid area of Nigeria.

MATERIALS AND METHODS

Field trials were conducted during 2018 and 2019 rainy seasons at a production farm (farmers field) at Gambawa village, Gumel Local

Government Area, Jigawa State located in Sudano-sahelian ecological zone of Nigeria (latitude 12° 60' N; longitude 9° 43' E).

The treatments consisted of six tillage methods:

T-1: Zero tillage (Paraquat at 1.0 kg a.i.ha⁻¹ followed by Primextra @ 1.0 kg a.i.ha⁻¹ pre-emergence Followed by 2, 4-D @ 1.5 kg a.i ha⁻¹ post emergence)

T-2: Minimum tillage (Light hoe weeding followed by atrazine at 1.0 kg a.i.ha⁻¹ pre-emergence followe by 2,4-D @ 1.5 kg a.i ha⁻¹ post emergence)

T-3: Minimum tillage (Paraquat at 1.0 kg a.i.ha⁻¹ followed by Primextra @ 1.0 kg a.i.ha⁻¹ pre-emergence followed by light hoe weeding post emergence.)

T-4: Minimum tillage (Ridging followed by supplementary hoe weedings),

T-5: Conventional tillage (Single harrowing followed by ridging followed by Primextra @ 1.0 kg a.i.ha⁻¹ pre-emergence followed by supplementary hoe weeding),

T-6: Conventional tillage (Double harrowing followed by ridging followed by Primextra @ 1.0 kg a.i.ha⁻¹ pre-emergence followed by supplementary hoe weeding,

Three Sowing Dates: Early June (1st – 10th): 6th June 2018, 2nd June 2019. Mid June (11th – 20th): 16th June 2018, 12th June 2019. Late June (21st – 30th): 26th June 2018, 22nd June 2019 and two varieties of millet: LCICMV-1 and LCICMV-3. All sowings were at intervals of 10 days from the beginning of the rainy season in the two years of study. The experiment was laid out in a Split-Split Plot Design (SSPD) with four replications. Tillage methods were assigned to the main plots, while the sowing dates and millet varieties were allocated to the sub and the sub-sub plots, respectively Sowing was manually done at inter-row and intra-row spacings of 75cm x 25cm. recommended fertilizer rates of 60 kg N, 30 kg P₂O₅ and 30 kg of K₂O were applied. Weeding was done as per treatment to eliminate weed competition in the respective

plots. Two pre-emergence herbicides were used; Atrazine and Primextra applied by the use of garden plastic hand operated manual pressure pump sprayer. The panicles were harvested at physiological maturity stage from the net plot by the use of sickle packed and labeled as per plots for easy identification and then sun dried to constant weight. After drying, manual threshing was done to separate the grains from the chaff.

Data on the weather conditions at were obtained from IITA Meteorological station at Wasai village. The meteorological data collected included rainfall, temperature and relative humidity.

Prior to sowing, soil samples were taken by random sampling from the experimental site at 0-15 cm and 15-30 cm depth, air dried at room temperature, ground, sieved using 2 mm sieve and then subjected to routine analysis using standard laboratory analytical procedure to determine physical and chemical properties (Oladoye, 2015)

Crop yield data collected are: Number of panicles, 1000-seed weight (g), grain yield (kg ha⁻¹), stover yield (kg ha⁻¹), harvest index (%) and threshing percentage (%). All data collected were statistically analysed using GENSTAT 17th edition. Significant treatment means were compared using Students Newman Keuls (SNK).

RESULTS AND DISCUSSION

The results of the physical and chemical properties of the soils at the experimental site in 2018 and 2019 rainy seasons are presented in Table 1. The results of the soil analysis showed that pearl millet is tolerant to acidic soils for high grain and stover yields. Dewey *et al.* (2012) stated that pearl millet appeared to be more tolerant to sandy and acidic soils than other summer grain crops in the southeastern United States. Due to high N levels, the soil at Gambawa will support vegetative growth of

crops as well as fruiting and flowering. The P level was low in the two years. The soil potassium content was low in 2018 and moderate in 2019. Egharevba *et al.* (1984) showed that millet does not give good response to application of potassium but may improve the vigour of young plants (Pieri, 1986).

The micronutrients are however required in trace amount. The soil was classified as sandy loam. This is in conformity with the report of Arnon (1972) who stated that pearl millet is adapted to poor sandy soil on which it produces reasonable yield relative to most other arable crops that would fail to produce good yields. The meteorological data of the experimental site in 2018 and 2019 rainy seasons are presented in Table 2. Total rainfall figures of 566.24 mm and 574.16 mm were recorded at the site in 2018 and 2019 rainy seasons respectively. The peak rainfall of 170.55 mm and 236.12 mm were received in August. It is evident from the study that the rainfall figures contributed to the yield of the crop in the two seasons.

Number of panicles ha⁻¹

Table 3 shows the effect of tillage and sowing date on number of panicles ha⁻¹ of millet varieties during 2018 and 2019 rainy seasons at Gambawa. The results in 2018 showed that minimum tillage (T₄) recorded the highest number of panicles ha⁻¹ (65,761). This high panicle number was produced as a result of high numbers of effective tillers. Verma *et al.* (2017) observed a significant increase in yield and yield attributes viz., effective tillers plant⁻¹, grain yield, straw yield and biological yield under conventional / minimum tillage as compared to zero tillage.

Millet sown early recorded the highest number of panicles ha⁻¹. LCICMV-3 recorded highest number of panicles ha⁻¹ in 2019 due to its high tillering ability.

Table 1. Physical and Chemical Properties of Soils of the Experimental Site (Gambawa) in 2018 and 2019 Rainy Seasons at 0-15 and 15-30 cm Soil Depths.

Properties of soil	2018		2019	
	0 – 15	15 – 30	0 – 15	15 – 30
Physical Properties (g kg ⁻¹)				
Sand	598.1	642.0	778.4	772.9
Silt	213.5	194.3	104.8	107.1
Clay	188.4	163.7	116.8	119.9
Textural class	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Chemical Properties				
pH in water (1:1)	6.41	7.35	5.82	6.18
Total N (g kg ⁻¹)	0.6	0.4	0.8	0.6
Organic carbon (g kg ⁻¹)	4.5	2.3	4.6	3.6
Total P (mg kg ⁻¹)	11.14	2.39	19.83	8.57
Cu (mg kg ⁻¹)	17.72	1.99	51.58	36.08
Mn (mg kg ⁻¹)	11.74	3.72	0.92	0.29
Zn (mg kg ⁻¹)	1.86	7.48	21.17	29.18
Fe (mg kg ⁻¹)	180.4	128.3	45.65	63.45
Exchangeable bases				
Ca ++ (cmol kg ⁻¹)	1.394	1.141	0.42	0.81
Mg + (cmol kg ⁻¹)	0.34	0.51	0.52	0.41
K + (cmol kg ⁻¹)	0.076	0.074	0.33	0.17
Na + (cmol kg ⁻¹)	0.015	0.013	0.09	0.22
C.E.C (cmol kg ⁻¹)	1.820	1.736	1.37	1.61

Analysed at the Centre for Dry-land Agriculture (CDA), Bayero University, Kano-Nigeria.

Table 2. Meteorological Data of the Experimental Site at Gambawa in the 2018 and 2019 Rainy Seasons

Months	2018				2019			
	Rainfall	Mean Humidity	Temperature		Rainfall	Mean Humidity	Temperature	
	(mm)	(%)	Min. (°C)	Max. (°C)	Mm	(%)	Min. (°C)	Max. (°C)
March	0.000	9.62	20.17	38.75	0.000	13.78	21.97	38.32
April	0.000	15.58	24.41	41.06	0.000	13.52	24.60	41.20
May	20.21	34.04	27.13	40.43	36.27	36.00	27.36	40.00
June	74.09	42.42	26.01	38.05	64.25	44.93	26.18	37.56
July	161.96	60.26	23.76	33.82	140.54	57.53	24.37	34.74
August	170.55	76.79	22.24	30.41	236.12	77.42	22.26	30.07
September	129.91	75.46	22.37	31.54	58.84	72.90	22.64	32.13
October	9.52	53.24	21.76	34.84	32.45	64.54	22.15	32.78
November	0.00	26.42	16.00	34.41	5.62	34.34	18.02	34.95
Total	566.24				574.15			

Source: International Crops Research Institute for Semi-Arid Tropics (ICRISAT) Weather Station, Gambawa, Jigawa State.

1000-Seed weight (g)

Table 3 also shows the effect of tillage, sowing date and millet variety on 1000-seed weight (g) in the 2018 and 2019 rainy seasons. Findings from the study showed that minimum tillage (T_3) produced the highest one thousand seed weight (9.46 g) in 2018. The high seed weight recorded may be due to favourable soil and ambient plant environment so obtained under the influence of tillage thereby increased the photosynthesis process and accumulation of photosynthates in grains.

The heaviest seeds were recorded in early June in the two years of study. This is in line with the findings of Killi and Altunbay (2005) who observed that seed weight was significantly affected by the sowing date. Results in 2018

Grain yield (kg ha^{-1})

Table 4 shows the effect of tillage and sowing date on grain yield (kg ha^{-1}) of millet varieties at Gambawa during the 2018 and 2019 rainy seasons. Minimum tillage (T_4) produced the highest grain yield of 2,346 kg ha^{-1} in 2018, while minimum tillage (T_3) recorded the highest grain yield of 1,651.1 kg ha^{-1} in 2019, respectively. Verma *et al.* (2017) observed a significant increase in grain yield under conventional tillage + ridging as compared to zero tillage.

This increase in yield could be attributed to improvement in growth attributes under the influence of tillage treatment through increased availability of soil moisture and nutrients, which favourably influenced physiological processes of the plants leading to storage and buildup of food material. Minimum tillage (T_2) recorded the lowest grain yield statistically similar to zero tillage. The low yields observed could be ascribed to the compacted soil condition and effects caused by weeds which were not

showed that millets sown early recorded the heaviest seeds of 9.48g, while in 2019, millets sown early on 2nd and 8th June 2019 recorded the highest thousand seed weight of 11.4g respectively.

However, Amanullah *et al.* (2015) reported that millet crop planted on 20th June had the highest thousand grain weight (12.3 g) in Peshawar, Pakistan while Shinggu and Gani (2012) reported that finger millet seeded on 9th July had the highest 1000-seed weight of 2.91g in northern Nigeria. Leila (2008) observed highest thousand grain weights (13.9 g) when pearl millet was sown on 3rd May.

Findings from the study also indicated that LCICMV-3 resulted in greater 1000-seed weight compared to LCICMV-1. This may be due to varietal differences in grain size.

eliminated by the post emergence herbicides applied as shown by high weed count. Significant improvement in grain yield under T_4 treatment seems to be an outcome of increased dry matter accumulation right from early stages of crop growth till harvest due to favourable soil and plant environment so obtained under the influence of tillage practices. Poor crop growth and yield so obtained under zero tillage practice further explains these contentions. It can also be safely assumed that increased availability of nutrients to the crop in the presence of ample moisture might have helped in the increased synthesis of growth substances and naturally occurring phyto-hormones probably the auxin, which ultimately helped in increased effective tillers plant⁻¹. Increased moisture availability due to the impact of ridging coincided with flower primordia initiation stage, which might have helped in increased flowering, fertilization and grain formation resulting in higher yields. This finding corroborates results of Usman *et al.* (2014) who reported similar effects of ridging in pearl millet.

Table 3. Effect of Tillage and Sowing Date on Number of Panicles ha⁻¹ and 1000-Seed Weight (g) of Millet Varieties during 2018 and 2019 Rainy Seasons at Gambawa, Nigeria

Treatments	Number of Panicles ha ⁻¹		1000-Seed Weight (g)	
	2018	2019	2018	2019
<u>Tillage (T)</u>				
T ₁	30326b	12722	8.33b	7.38
T ₂	31103b	19999	8.62ab	10.25
T ₃	34716b	19111	9.46a	8.13
T ₄	65761a	21722	8.92ab	8.58
T ₅	42045b	21666	9.42a	8.67
T ₆	48155b	24833	9.04ab	10.88
SE±	4807.1	2516.9	0.235	1.207
P. value	<.001	0.068	0.026	0.355
<u>Sowing Date (SD)</u>				
Early June	56791a	27055a	9.48a	11.38a
Mid June	30770c	20861b	8.96b	8.58b
Late June	38491b	12111c	8.46b	6.98b
SE±	2540.6	1950.3	0.178	0.677
P. value	<.001	<.001	0.001	<.001
<u>Variety (V)</u>				
LCICMV-1	40861	11481b	8.74b	9.42
LCICMV-3	43174	28536a	9.19a	8.54
SE±	2141.1	1275.9	0.142	0.667
P. value	0.448	<.001	0.027	0.357

Means within same treatment column followed by different letters differ significantly using Student - Newman Keuls Test (SNK). T₁ (Zero tillage); T₂ (pre-plant light hoe weeding); T₃ (post emergence light hoe weeding); T₄ (Ridging); T₅ (Single harrowing + ridging); T₆ (Double harrowing + ridging); Early June (1st - 10th); Mid June (11th - 20th); Late June (21st - 30th).

Millet planted in early June in 2019 recorded the highest grain yield. This is similar to Anderson (1994) who reported that millet sown on the 8th of June was best date for grain yield while Uzoma et al. (2010) reported that 17th June was the best planting date with a grain yield of 3371 kg ha⁻¹ in northern Nigeria. The lowest grain yield was however recorded by millets sown in late June. Kamara et al. (2003) stated planting too late might reduce valuable growing time and crop yield.

The result of this study showed that LCICMV-3 recorded a higher grain yield than LCICMV-1 in the two years of study. In a similar trial, Verma et al. (2017) observed that the difference in grain yield so obtained might be due to difference in their genetic potentials, which led to varied assimilation of photosynthates and its

translocation to the sink for grain yield formation.

Stover yield (kg ha⁻¹)

The stover yield (kg ha⁻¹) of millet varieties in the 2018 and 2019 rainy seasons at Wasai and Gambawa are presented in Table 4. Minimum tillage (T₄) recorded the highest stover yield of 3113 kg ha⁻¹ in 2018 and Conventional tillage (T₆) recorded the highest in 2019 which was statistically similar to T₂ – T₅. The higher stover yield in T₄ and T₆ could be attributed to less weed competition due to inverted top soil and availability of nutrient and moisture that facilitated nutrient absorption for plant growth and development. Zero tillage (T₁) recorded the lowest stover yield in the two locations due partly to weed competition and less percolation

and absorption of water and nutrient that contributed to retarded growth and consequently affected the yield. Millet seeded in mid-June in 2018 and late June in 2019 produced the highest stover yield (2 914 kg ha⁻¹) and (2,124 kg ha⁻¹), respectively. Parihar *et al.* (2009) reported highest dry stover yield of 7.54 t ha⁻¹ in India while Abd El-Latief (2011) reported highest dry matter yields of 3.99 t ha⁻¹, 4.49 t ha⁻¹ and 2.77 t ha⁻¹ for first, second and third forage cuts, respectively when millet was sown on 15th May in Egypt. However, Obeng *et al.* (2012) reported a dry matter yield of (3,240 kg ha⁻¹) when millet was sown on 25th June in the United States of America. LCICMV-3 also outperformed LCICMV-1 in stover yield. Genetic variability accounted largely for the differences in yield as reported by Anonymous (1984).

Harvest index (%)

Table 5 shows the effect of tillage, sowing date and millet variety on harvest index (%) in the

2019 rainy seasons at Gambawa. Minimum tillage (T₃) and (T₄) recorded the highest harvest index of 22.9 % and 12.2 % in 2018 and 2019 wet season at the location. In a similar trial by Sidar (2017) harvest index was significantly highest in minimum tillage. Millet sown early June in the two years recorded the highest harvest index of 34.5% in 2018 while millet planted in late June recorded the lowest (12.4%) in 2019. Delay in sowing does not only affect yield, but also affects the yield components and other aspects of growth and development. It is generally associated with reduced kernel weight, reduced number of ear per plant, grain number per plant and LAI (Elemo, 1991; Cirilo and Andrade, 1996; Valencia, 1999; Maryam *et al.*, 2013). LCICMV-3 also recorded significantly higher harvest index compared to LCICMV-1 at Gambawa in 2019. Verma *et al.* (2017) in a similar trial recorded a highest harvest index of 30% in cultivar MPMH-17.

Table 4. Effect of Tillage and Sowing Date on Grain yield (kg ha⁻¹) and Stover Yield (kg ha⁻¹) of Millet Varieties During 2018 and 2019 Rainy Seasons at Gambawa, Nigeria

Treatments	Grain yield (kg ha ⁻¹)		Stover Yield (kg ha ⁻¹)	
	2018	2019	2018	2019
<u>Tillage (T)</u>				
T ₁	1676c	1422.6b	1398c	816b
T ₂	1641c	1416.5b	1997bc	1619a
T ₃	1879b	1651.1a	2517ab	2063a
T ₄	2346a	1550.4a	3113a	1968a
T ₅	2076b	1583.5a	2742ab	2097a
T ₆	2044b	1607.4a	3062a	2228a
SE±	61.8	40.0	209.9	234.0
P. value	<.001	0.003	<.001	0.007
<u>Sowing Date (SD)</u>				
Early June	2282a	1803a	2682a	1544b
Mid June	1856b	1489.5b	2914a	1723ab
Late June	1692c	1336.8c	1819b	2128a
SE±	44.8	33.8	192.7	157.8
P. value	<.001	<.001	<.001	0.038
<u>Variety (V)</u>				
LCICMV-1	1924	1421b	2479	1459b
LCICMV-3	1964	1666a	2464	2138a
SE±	29.3	20.7	97.3	127.1
P. value	0.340	<.001	0.911	<.001

Means within same treatment column followed by different letters differ significantly using Student - Newman Keuls Test (SNK). T₁ (Zero tillage); T₂ (pre-plant light hoe weeding); T₃ (post emergence light hoe weeding); T₄ (Ridging); T₅ (Single harrowing + ridging); T₆ (Double harrowing + ridging); Early June (1st -10th); Mid June (11th - 20th); Late June (21st - 30th).

Table 6. Effect of Tillage and Sowing Date on Harvest Index (%) and Threshing Percentage (TH%) of Millet Varieties in the 2018 and 2019 Rainy Seasons at Gambawa, Nigeria

Treatments	Harvest Index (%)		Threshing Percentage (TH%)	
	2018	2019	2018	2019
Tillage (T)				
T ₁	24.2c	20.2ab	65.0b	48.2
T ₂	23.1c	16.2b	66.4b	42.5
T ₃	27.3bc	22.2a	73.0a	60.6
T ₄	32.9a	20.5ab	79.1a	55.2
T ₅	30.4ab	21.3ab	79.9a	55.1
T ₆	27.5bc	19.4ab	75.8a	54.6
SE±	1.43	1.22	1.97	4.01
P. value	0.002	0.049	<.001	0.075
Sowing Date (SD)				
Early June	34.5a	28.7a	83.10a	63.9a
Mid June	23.2b	18.7b	70.06b	52.3b
Late June	25.0b	12.4c	66.41b	41.8c
SE±	1.10	1.08	1.94	3.02
P. value	<.001	<.001	<.001	<.001
Variety (V)				
LCICMV-1	27.1	18.5b	72.4	54.0
LCICMV-3	28.0	21.4a	74.0	51.4
SE±	0.69	0.75	1.28	2.33
P. value	0.331	0.009	0.401	0.431

Means within same treatment column followed by different letters differ significantly using Student - Newman Keuls Test (SNK). T₁ (Zero tillage); T₂ (pre-plant light hoe weeding); T₃ (post emergence light hoe weeding); T₄ (Ridging); T₅ (Single harrowing + ridging); T₆ (Double harrowing + ridging); Early June (1st - 10th); Mid June (11th - 20th); Late June (21st - 30th).

Threshing percentage (TH %)

Table 5 also shows the effect of tillage and sowing date on threshing percentage (%) of pearl millet varieties in the 2019 rainy season at Gambawa. The highest threshing percentage of 79.9 % in 2018 observed in conventional tillage (T₅) though statistically similar to T₃, T₄ and T₆ was attributed to favourable climatic condition due to high rainfall and plant environment so obtained under the influence of tillage thereby increased the photosynthesis process and accumulation of photosynthates in grains. Minimum tillage T₃ in 2019 recorded the highest TH%.

Millet sown early between 1st - 10th June recorded the highest threshing percentage (83.1%) which is considered optimum while millets sown in mid and late June recorded the

lowest due to delay in sowing. This result is similar to the findings of Maryam *et al.* (2013) who reported that delay in sowing affects yield and yield components of maize.

CONCLUSION

The results of this study showed that minimum tillage (T₄) produced higher yield attributes for millet compared to other tillage methods. Similarly, millet variety sown in early June between 1st and 10th after the first heavy rains recorded significantly highest yield characters. Furthermore, LCICMV-3 outperformed LCICMV-1 on grain yield and other yield components. It could therefore be concluded that early sowing of LCICMV-3 in soil prepared by ridging followed by supplementary hoe weeding at 3 and 6 WAS produced higher grain yield.

Based on this trial, it is therefore recommended that millet variety LCICMV-3 should be sown early after the first heavy rainfall within the periods of 1st – 10th June in soil prepared by ridging followed by supplementary hoe weeding at 4 and 6 WAS for high grain and stover yields in sudano-sahelian ecological zone of Nigeria.

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EFFECTS OF *Striga gesnerioides* SEED DENSITY ON YIELD OF SOME COWPEA (*Vigna unguiculata* (L), walp) VARIETIES.

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ABSTRACT

Parasitic weed *Striga gesnerioides* (Willd.) is one of the major constraints of cowpea production. Host-plant resistance seems to be efficient and economical in controlling the pest. Experiment was carried out at International Institute for Tropical Agriculture (IITA), located at 120 03N latitude and 80 32E longitude, Kano, Nigeria. The aim of the study was to evaluate the effect of different levels of *Striga* infestation on yield of some varieties of cowpea. Eight cowpea varieties were selected for the study. The experiment was laid out in completely randomized design (CRD) replicated three times with four treatment regimens of *Striga* infestation. The levels of *Striga* seed density include 0.07g, 0.5g, 0.3g and 0.0g control. The results showed that IT08K-150-24, IT90K-39 and IT09K-297-13, IT99K-573-1-1 recorded higher plant height irrespective of level of *Striga* infestation, but IT93K-452-1, IT08K-150-24 and TVX 3236. Showed lower plant height at 0.7g of *Striga* infestation. The result for chlorophyll content (SPAD) indicates that at 42 days after *Striga* infestation, IT08K-150-24, IT90K-39 recorded higher chlorophyll SPAD value of 77.39. But TVX 3236 had lower chlorophyll SPAD value of 45.35. Higher number of days to 50% flowering was recorded in TVX 3236 across the treatment. IT99K-573-1-1. IT93K-452-1. recorded early days to 50% flowering across the treatment. IT93K-452-1 IT08K-150-24. and TVX 3236 recorded Higher number of *Striga* emergence followed by IT07K-292-10, IT07K-297-13, IT07K-318-33, IT07K-318-33 and IT89KD-391, IT07K-292-1. But IT08K-150-24. IT90K-39, IT09K-297-13 IT99K-573-1-1 and IT99K-573-1-1, IT93K-452-1 had few *Striga* emerged. The present study concludes that varieties IT99K-573-1-1, IT93K-452-1 and IT08K-150-24, IT90K-39 were resistance across the treatment while IT07K-292-10, IT07K-297-13, IT07K-318-33 IT07K-318-33 and IT89KD-391 IT07K-292-10 were tolerant to *Striga* at 0.1 and 0.3g of *Striga* infestation. IT93K-452-1, IT08K-150-24 and TVX 3236 were susceptible across the treatments. Therefore, it is recommended that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 should be adopted by famers in regions where there has been high infestation of *Striga gesnerioides* on cowpea.

Keywords: *Striga gesnerioides*, Seed Density. Yield and Cowpea Varieties

INTRODUCTION

Cowpea feeds millions of people in the developing world with an annual worldwide production estimated around 4.5 million metric

tons on 12 to 14 million ha (Diouf, 2011). Nigeria, Brazil, Niger and Burkina Faso are among the major producers and account for over 70 % of the world crop (FAO, 2008). Cowpea

production is constrained by many factors that are both biotic and abiotic (Hall *et al.*, 1997).

Parasitic weeds are serious problems in many agricultural systems in the tropics. *Striga* also known as "witchweed" is an angiospermic, hemi-parasite belonging to the family orobanchaceae (formerly scrophulariaceae). *Striga* parasitic weeds are considered to be one of the major biological constraints to food production in Sub-Saharan Africa, probably a more serious agricultural problem than insects, birds or plant diseases (Singh 2000).

In northern Nigeria, *Striga* may cause cowpea yield losses varying from few Kg ha⁻¹ to total crop failure (Obilana, 1987). According to Emechebe and Leleji (1988) this had also led to abandonment of *Striga* infested fields to cowpea production. This topical constrains explains the urgent need for studying and identifying tolerant/resistant varieties against the parasite. The identification of resistant/tolerant cowpea varieties is one of the research priorities for solving this problem.

The aim of this research is to determine the effect of *Striga gesnerioides* on the growth and yield of some cowpea varieties. Specific Objective was to assess the performance of the varieties of cowpea under the stress of *gestenerioides* at different seed density levels of *Striga gesnerioides*.

MATERIALS AND METHODS

The experiment was conducted in the screen house at the International Institute of Tropical Agriculture (IITA) substation located at 12° 03'N latitude and 8° 32'E longitude, Kano, Nigeria. The treatments consisted of four different weight of *Striga* seed (T_{1.0g}, T_{2.0.3g}, T_{3.0.05g} and T_{4.0.07g}) and eight varieties of cowpea (IT93K-452-1, IT90K-391, IT99K-573-1-1, IT07K-297-13, IT07K-318-33, IT07K-292-10, IT08K-150-24, TVX 3236). Factorially

combined to form 32 treatments which was laid out in complete randomize design (CRD) with three replication.

Ninety-six (96) Plastic pots with a height of 27 cm and diameters of 25 and 17.5 cm for the top and bottom, with 6 drainage holes at the bottom respectively and was filled with 8kg of sterilized soil. *Striga gestenerioides* seed of minjibir strain was weighted by using electric weighting balance in to individual (T_{2.0.3g}, T_{3.0.05g} and T_{4.0.07g}) each level was inoculated in to their respective prepared label pots arranged according to the experimental layout. After the inoculation the *Striga gesnerioides* seed were conditioned for 14 days before planting. (According to IITA *Striga* research method 1997). Three holes of 2-4 cm depth were made in each pot and one seed was sown into each hole making three seeds per pot. One week after planting, the plants were thinned to maintain two plant per pot. While watering was maintained as required throughout the experiment

Data collected were (Number of pods, Pod weights, Numbers of seed per pot, *Striga* density (DS). *Striga* shoots per pot (SSP), *Striga* height has been measured). The data collected were subjected to statistical analysis of variance using Genstat 3 edition and where there is significant difference; the means were separated using Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

Effect of Variety and *Striga gesnerioides* Doses on the Yield and Yield Component of Cowpea Plant.

The results on effect of variety and *Striga gesnerioides* doses on the yield and yield component of cowpea plant during 2019 and 2020 Trials (Table 1) showed that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 consistently

recorded higher pod number ranged from 14.42 pods – 15.42 in both years of cropping compared to other studied varieties of IT07K-292-10, IT07K-318-33, IT89KD-391, IT93K-452-1 and TVX 3236 with pod number ranged from 4.42 – 5.52 per cowpea plants. This shows that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 have competing strength against *Striga* does compared to other varieties in both years of cropping. This agrees with the work of Alemu *et al.* (2016) which established that varieties of cowpea with good competing strength and adaptability has higher pod numbers. Also, Erik and Michael (2020) argued that though pods per plant could be accounted for by other phenotypic characters such as numbers of branches, days to pod formation, days to flowering, farming practices among others, the most significant factor could be adaptability of cowpea seeds to invading plants such as *Striga gesnerioides*. The value of pods recorded for IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 were higher than those recorded by black-eyed pea in Nigeria but less than numbers of pods per plant recorded by Rangel *et al.* (2013) for yardlong bean enhanced varieties, but similar to that of Futuless and Bake for Africa

Also, the results on the effect of varieties on pod weight, showed that in both years of trials; the highest pod weight were recorded in IT08K-150-24, while IT99K-573-1-1 and IT09K-297-13 closely followed with respective ranged from 353.83 - 460.17 kg/ha unlike other varieties such as IT07K-292-10, IT07K-318-33, IT89KD-391, IT93K-452-1 and TVX 3236 with least pod weight ranged from 175.54 – 358.81 kg/ha. This shows that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 recorded better pod weight which could be attributed to the adaptability and competitive strength against invading plants such as *Striga gesnerioides*. This result is in accordance with the finding by Oyinbo and Zibah (2014) that reported range of 314.9 –

394.6 kg/hect for black-eyed pea and sow-pea. The results are similar to the findings of Gbaguidi *et al.* (2013), who reported that IITA-improved varieties were superior in terms of pod weight.

The results on the effect of variety and *Striga gesnerioides* doses on number of seed in both years of trials showed that the IT99K-573-1-1, IT08K-150-24, and IT09K-297-13 consistently showed higher seed number per plant, while the least seed numbers per plant were consistently recorded in TVx 3236. This shows that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 are consistent in yield compare to others which could be as results of adaptability and strength of competing by the three varieties. The numbers of seed directly determine the yield rate and could be affected by factors such as diseases and pest due to poor farm management that allow pressure of competing plants (weeds) on the cowpea plants. The mean seed number of Erik and Michael (2020) recorded in IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 fall within the range of seed number recorded by Atokple *et al.* (2017) and Alemu *et al.* (2016). Also, it's established that seed number is dependent on the pod length and weight which in overall depend on phenotypic qualities of cowpea. Welsh and Mohamed (2016) expressed that resistant of cowpea plant or its adaptability to compete with against invading plants (weeds) could define the overall mean value of seed number per pod or plants.

The effects of *Striga* doses on the yield and yield component of cowpea plant during 2019 and 2020 trials showed that in both trials the 0.3 doses of *Striga gesnerioides* recorded highest number of pods, compared to 0.7 doses of *Striga gesnerioides* that has least yield persistently for the two trials. This shows that the more the doses of *Striga gesnerioides*, the less the cowpea yields. This concurs with the findings of Alemu

et al. (2016) and Michael et al. (2017) which showed that cowpea yields are significantly affected by the proportion of weeds in respect to adaptability of cowpea varieties and farm management effectiveness. Similar conclusion was reached by Atokple et al. (2017) and Travlos et al. (2020); which established that cowpea varieties qualities such as competing strength could affects overall yield. In short, the current study has shown that.

Also, the results on the effect of *Striga* doses on the pod weight showed that in both trials the highest pod weight was recorded against 0.3 *Striga* doses, while the least pod weights were recorded against 0.7 *Striga* doses. This shows that as doses of *Striga gesnerioides* increases, the weight of pods decrease. This indicates that introducing more doses of *Striga gesnerioides* could affect the pod weight. This concurs with the works by Rangel *et al.* (2013) and Welsh and Mohamed (2016) which showed that competing plants have effects on pod weight. Though, Peterson (2019) maintained that other factors such as pests and diseases, farm management, nature of soils and other environmental variables.

The results on the effect of *Striga* doses on number of seed showed that in both trials highest number of seeds was recorded against 0.3 *Striga* doses, while the least number of seeds were recorded in 0.7 *Striga* doses. This shows that the more the doses of *Striga gesnerioides* the lower the number of seed. This finding is in accordance with the submission made by Michael et al. (2017) that higher proportion of competing plant could retard plant growth, pods weight and length as well as numbers of seed.

The results on the effect of *Striga* doses on the seed weight showed that in both trials the highest seed weight were recorded at 0.3 while the least seed weight were consistently recorded

against 0.7 *Striga* doses. This shows that the higher the ratio of *Striga* doses, the lower the seed weight. This shows consistent with the earlier studies by Michael et al. (2017) that seed weight could be greatly affected by higher rate of competing plants.

The results on interaction effect between variety and *Striga gesnerioides* doses on cowpea plant number of pod, pod weight and number of seed in both trials showed that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 had non-interaction with *Striga* doses, thereby recorded higher number of pods irrespective of doses of *Striga gesnerioides*. However, the other studied varieties (IT07K-292-10 – TVX 3236) recorded significant interaction effect, which affected pod numbers, weight and seed number. This shows that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 shows some consistent against doses of *Striga gesnerioides* due to adaptability and competing Strength.

This concurs with the findings by Rangel *et al.* (2013), which shows that interaction effect between competing plants and crop with weak phenotypic quality could results in poor yield.

The results on interaction effect between variety and *Striga gesnerioides* doses on cowpea seed in both Trials showed that IT99K-573-1-1 and IT08K-150-24 interacted significantly with *Striga* doses to influence higher seed weights, while other varieties recorded lower weight of cowpea seed. This shows cowpea varieties with weaker phenotypic quality are affected by higher numbers of invading plants such as *Striga gesnerioides*.

This is in line with the submission made by Rangel *et al.* (2013) and Michael *et al.* (2017), that plant without strong resistant to competing plant do recorded less weight which affected the commercial values of grain as well as reduced farmers' incomes.

Table 1: Effect of Variety and *Striga* Doses on the Yield and Yield Component of Cowpea Plant.

Variety	Number of Pod/plant		Pod Weight kg/ha		Number of Seed/plant		Seed Weight kg/ha	
	2019	2020	2019	2020	2019	2020	2019	2020
IT99K-573-1-1	14.42 ^a	15.17 ^a	447.52 ^a	365.76 ^a	49.17 ^a	49.17 ^{ab}	391.72 ^a	172.20 ^a
IT08K-150-24	14.17 ^a	13.42 ^b	460.17 ^a	330.00 ^a	47.83 ^a	44.5 ^b	382.13 ^a	157.14 ^a
IT09K-297-13	11.08 ^b	15.42 ^a	415.56 ^a	353.83 ^a	52.67 ^a	52.67 ^a	350.35 ^b	168.49 ^a
IT07K-292-10	5.42 ^c	5.42 ^c	358.81 ^b	358.72 ^b	35.92 ^b	35.92 ^c	247.87 ^c	127.40 ^b
IT07K-318-33	5.33 ^c	5.67 ^c	267.53 ^b	264.00 ^b	34.83 ^b	34.5 ^c	238.88 ^c	125.71 ^b
IT89KD-391	4.33 ^c	4.33 ^c	238.33 ^c	178.75 ^c	21.42 ^c	21.42 ^d	184.31 ^d	85.12 ^c
IT93K-452-1	5.33 ^c	5.58 ^c	224.71 ^c	186.40 ^c	20.75 ^c	21.83 ^d	159.56 ^d	88.76 ^c
TVx 3236	4.42 ^c	4.42 ^c	224.89 ^c	175.54 ^c	19.58 ^c	20.58 ^d	173.31 ^d	83.59 ^c
SE ($\pm$)	0.45	0.53	14.96	12.62	1.69	1.65	13.98	6.01
<i>Striga</i> Doses								
Control	11.92 ^a	12.50 ^a	485.13 ^a	373.70 ^a	52.79 ^a	52.54 ^a	395.18 ^a	177.95 ^a
0.3	7.25 ^b	8.00 ^b	312.67 ^b	233.52 ^b	32.33 ^b	31.71 ^b	239.95 ^b	111.2 ^b
0.5	6.83 ^{bc}	7.33 ^{bc}	298.13 ^{bc}	231.62 ^b	29.58 ^{bc}	29.21 ^{bc}	234.39 ^b	110.30 ^b
0.7	6.25 ^c	6.88 ^c	269.90 ^c	220.00 ^b	26.38 ^c	26.83 ^c	202.40 ^c	104.76 ^b
SE ($\pm$)	0.32	0.37	10.58	8.92	1.19	1.17	9.89	4.25
Interaction								
Variety x <i>Striga</i>	*	Ns	**	Ns	ns	**	**	**

Means followed by the same letter(s) within a column and treatment group are not significantly different at P = 0.05 using Duncan's new multiple Range Test (DMRT).

Combined Effect of Variety and *Striga* doses on the Yield and Yield Component of Cowpea during two Trials

The effects of combined analysis of varieties and *Striga* doses on number of pods (Table 2) indicate that there was no significant difference between IT08K-150-24 and IT09K-297-13 likewise, the numbers of pods among IT07K-292-10, IT07K-318-33, and IT93K-452-1 were not significantly different along doses of *Striga gesnerioides*. This showed that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 are consistent in high yield especially in the number of pods, compare to IT07K-292-10, IT07K-318-33, IT89KD-391, IT93K-452-1 and TVx 3236 that recorded lesser number of pods along doses of *Striga gesnerioides* respectively. Also, the results from analysis showed that in two farming

Trials, seed weight for IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 are consistently higher than those seed weight recorded in the varieties of studied cowpea IT07K-292-10, IT07K-318-33, IT89KD-391, IT93K-452-1 and TVx 3236 respectively.

The consistent higher yield recorded in varieties of studied cowpea IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 against different doses of *Striga gesnerioides* showed that these cowpea varieties have quality to survive against pressure and stress from competing plants, while the low pod size, number and weight recorded in other varieties such as IT07K-292-10, IT07K-318-33, IT89KD-391, IT93K-452-1 and TVx 3236 could be attributed to weak phenotypic characteristics qualities of the varieties of cowpea which make them susceptible to effect of *Striga gesnerioides* doses. This agrees with

the conclusion drawn by Awuku (2017) that highly quality cowpea plants survive against stress of invasion plants, while less quality cowpea plants mostly local varieties required lots of farming management process and high cost of production to stir them against competing plants.

Combined interaction effect between variety and Trials on Cowpea Plant Number of pod, pod weight kg/ ha and Seed Weight Kg/ha

The combine interaction effect between variety and *Striga gesnerioides* doses on cowpea number of pod, pod weight kg/hectare number of seed and seed weight kg/ha consistently (Table 2) shown that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 were generally better compare to others varieties such as IT07K-292-10, IT07K-318-33, IT89KD-391, IT93K-452-1 and TVx 3236. This shows that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 consistently overcome the interaction effect of varieties and *Striga* doses which could be as results of their qualitative phenotypic characteristics that resulted to higher yield in term of number pod, pod weight, number of seed and seed weight. This concurs with the earlier finding by Berner *et al.* (2019) that *Striga gesnerioides* doses do not significantly interact with qualitative cowpea varieties expected those with weak phenotypic characteristics. Similar conclusion was reached by Awuku (2017) and Asare *et al.* (2013).

The effects of combined interaction analysis between Trials and varieties of cowpea on number of pods and pod weight (kg/ha), showed that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 recorded better number and weight of pod per pot across Trialsal interaction compare to IT07K-292-10, IT07K-318-33, IT89KD-391, IT93K-452-1 and TVX 3236. This shows that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 are consistent in their yield despite trials

changes due to adaptability and phenotypic qualitative. Similarly, the effects of combined interaction analysis between Trials and varieties of cowpea on number of seed and seed weight (Kilogram/Hectare) showed that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 recorded better number and weight of seed per pot, compare to IT07K-292-10, IT07K-318-33, IT89KD-391, IT93K-452-1 and TVX 3236. This shows that IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 are consistent in seed number and seed weight in despite trials changes due to their adaptability and phenotypic qualitative. This concurs with work by Iseki *et al.* (2019) which established that despite variation, some hybrid cowpeas have shown consistent with their yield compare to local varieties. Also, Ismail *et al.* (2015) noted that seed weight is marketing determinant for cowpea along with other qualities such as size and colour.

CONCLUSION

It can be concluded that cowpea varieties IT99K-573-1-1, IT08K-150-24 AND IT09K-297-13 which gave the highest yield were resistance to *Striga gesnerioides*, whereas IT89KD-391, IT93K-452-1 AND TVX 3236 which developed symptoms with reduced yield is said to be susceptible to *Striga gesnerioides*. At all level of *Striga* seed density there was infestation. It can also be concluded that IT07K-292-10, and IT07K-318-33 except tolerant characteristic as they produce some number of seed despite recording high infestation of *Striga gesnerioides*

RECOMMENDATIONS

Base on the findings from the study the following recommendations were made. IT99K-573-1-1, IT08K-150-24 and IT09K-297-13 should be adopted by famers in regions where there has been high infestation of *Striga gesnerioides* on cowpea. IT07K-292-10 and.

Table 2: Combined Effect of Variety and *Striga* doses on the Yield and Yield Component of Cowpea Plants.

Source of Variation	Number of Pod	Pod Weight kg/hect	Number of Seed	Seed Weight kg/hect
Variety				
IT99K-573-1-1	14.79 ^a	404.57 ^a	49.17 ^b	281.95 ^a
IT08K-150-24	13.79 ^b	395.08 ^a	46.17 ^b	277.48 ^{ab}
IT09K-297-13	13.25 ^b	384.69 ^a	52.67 ^a	259.41 ^b
IT07K-292-10	5.42 ^c	314.65 ^b	35.92 ^c	187.63 ^c
IT07K-318-33	5.50 ^c	311.36 ^b	34.67 ^c	182.30 ^c
IT89KD-391	4.33 ^d	208.54 ^c	21.42 ^d	134.72 ^d
IT93K-452-1	5.46 ^c	205.55 ^c	21.29 ^d	124.16 ^d
TVx 3236	4.42 ^d	200.22 ^c	20.08 ^d	128.46 ^d
SE (±)	0.35	9.79	1.18	7.61
Striga Doses				
Control	12.21 ^a	429.42 ^a	52.67 ^a	286.56 ^a
0.3	7.63 ^b	273.10 ^b	32.02 ^b	175.57 ^b
0.5	7.08 ^{bc}	264.88 ^b	29.40 ^c	172.34 ^b
0.7	6.56 ^c	244.95 ^c	26.60 ^d	153.58 ^c
SE (±)	0.24	6.92	0.83	5.38
Trials				
2019	8.06 ^b	341.46 ^a	35.27 ^a	267.98 ^a
2020	8.68 ^a	264.71 ^b	35.07 ^a	126.05 ^b
SE(±)	0.17	4.89	0.59	3.81
Interaction				
Variety x <i>Striga</i> Doses	**	**	**	**
Variety x Trials	**	*	Ns	**
<i>Striga</i> Doses x Trials	Ns	*	Ns	**
Variety x <i>Striga</i> Doses x Trials	Ns	Ns	Ns	Ns

Means followed by the same letter(s) within a column and treatment group are not significantly different at P = 0.05 using Duncan's new multiple Range Test (DMRT)

IT07K-318-33 are also recommended as they exhibit tolerant characteristic they produce some amount of seed despite high infestation of *Striga gesnerioides*

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EVALUATION OF SOME PHYSICAL AND CHEMICAL PROPERTIES OF EXTRACTED SISAL LEAVES FIBER (*agave sisalana*La) FOR ENGINEERING APPLICATIONS

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ABSTRACTS

This paper evaluates some physical and chemical properties of extracted sisal hemp leaves fiber for its possible utilization in engineering. The fiber was extracted from *Agave sisalana* leaves obtained locally in a government forest reserves Area, Adamawa state, Nigeria using water retting extraction procedure. Studies were carried out on its physical and chemical properties relevant to engineering applications. The parameters evaluated were Moisture absorption ranging from (3.00 % to 3.17 %), density ranging from (0.610 g/cm³ to 3.167 g/cm³), fiber diameter which was found to range between (1.933 µm to 2.50 µm), lumen width ranged between (1.00 µm to 1.50 µm), from a wall thickness of (0.50 µm. Proximate analysis was carried out for cellulose content, hemicelluloses, lignin and ash content which was found to range between 70.00 % to 83.33 %, 16.67 % to 23.33 %, 55.00 % to 75.00 % and 30.00 % to 30.50 % respectively. Statistical package for social sciences (SPSS) was used to determine significantly different means, and the (ANOVA) table and bar chart for chemical compositions were constructed from which observations, conclusions and recommendations were made. The results show that *agave sisalana* leaves fiber were characterized by low density, high cellulose content, and low moisture absorbency in comparison with other leave fibers in its category. Therefore, it is recommended for possible utilization in pulp and paper making, textile, and automobile products such as brake parts, and car interior.

Keywords: physico-chemical, sisal hemp, leaves fiber, composites applications.

INTRODUCTION

Fiber is defined as flexible material having a high ratio of length to width and cross section (Herman and Raymond 1988). Fibers has been classified into natural and manufactured. Natural fibers have made a remarkable impact as a

potential substitute for conventional synthetic fibers like aramid and glass fiber over a past few decades. Owing to their mechanical properties, good thermal insulation properties, low density, nonabrasive nature, easy availability from replenish able sources, cheaper prices and recyclability of natural fiber reinforced polymer

composites have attracted the composite industry, both for structural and nonstructural applications. The chemical composition of lignocelluloses is inherent according to the particular needs of the plants. Celluloses, hemicelluloses and lignin are the three main constituent of any lignocelluloses source and proportion of these components in a fiber depends on the age, source of the fiber and the extraction condition used to obtain the fibers (Batra, 1985).

MATERIALS AND METHODS

Materials

The materials used in this research work include the following; Sisal (*agave sisalana*) leaves obtained locally in Adamawa State, sisal fiber from the leave, NaOH, H₂SO₄, potassium Sulphate, Safranin red, potassium chromate, HCl, HNO₃, distilled water and water. Tools and equipment used was electronic oven dryer M/C NO.11/084 Mod., and Motic electric microscope.

METHODS

Fiber Extraction

The sisal (*agave sisalana*) leaves was cut from the main stock using a sharp knife object at the base of the stalks at matured leaf length. The leaves were tied in bundles, weighed and submerge in a water pond for a period of three (3) weeks to allow the bacteria and fungi in the environment to remove non cellulose substance. The fiber was extracted from the core by hand stripping, clean and dries as describe by Sahay and Singh (2001), Narendra and Yang (2005) and Paridah *et al.*, (2011) and adopted by TAPPI (1980)

Chemical Treatment of Fiber

After the extraction of the fiber, 400 g of sodium hydroxide (NaOH) was dissolved in 8 litres of distilled water which is equivalent to 5 % preparation of NaOH solution, about 990 g of fibre was immersed into the solution for 48 hours at room temperature as a method described by Ray *et al* (2001) and Mishra *et al* (2001). The fiber was removed from the solution and then dried for 48 hours at room temperature, followed by oven drying at 100°C for 6 hours.

Analysis of Fibers Physical Properties

In accordance with Ververis *et al.*, (2004), Sharma *et al.*, (2011), for fiber length dimension, small silver was obtained and macerate with 10ml of 67% HNO₃ and boil in a water bath (100±2°C) for 10minutes. The silvers were then washed and placed in a small flask with 50ml distilled water and the fiber bundles were separated into individual fiber using a small brush with a plastic end to avoid fiber breaking. The macerated fiber suspension was finally placed on a glass slide (7.5cm X 2.5cm) by means of a rubber pipette. For the fiber diameter, fiber lumen width and fiber cell wall thickness determination, cross sections was obtained from the same height as mentioned above and was stained with 1:1 aniline sulphite –glycerine /safranin red mixture to enhance cell wall visibility. Sisal fibre cell was viewed under calibrated motic electric microscope on ×10 objective lence.

Determination of the Fiber Moisture Absorption (Regain)

American society for testing and material (1997) standard testing method for moisture regain as reported by Brindha *et al.*, (2013) was adapted to determine moisture absorption of sisal fiber at matured stage. Sisal fiber samples were conditioned for 24hours using ice blocked at 27 ± 2°C and the weight taken as (L). The

conditioned fiber sample was oven dried at temperature of 105°C for 4hrs and the weight was taken as (W). Moisture absorption percentage of the sample was calculated according to equation 2 below;

$$\text{Moisture Absorption \%} = \frac{L-W}{L} \times 100 \quad (1)$$

Determination of the Fiber Density

Technical Association of Pulp and Paper Industries (TAPPI) standard method was adopted as reported in Modibbo et al., (2009). The density plant fiber at matured stage was determined by conditioning the fiber sample for 24hrs at 27°C±2°C using water ice blocked before the test was carried. 2g of the sample was accurately weighed out for each fiber sample. The weight was immersed in toluene in a calibrated glass tube (30ml measuring cylinder) and volume of toluene displaced was determined and equal to the volume of sisal fiber immersed. The density of the fiber sample was calculated as follows;

$$\text{Density} = \frac{\text{Mass of fibre}}{\text{Volume of fibre}} \text{ in } g/cm^3 \quad (2)$$

Analysis of the Fiber Chemical Properties

Proximate analysis of the fiber was carried out to determine the percentage content of cellulose (alpha-cellulose), hemicelluloses (beta and gamma cellulose) lignin and ash as described by Technical Association of pulp and paper industries (TAPPI, 1980).

Determination of Cellulose Content

The alkali solubility test for Alpha – cellulose which involved treating 3g of sample with 100mls of 18% NaOH at 25°C ±2°C, was carried out using water ice blocked. The weight of the undissolved residue which is the alpha-cellulose was expressed as a percentage of the initial weight of the dry ground sample (TAPPI, 1980).

Determination of Hemicellulose Content

Following the 18% alkali solubility test for the alpha cellulose, the dissolved cellulose portion (aliquot) was collected separately at the end of one hour and treated with 0.1N dilute H₂SO₄. The treatment caused a precipitate form, which was the beta cellulose. The cleared portion (aliquot) was further oxidized with potassium chromate and potassium iodine was added. The aliquot was back treated with 0.1N solution of potassium thio-sulphate. The titration caused a precipitate form, which was the remaining dissolved gamma cellulose. The weight of the beta and gamma cellulose was added together and got the weight of the hemicelluloses which was then be expressed as a percentage of the initial dry weight of the ground fiber sample (TAPPI, 1980).

Determination of Lignin Content

The dry specimen of ground sisal fiber was chilled in ice breaker and treated with 38% concentrated HCL, stir and left to cool in the ice under a fume cupboard. Thereafter, concentrated H₂SO₄ was added drop wise to the mixture, stir and left over night at room temperature. The mixture was diluted with distilled water and boiled to coagulate the lignin which was then filtered hot and rinsed alternatively with concentrated HCL and water. The coagulated lignin was dried, weight and expressed as percentage of the initial weight of the dry specimen.

Determination of Ash Content

Proximate analysis as described by Aisha *et al.*, (2013) was adopted in determining the quality of ash content in the fiber, crucible was washed dried in an oven at temperature of 180°C for 30mins, cooled and then weight as M₀(g). 2g of the fiber sample was placed into the crucible and weighted again as M₁(g). Crucible with the fiber

sample, transferred into the muffle furnace whose temperature set at 600°C and allow for 3hrs until the content becomes whitish in colour. Afterward, the crucible was brought out, cooled in the desiccators and weighted as M_2 (g). The percentage of ash content was calculated as follows;

$$\% \text{Ash Content} = \frac{\text{Mass of ash (g)}}{\text{Mass of sample (g)}} \times 100 \quad (3)$$

Statistical package for social science (SPSS) was used to determine the analysis of variance (ANOVA) and the means that were significantly different between the samples at 5% level of probability. The chemical properties were subjected to bar-chart and the percentages compositions were determined from which the observations, conclusions and recommendations were drawn for further studies.

Statistical Analysis



Plate I: Sisal Matured Leaves for Fibre Extraction



Plate II Extracted Fiber from matured sisal leaves.

RESULTS AND DISCUSSION

Fiber Physical Properties

Moisture absorption

The mean values of moisture absorption evaluated at different stages of fiber length was presented in Table 5 and were found to be 3.0 %, 3.0 %, 3.0 %, 3.2 % and 3.1 % for the length of 153.0 μm , 190.0 μm , 243.0 μm , 265.3 μm and 316.7 μm respectively. It was observed that the moisture absorption at all stages investigated were lower than cotton fiber of 8.0 – 25.0 % (Naveen *et al.*, 2014), flax of 6.2 – 7.0 % (Brindha, *et al.*, 2013), and *Agave Americana* with moisture absorption ranged between 8-9% (Ashish *et al.*, 2015). This is in agreement with the report of (Saheb, 1999) that, fiber with low moisture absorption capacity is suited for different application as composite due to its moisture resistance. The moisture absorption increases to 3.16 % with further increase of fiber length (265.3 μm) but decrease to 3.133 % at fiber length of 316 μm . this might be due to the differences in fibre diameter from the bottom to the top. The analysis of variance (Table 2)

shows that moisture absorption is not significant at 5 % probability level.

Fiber density

The density values measured at different stages of length as presented in Table 1, were 0.667 g/cm^2 , 0.654 g/cm^2 , 0.621 g/cm^2 , 0.647 g/cm^2 and 0.610 g/cm^2 for length of 153.0 μm , 190.0 μm , 243.0 μm , 265.3 μm and 316.7 μm respectively. The results revealed that the density of sisal fiber ranged between 0.610 ± 0.407 to 0.667 ± 0.445 . The results were in agreement with the studies investigated on natural fibers by (Pai, *et al.*, 2015) and reported that, good quality natural fibers most possess good thermal insulation properties, low density, non abrasive nature, easily available from replenish able sources, recyclable in nature and sustained good application as composite for structural and non-structural applications. It was observed that fiber density decreases with an increase in fiber length. The analysis of variance (Table 3) indicates that the density of the fiber investigated at all stages of length were significant at $p \leq 0.05$ level for the replications and not significant for the treatments.

Table 1. Determined Fiber Physical Properties

FIBRE LENGTH (μm)	Mean Moisture absorption (%)	Mean Density g/cm^3
153.0	3.0 $\pm$ 2.000	0.667 $\pm$ 0.445
190.0	3.0 $\pm$ 2.000	0.654 $\pm$ 0.436
243.0	3.0 $\pm$ 2.000	0.621 $\pm$ 0.414
265.3	3.167 $\pm$ 2.111	0.647 $\pm$ 0.431
316.7	3.133 $\pm$ 2.089	0.610 $\pm$ 0.407

Table 3 Analysis of variance (Mean Square) for fiber moisture absorption and density

Sources of Variation	DF	Moisture Absorption (%)	Density (g/cm^3)
Replication	2	297.295 ^{ns}	30.045*
Treatment	4	73.492 ^{ns}	18.075 ^{ns}
Error	8	10.256	6.013
Total	14		

Table 4 Determined Fiber Chemical Properties

Parameters	Base T ₁	Middle T ₂	Top T ₃
Cellulose (%)	83.33±55.553	76.67±51.113	70.00±46.667
Hemicelluloses (%)	17.77±11.847	23.33±15.553	16.67±11.113
Lignin (%)	75.00±50.00	55.00±36.667	65.00±43.333
Ash (%)	30.50±20.333	30.50±20.333	30.00±20.000

Celluloses content

The mean values of cellulose content of *agave sisalana* leaves fiber as shown in Table 4 were 83.33%, 76.67% and 70.00% for the fiber length at base, middle and top respectively. The celluloses content decrease from the base to top level of the fiber as presented in Figure 1. The values in all stages were lower than seed flax, kenaf, ramie, jute, abaca, but fallen within the ranged of Henequen, fiber flax (Xue *et al.*, 2007), *Agave Americana* (Ashish *et al.*, 2015). The content in all stages investigated were 70% and above, this is in agreement with (Ververis *et al.*, 2004) and (Sharma *et al.*, 2011) that, investigated plant materials using standard rating system and recommended that plant material with 34% and above cellulose content were characterized as promising plant for pulp and paper manufacturing from chemical composition point of view. It was observed from the results that the cellulose content was high in comparison with other plant fibers, and the higher the cellulose content the smaller the fiber diameter and proves that the fiber will be stronger in accordance with (Ishak *et al.*, 2009). Also, in agreement with the report of (Mohanty *et al.*, 2000) that, cellulosic fibers change their dimensions and properties with varying moisture content.

Hemicellulose content

The hemicellulose content of *agave sisalana* leaves fiber as shown in Table 4, were 17.77 %, 23.33 % and 16.67 % for the fiber length at the base, middle and top respectively. The hemicellulose content increases from the base level to the middle and decrease to top level.

This is in agreement with the reports of (Ebringerova *et al.*, 2000) that, hemicellulose content of plant fluctuate due to presence of sugar, glucose, xylems, galactose, arabinose in its composition. It was observed from the result in Figure 1 that, in all stages investigated the hemicellulose content was higher than henequen with 4-8 %, abaca with 15-17 %, ramie 5-16.7 %. But lower than seed flax 30 – 45 %, (Xue, *et al.*, 2007). It was also observed that, the hemicellulose content of the fiber was very low, and this is in agreement with (Agu *et al.*, 2012) that, low hemicellulose content in fiber is responsible for less water absorbing capacity which has advantages in utilization in different applications as composites.

Lignin content

The values of lignin content determined were presented in Table 4 and were found to be 75.00 %, 55.00 % and 65.00 % for the fiber length at base, middle and top respectively. The result showed that the lignin content were decrease from base to the middle and increase to the top level (Figure 1). But in all cases investigated the lignin was higher than pineapple crown leaves, rice straw, kenaf and bagasse (Khristova *et al.*, 2002; Tran, 2006; Huang, *et al.*, 2007). Lignin content in fiber improved the fiber strength and makes it suitable for paper making and other strong applications (Waranyou, *et al.*, 2010).

Ash content

The values of ash content determined as shown in Table 4 were 30.50 %, 30.50 % and 30.00 % for the fiber length at the base, middle and top respectively. The result shows that the ash

content at the base and middle were the same, but decrease with 0.50 % at the top. The content was higher from the base to the middle and lower at the top level as presented in Figure 1. This is in agreement with (Steyn *et al.*, 2006) that, natural plant fibers are subject to growth irregularities to extent of the same plant possess different sizes and properties. The content in all stages investigated were higher than borassus fiber with 0.64 %, rice straw with 9.2 %, jute leaves with 8.8 % (Basak *et al.*, 1996), kenaf

with 4 % (Khristova *et al.*, 2002) and bagasse with 1.5% (Khristova, *et al.*, 2006). Chemically sisal leaves fiber was rich in cellulose, and the higher the cellulose, the higher the ash content and vice versa (Waranyou, *et al.*, 2010). The higher the ash content, the easier the processing techniques of materials during application (Namessan, 2008). It was observed that, sisal fiber has high ash content in comparison to other natural plant fibers, therefore, it will have good processing ability in most of its applications.

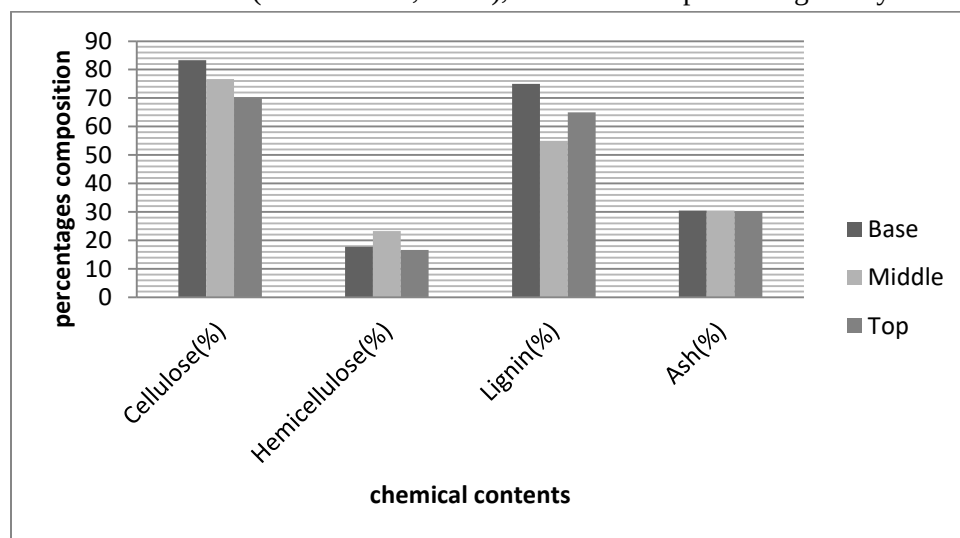


Figure1 Chemical Properties Distribution Chart

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Agave sisalana leaves fiber extracted from the leaves obtained locally from Maiha L.G.A of Adamawa state, were studied for its physico-chemical properties for engineering application. The fiber was extracted using water retting procedure and treated with alkaline (NaOH).

The following conclusions were drawn; the fiber runkle ratio in some stages of length (153.0 and 190.0) were less than one (<1) while slenderness ratio in all stages of fiber length were greater than seventy (>70) which is considered good for paper production. It was found that the fiber has

moisture absorption is 3.1 % and the density of 0.64 %, cellulose ranged between 70 – 83 % and this can be used in many applications due to its moisture resistance ability and is within the standard rating system of fiber with 34 % and above. Fiber cellulose content with this percentage is characterized as promising plant for pulp and paper manufacturing from the chemical point of view.

RECOMMENDATIONS

Based on this study conducted on Physico-chemical properties of sisal hemp (*agave sisalana*) leaves fiber at different stages of fiber length and thickness, the following recommendations were made;

1. It was recommended for pulp and paper making due to its high cellulose content >70%.
2. It was recommended for application in piteado technique for leather embroidery and plaster of Paris (POP) due to its high tensile strength and low density.
3. Based on these finding, the design and construction of machine for processing of sisal fiber should be carried out.

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GENETIC VARIABILITY AND GRAIN YIELD PERFORMANCE OF BREAD WHEAT (*Triticum aestivum* L.) LINES UNDER RAINFED CONDITIONS IN PLATEAU STATE, NIGERIA

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ABSTRACT

Bread wheat (*Triticum aestivum* L.) is an important cereal and food security crop in Nigeria. The current national breeding program aims to select wheat genotypes adapted to rain-fed environment for the release of improved varieties. The present study was undertaken with 50 wheat genotypes including one check at two locations; Miango and Vom, Plateau State in 2023 and 2024 to study variability among traits viz; Plant height, Days to heading, Days to maturity, Number of productive tillers, Spike length, Number of spikelets per spike, Number of grains per spike, 1000-grain weight, Biological Yield, Grain Weight and Harvest Index. Data collected were subjected to combined Analysis of Variance (ANOVA) using R (version 4.5). The pooled ANOVA indicated significant variation between the Years, among Lines and Location x Line interaction for all the traits studied. At the two locations, the ANOVA indicated non-significant variation among the lines for all the studied traits. For Grain yield, Line 2 (977.5g) had the highest mean followed by Line 28 (948.2g/plot) and line 3 (936.3g/plot). In terms of performance across the years under study, Lines in 2024 (681.2g/plot) performed better than lines in 2023 (619.1g) with Lines at Vom (735.1g/plot) out performing those at Miango (565.2g/plot). Finlay-Wilkinson's regression revealed Lines 10, 15, 18, 41 and 50 as lines with grain yield stability. Notable differences in response to environment indicated genetic variability which allows for the selection of lines for genetic improvement. Therefore, Lines 2, 3 and 28 among others are recommended selection.

Keywords: Bread wheat, Lines, variation and Yield

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a vital cereal crop globally, belonging to the Poaceae family, and serves as a key food source for human nutrition. It is cultivated across various agro-ecological regions, including Nigeria, despite its origins in temperate climates (Baenziger, 2016). It is a major staple crop for several countries and

an imported commodity in all of Africa. Its widespread adoption is attributable to its remarkable environmental adaptability and beneficial nutritional properties, notably the gluten that enhances baking quality (Baenziger, 2016; Dubcovsky and Dvorak, 2007; Charmet *et al.*, 2013).

China (17 %) and India (13 %) rank as the top two producers of wheat on a global scale, while

the Russian Federation was the third largest wheat producer in 2022, also with 13% of the global production [Food and Agricultural Organization, (FAOSTAT, 2023)]. In Nigeria, wheat holds strategic significance, with domestic consumption reaching 4.2 million metric tonnes, incurring over \$4 billion in foreign exchange annually for imports, whereas national production stands at a mere 300,000 metric tonnes (LCRI, 2016). This makes wheat the second-largest contributor to Nigeria's food import bill, straining the national foreign reserves as over \$2 billion is spent yearly on importing over five million metric tonnes (Central Bank of Nigeria [CBN] 2021). Local wheat production was around 200,000 metric tonnes in 2020 (Wheat Farmers Association of Nigeria, WFAN, 2021), falling short of expectations primarily due to unfavorable weather and subpar seed varieties.

In Nigeria, the predominant species is Common wheat or Bread wheat, known scientifically as *Triticum aestivum*, primarily used for producing flour for bread. Wheat is utilized to produce flour for various foods including cakes, biscuits, breads, noodles, semolina, pasta, breakfast cereals, and local dishes like *Taliya*, *Gurasa*, *Tuwo*, *Alkaki*, *Fura*, *Algaragis*, *Alkubus*, *Danwake* and *Fura* (Falaki *et al.*, 1990).

Pasta wheat, scientifically termed *Triticum durum* or Durum Wheat, is mainly processed into Semolina for making products like Spaghetti and Macaroni but accounts for only about 10% of wheat consumption in the country (Sall *et al.*, 2019). Nigeria has relied heavily on wheat imports to satisfy the increasing demands of its growing population, particularly as urban dwellers and youth gravitate towards wheat over traditional staples. Globally, wheat constitutes 19% of daily caloric intake and 21% of protein requirements, supporting both human diets and livestock feed (Hawkesford, 2013).

The absence of genotypes suited for particular locations in Nigeria, coupled with the advent of rain-fed wheat systems, has contributed to declining cultivation areas and productivity, compounded by biotic and abiotic stresses. This underscores the urgency for crop breeders to develop superior strains capable of withstanding adverse conditions, making the assessment of genotype stability crucial. The objective of this study was to evaluate the variability and identify superior wheat genotypes in terms of grain yield under rain-fed conditions.

MATERIALS AND METHODS

Experimental Sites

The study was conducted for two years (2023 and 2024) in two locations under rain-fed conditions. The two locations were the Research site of National Root Crops Research Institute (NRCRI), Vom, Jos South LGA of Plateau State (Lat. 9° 44' 22" 119 and long. 8° 48' 24.73848", with an Elevation of 1251.0 m asl), and Farmers' Field at Miango, Bassa LGA of Plateau State (Lat. 9° 43' 20" 27064 and long. 8° 47' 36.19968", with an elevation of 2734.0 m asl), North Central Nigeria.

Source of Planting Materials

The planting materials consisted of forty-nine lines, which were obtained from the germplasm of the International Centre for Maize and Wheat Improvement (CIMMYT), Mexico, and one check; LACRWHT-7 obtained from the Lake Chad Research Institute (LCRI), Maiduguri. The materials are herein referred to as lines 1-50

Experimental Design

The trial was evaluated following the Alpha-Lattice design with two replications. Each replication consisted of 5 blocks consisting of 10 plots (5×10). Each line was sown in a 2×3m².

Agronomic Practices

The standard agronomic cultivation protocol described by LCRI (2016) was followed to raise the crop.

Statistical Analysis

Analysis of Variance (ANOVA) of all the parameters and calculation of means was done by using R 4.5, a software package for alpha lattice designed by ADEL-R (2018)

RESULTS AND DISCUSSION

Variability of 50 Wheat Lines Evaluated at Miango and Vom in 2023 and 2024

The mean squares from ANOVA for all phenotypic traits viz; days to heading, days to maturity, plant height, number of tillers, spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight, biological yield and grain yield and harvest index, for two years, are presented in Table 1. The table shows that the mean squares for all all traits were significant ($P < 0.05$) among the lines for plant height and number of tillers per plant and highly significant ($p < 0.001$) for days to heading, days to maturity, spike length, number of grains per spike, grain weight, biological yield, grain yield and harvest index. The Line X Location interaction was also significant ($P < 0.05$) for number of spikelets per spike and biological while other traits such as days to heading, days to maturity, number of tillers per plant, spike length, number of grains per spike, grain weight, 100-grain weight and harvest index were highly significant ($P < 0.001$). The difference in environments and lines for most of the traits investigated were not statistically significant ($P \leq 0.05$).

The significance of Line x Location interaction suggests that lines behaved differently in

different environments. The 50 lines showed significant differences for all the traits. It reveals that the selected lines had significant variation for all traits and may not show uniform performance in different environments. Whereas, Line x Location interaction components showed significant differences for all. It indicates wide differential behavior of lines in changing environments.

The differences observed among wheat genotypes for all of the traits under study indicated presence of considerable amount of variability among the lines. This variation could be exploited for hybridization among the wheat genotypes followed by selection. The differential response among the lines indicates the presence of genetic variability and thus provides an opportunity for crop breeders to select top-performing lines. In addition, days to heading, spike length, grain weight, biological yield and harvest index are valuable grain-yield related traits in wheat which are useful for wheat breeders to assess crop performance and productivity under varying conditions such as rain-fed condition adopted in this study. Significant year effect for days to heading, number of tillers, grain weight and biological yield suggests the variation in the environmental conditions between the years under study which may have resulted in the differences observed.

Significant interactions between Location X Line effect observed for all the traits except plant height and 1000-grain weights suggest that the lines performed differently in different locations under study. Therefore, crop breeders have an opportunity to select wheat genotypes with desirable traits such as grain yield across the two locations of study. The use of different locations for the evaluation of lines may have led to variation in the responses of the lines to the two locations. This allows crop breeders to target specific wheat genotypes with good

performance under rain-fed high-altitude environments. magnitude of interaction among the lines and the locations under study which resulted in the differences observed. The significant environmental effect observed implies that the environment substantially influenced the expression of traits among the wheat genotypes. The result of this study is similar to Amelework *et al.* (2023); Sansa *et al.* (2025).

The coefficient of variability (CV) ranged from 5 to 59 % with Grain yield and Grain Weight having the highest percentage CV and days to maturity having the lowest CV of 5%. Highest heritability of 98% was exhibited by harvest index while lowest heritability was exhibited by number of grains per spike. The coefficient of variability suggests that location had no influence on the traits under study. The present results are in accordance with those previously reported by Jedynski (2001) in wheat for this trait. Narrow-sense heritability estimates for measured traits across environments were considerably moderate and high, which implied that the variation observed among the lines may be largely attributed to genetic variances which may be heritable. Therefore, there is reliability in the measured traits to effectively select wheat genotypes for both locations. Heritability of 93 and 59% was observed for spike length and grain yield per plot, respectively. These results differ with findings of Nabi *et al.* (1998) and Jedynski (2001) who reported very low heritability estimates for spike length and grain yield per plant. High heritability estimates in this study depict that, days to heading, spike length, days to maturity, harvest index and grain yield per plant have high transmitting ability to next generation of lines. The other traits, such as grains per spike, 1000-grain weight and spikelets per spike and flag leaf area displayed moderately high heritability values respectively. Chowdhry and Salahuddin (1990) illustrated similar

findings for number of grains per spike. Lowest heritability was observed for fertile tillers per plant with value of 40.71%. In contrast, Pal and Garg (1992) and Mahmood and Shahid (1993) reported high heritability value for fertile tillers per plant. The difference in findings may be due to various reasons including the genetic materials used and environmental conditions. The moderate to high heritability estimates suggests that crop breeders can incorporate these traits into selection strategies to develop wheat genotypes with good performance for rain-fed high altitude environments. Also, prioritizing these traits in selection indices could possibly result in consistent genetic gains.

Mean Performance of 50 Wheat Lines Evaluated at Miango and Vom in 2023 and 2024

The mean performance of wheat genotypes in Table 2 reveals significant variability across several phenotypic traits. Ranking of Means for grain weight, 1000-grain weight, grain yield, biological yield and harvest index indicated an average of 390.1g/plot, 30.6g/plot, 650.2g/plot, 354.6g/plot and 17.8% with corresponding means for the year 2024 averaging 408.7, 32.9, 681.2, 358.6, 18.4 as the best. Line 30 (559.7g) had the highest grain weight while line 40 (197g) had the lowest with Vom having the highest mean grain weight of 441.1 was better than Miango. In terms of 1000-grain weight, Miango (31.2g) outperformed Vom while line 3 (32.3 g) had the highest mean with line 12 (28.2g) having the lowest mean for this trait. For Grain yield, Line 2 (977.5g) had the highest mean followed by Line 28 (948.2g) and line 3 (936.3g). Lines with highest biological yield measurements were Lines 28 (436.8g), 22 (457.1g) and 2 (443.1g) while Lines 37 (227.6g) had the lowest mean for this trait with Vom (378.7g) outperforming Miango. The harvest index, averaged 18.8% for Vom outperforming

Table 4a: Mean Squares from Analysis of Variance (ANOVA) of 12 traits evaluated at Miango and Vom in 2023 and 2024

Source of Variation	Degree of Freedom	DH	PH	DM	NT	SL	NGS	NS/S	GW	1000-GW	BY	Yield	HI
Location	1	1652.42	1251.4	183.60	15.602	26.11	11466.1	243.7	1038758	114.06	233608	2885440	399.99
Year	1	150.063*	3726.5	11.22	131.10*	10.304	28163.6	5011.2	138604*	2072.07	6236*	385010	161.77
Location X Year	1	39.06	458.6	152.52	1.32	2.66	5673.1	177.4	9	411.28	1209	25	11
Rep (LY)	1	91.20	193.1	16.40	4.203	6.502	5214.3	221.4	1328521	437.02	432241	3690337	484.62
Line	49	101.021**	309.5*	21.17**	5.54*	5.49**	531.5**	215.8	61890**	6.01	20436**	171916**	43.59**
Line X Location	49	22.07**	213.1	14.49**	6.56**	4.67**	428.3**	319*	37590**	5.42	13587*	104417**	29.37**
Line X Year	49	3.93	90.4	5.15	0.95	0.53	182.1	19	3279	6.60	149	9107	7.28
Line X Year X Location	49	2.13	88.2	3.27	1.18	0.57	158	24.2	3613	5.61	106	10037	8.17
Residual	196	6.997	196.3	7.91	3.04	2.32	257	184.2	18250	6.56	7578	50696	15.7
CV (%)		8	46	5	40	34	45	16	59	24	40	59	39
Heritability (h^2)		82	46	80	62	93	35	58	59		56	59	98

DH (Days to Heading), Plant Height (PH), Days to Maturity (DM), Number of Tillers (NT), Number of Grains per Spike (NGS), Number of Spikelets per Spike (NS/S), Grain Weight (GW), 1000-Grain Weight (1000-GW), Biological Yield (BY), Harvest Index (HI)

Figures with * and ** are significant at 5% and 1% level, respectively

Miango while Lines 3 (23.9%), 30 (22.5%), 28 and 5 (21.5%) had the highest percentage for this trait with Line 40 (13.5%) had the least percentage harvest index. The results reveal the superiority of Lines 2, 3, 22, 28 and 30 as highest high-yielding lines due to their mean performance for grain yield and other yield-contributing traits. The results are in line with those of Amanuel *et al.* (2017) and Falaki and Mohammed (2011)

Finlay-Wilkinson's Regression for Estimating Grain yield Stability among Wheat Lines

When the regression coefficients are approximating to 1.0 and are associated with high yield mean, lines are adapted to all environments. When associated with low mean yields, lines are poorly adapted to all environments. Regression coefficients above 1.0 indicate lines with increasing sensitivity to environmental change, showing below average stability and great specific adaptability to high yielding environments. Regression coefficients decreasing below 1.0 provide a measure of greater resistance to environmental change, having above average stability but showing specific adaption to low yielding environments.

Table 2: Mean performance of 50 wheat lines evaluated in Miango and Vom in 2023 and 2024

Line	DH	PH	DM	NT	SL	NGS	NS/S	GW	1000-GW	BY	Grain Yield	HI
1	59.0	68.1	99.0	7.8	8.5	86.0	150.3	367.4	29.4	351.5	612.4	16.6
2	60.0	62.5	98.0	8.4	8.2	83.3	153.3	586.5	30.6	443.9	977.5	20.6
3	60.0	50.1	98.0	7.4	7.0	98.5	149.9	561.8	32.3	383.2	936.3	23.9
4	66.0	58.5	100.0	8.5	8.3	80.0	140.2	416.8	31.2	350.5	694.7	19.7
5	61.0	56.5	96.0	9.3	7.2	74.1	152.9	448.2	31.7	340.0	747.0	21.5
6	59.0	54.1	97.0	9.3	9.7	87.5	55.5	344.8	29.4	348.2	574.6	16.5
7	65.0	47.7	100.0	7.6	8.0	76.8	157.2	273.4	30.4	278.4	455.7	16.2
8	60.0	59.6	96.0	7.6	9.6	96.0	155.5	396.2	30.1	378.4	660.4	17.4
9	66.0	64.7	102.0	7.0	6.5	73.3	144.7	319.3	30.0	318.3	532.2	16.7
10	61.0	57.6	98.0	9.4	6.8	87.1	145.6	402.1	29.7	326.8	581.9	16.0
11	61.0	66.7	101.0	8.9	7.5	88.1	148.2	289.8	31.5	390.2	670.2	17.1
12	65.0	58.9	101.0	8.3	8.5	92.8	153.0	446.1	28.9	300.8	483.1	16.1
13	63.0	49.3	101.0	9.3	8.4	88.6	152.3	393.1	31.6	399.5	743.5	18.1
14	66.0	55.1	101.0	9.8	8.3	98.4	164.2	462.8	29.2	346.5	655.2	17.5
15	68.0	69.4	102.0	8.0	8.8	84.9	154.3	373.8	31.4	424.7	771.4	16.9
16	66.0	58.5	102.0	9.5	7.2	76.3	151.7	437.1	30.0	392.6	623.0	15.7
17	61.0	52.8	99.0	8.6	7.5	87.6	151.5	320.3	31.5	368.7	728.4	18.3
18	70.0	53.1	100.0	9.5	8.7	83.4	148.5	418.4	29.6	334.7	533.9	15.3
19	67.0	61.1	102.0	7.9	8.0	72.3	153.7	586.5	31.6	351.7	687.4	19.0
20	67.0	57.2	102.0	7.6	7.8	95.3	152.9	303.8	30.5	333.5	506.3	14.9
21	54.0	62.3	96.0	8.1	7.9	78.0	156.2	370.9	32.1	393.3	618.2	15.9
22	61.0	51.0	98.0	9.1	7.8	87.7	152.8	508.4	30.0	457.1	847.4	18.7
23	60.0	57.7	98.0	7.1	7.8	92.2	150.6	400.8	31.1	396.6	668.1	15.6
24	63.0	55.6	100.0	9.4	6.6	81.4	150.2	292.2	29.9	327.0	487.0	14.2
25	65.0	60.3	100.0	7.6	6.0	102.1	156.3	385.2	30.5	345.0	642.1	18.7

DH (Days to Heading), Plant Height (PH), Days to Maturity (DM), Number of Tillers (NT), Number of Grains per Spike (NGS), Number of Spikelets per Spike (NS/S), Grain Weight (GW), 1000-Grain Weight (1000-GW), Biological Yield (BY), Harvest Index (HI)

Table 2 Cont'd: Mean performance of 50 wheat genotypes evaluated in Miango and Vom in 2023 and 2024

Line	DH	PH	DM	NT	SL	NGS	NS/S	GW	1000-GW	BY	Grain Yield	HI
26	62.0	49.0	98.0	8.2	8.4	84.5	149.9	486.4	31.6	420.7	810.8	19.0
27	57.0	61.1	98.0	7.3	7.4	73.9	154.9	493.6	30.7	418.9	822.7	19.5
28	63.0	55.2	100.0	7.8	9.4	84.8	153.1	568.9	31.8	436.8	948.2	21.5
29	64.0	43.9	100.0	9.5	8.2	80.3	159.8	255.9	30.1	264.9	426.5	16.0
30	65.0	56.6	99.0	8.1	7.2	92.0	155.9	559.7	32.1	416.4	932.8	22.5
31	66.0	58.0	100.0	8.9	8.4	80.7	149.0	376.2	30.1	340.5	639.9	18.0
32	65.0	54.1	100.0	8.9	6.0	85.8	158.0	414.9	30.4	345.5	691.6	19.7
33	67.0	59.5	101.0	8.1	8.2	86.8	145.7	255.2	30.0	303.7	425.3	13.6
34	67.0	45.9	99.0	9.1	6.5	78.7	157.8	248.2	30.8	241.8	413.7	17.2
35	67.0	51.0	100.0	8.4	7.7	94.8	157.1	506.5	31.3	386.7	844.1	21.3
36	65.0	44.0	100.0	9.1	8.6	85.6	139.7	421.6	30.7	366.9	702.7	18.1
37	62.0	50.4	99.0	9.9	8.4	74.7	152.0	299.7	31.1	227.6	499.6	21.7
38	60.0	42.4	97.0	7.1	7.5	84.8	155.4	384.3	31.3	344.6	640.5	18.2
39	60.0	62.4	98.0	7.0	8.8	78.1	145.7	341.0	29.2	338.4	568.4	16.1
40	65.0	53.9	99.0	9.8	7.2	78.4	153.0	197.0	29.4	243.2	328.3	13.5
41	67.0	50.9	100.0	9.3	6.8	76.2	157.5	329.6	29.6	319.2	549.3	17.1
42	68.0	57.7	100.0	7.9	7.4	97.0	161.0	318.7	30.4	346.4	531.2	14.9
43	68.0	60.8	100.0	9.3	7.5	80.9	164.9	353.0	31.4	357.5	588.4	15.7
44	59.0	50.8	98.0	7.5	7.8	75.2	148.8	354.7	31.7	333.1	591.2	17.2
45	66.0	61.2	100.0	8.6	6.7	68.2	151.8	333.1	30.9	334.4	555.2	16.7
46	64.0	60.6	98.0	8.4	7.8	80.6	157.6	457.0	30.7	337.4	763.0	19.7
47	61.0	58.0	97.0	6.3	7.4	97.6	150.8	384.8	31.0	397.2	641.4	16.0
48	60.0	51.5	100.0	8.9	8.1	81.0	160.1	453.9	29.8	388.8	756.5	18.5
49	56.0	59.9	96.0	8.5	8.1	95.7	150.3	410.2	30.3	326.3	683.6	20.6
50	60.0	65.0	100.0	8.1	7.8	72.4	156.1	431.1	30.6	368.5	718.5	18.0
Year												
2023	64.0	53.2	99.0	7.8	7.6	80.0	149.4	371.5	28.3	350.7	619.1	17.1
2024	63.0	59.3	99.0	9.0	8.0	92.7	156.5	408.7	32.9	358.6	681.2	18.4
Location												
Miango	65.0	54.5	99.0	8.2	8.0	79.0	152.1	339.1	31.2	330.4	565.2	16.8
Vom	61.0	58.0	100.0	8.6	7.5	89.7	153.7	441.1	30.1	378.8	735.1	18.8
Grand Mean	63.0		99.0	8.4	7.8	84.4	152.9	390.1	30.6	354.6	650.2	17.8

DH (Days to Heading), Plant Height (PH), Days to Maturity (DM), Number of Tillers (NT), Number of Grains per Spike (NGS), Number of Spikelets per Spike (NS/S), Grain Weight (GW), 1000-Grain Weight (1000-GW), Biological Yield (BY), Harvest Index (HI)

The Finlay-Wilkinson's regression graph is shown in figure 1.

The stability coefficients and line sensitivities are presented in figure 2. There were high

significant differences were observed among the environments and the lines, as well as the interaction between them. Based on the Finlay and Wilkinson's approach the stability

coefficient for grain yield of most of the lines was less than one, with only six lines having sensitivity (bi) values more than one. The highest bi value was line 50 (-1.54). Other bi values were observed for Line 15 (-1.42), 18 (-0.84), 41 (-0.64) and 10 (-0.62). The stable lines can be considered phenotypically stable based on grain yield across the different environments. The smallest bi value was noted for Line 10, followed by Line 41, 18, 15 and 50. Line in Vom had greater grain yield stability than those in Miango with year 2024 lines having the most sensitive stability coefficients for grain yield.

Yaghotipoor *et al.* (2017); Jhinjer *et al.* (2017) and Naheed *et al.* (2021) suggested that varieties with lower bi values can be recommended for this study.

locations with poor growing conditions. The regression results for grain yield only are in agreement with Naheed *et al.* (2021); Alemu *et al.* (2018) and Ali *et al.* (2008). Mahmodi *et al.* (2011) who determined stable bread wheat genotypes with high grain yield via a single parameter, field experiments were conducted with 14 genotypes for 3 consecutive years (2008-2011) under two different conditions (irrigated and rain-fed) in a complete randomized block design with three replications in each environment. A major biological problem pointed out by Westcott (1986) and Crossa (1990) is when only a few low or high yielding sites are included in a regression analysis as adopted in

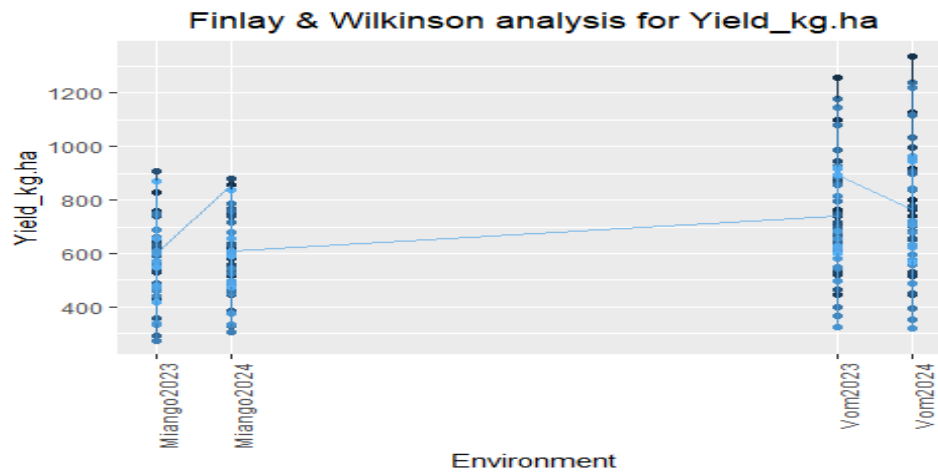


Figure 1: A Finlay-Wilkinson and Factorial regression graph for Grain yield (kg/ha)

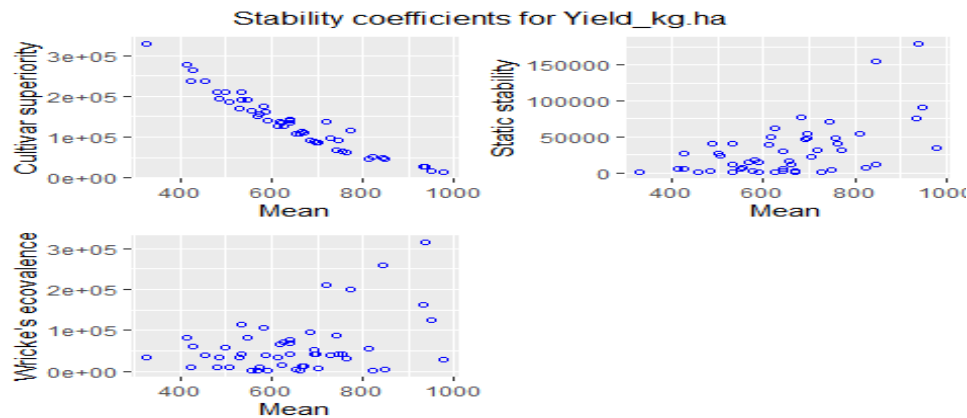


Figure 2: Stability Coefficients for Yield of 50 wheat genotypes evaluated in Vom and Miango in 2023 and 2024

CONCLUSION

This study has shown considerable variation among wheat genotypes. Results of the study showed that these lines may provide good source of material for further breeding program. Results reveal the superiority of Lines 2, 3, 22, 28 and 30 as highest high-yielding lines due to their mean performance for grain yield and other yield-contributing traits. The coefficient of variability suggests that location used in this study had no influence on the traits.

For regression results that estimated grain yield stability, the smallest *bi* value was noted for Line 10, 41, 18, 15 and 50 indicating their stability for grain yield. These lines provide a measure of greater resistance to environmental change, having above average stability but more specific adaptation to low yielding environments. Lines in Vom had greater grain yield stability than those in Miango with year 2024 lines having the most sensitive stability coefficients for grain yield. The study revealed the superiority of Lines 2, 3, 15, and 30 over other lines while Lines 10, 41, 18 and 50 show stability in terms of grain yield. The Lines at Vom performed better than those of Miango with year 2024 proving better conditions for high yields. Information from this study would be valuable to wheat breeders for developing high yielding varieties of wheat.

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FINGER MILLET: A CLIMATE RESILIENT CROP FOR SUSTAINABLE FOOD AND NUTRITION SECURITY IN NIGERIA

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ABSTRACT

Finger millet (*Eleusine coracana*) is a well known cereal crop that is grown in Africa and India as a staple food grain. Millets in general are the major food source for resource-poor farmers in the semi-arid tropics, due to their ability to grow in poor soils with limited inputs. The crop is considered as highly nutritious cereal with enhanced levels of essential nutrients compared to other cereals like; rice, maize and sorghum and it also has good storage qualities. Finger millet grain is said to have a better market price compared to other cereals as it contain 65-75% carbohydrates, 5-8% protein, 15-20% dietary fiber and 2.5-3.5% minerals and 0.3-0.4% calcium. Annual world production of finger millet has been projected to be over 4.5 million metric tons of grain. Finger millet is adaptable to diverse agro-ecological conditions, has beneficial nutritional properties and outstanding agronomic attributes as a subsistence food crop; therefore, it holds a great promise for the future of food and nutrition security in Africa and around the world. The primary obstacles to millet farming include; lack of high yielding varieties, decreasing cultivable land, Lack of awareness on the nutrient composition and value and neglect by research and development sector. It is therefore important to make the farmers aware of the crop and its importance. Furthermore, development of proper value chains, establishment of production cooperatives, and various value addition initiatives should be given adequate attention so that demand can drive the cultivation at greater scale.

Keywords: Finger millet, Food security and Nutritional importance

INTRODUCTION

Finger millet (*Eleusine coracana* subsp. *Coracana*, 2n= 4x =36) is known to be one of the main subsistence cereal crops in Africa and India. Currently, the crop is grown and used in over 25 countries of Africa and Asia mainly as a staple food grain (Zerihun, 2009). Millets in general are known to be major food source for resource-poor farmers in the semi-arid tropics, due to their ability to grow in poor soils with

limited inputs (Kothari *et al.*, 2005). The crop is considered as highly nutritious cereal with enhanced levels of essential nutrients compared to rice, maize and sorghum (Kandel *et al.*, 2019), and it also owes good storage qualities (Dida *et al.*, 2007). Finger millet grain is said to have a better market price compared to maize (Chimdo *et al.*, 2006), and contain 65-75% carbohydrates, 5-8% protein, 15-20% dietary fiber and 2.5-3.5% minerals (Chetan and Malleshi, 2007), and 0.3-0.4% calcium (Panwar *et al.*, 2010). Annual

world production of finger millet has been projected to be over 4.5 million metric tons of grain International Crop Research Institute for the Semi-Arid Tropics (2008). About 50% of the world finger millet production is produced annually in Africa (National Research Council, 1996). The crop is ranked fourth in importance among millets in the world after sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*) and foxtail millet (*Setaria italica*); and can be cultivated under varied agro-climatic conditions (Tsadol *et al.*, 2016; Upadhyaya *et al.*, 2007 and Dida *et al.*, 2007). In Nigeria, Glew *et al.* (2008) reported that the crop is cultivated in Southern part of Kaduna state in the Northern Guinea savanna and in the highlands of Jos

Plateau in the north central Nigeria. From survey the crop has also been found to be cultivated in Kano, Gombe, Bauchi, Nasarawa and Abuja (Umar and Kwon–Ndung, 2014).

In Nigeria, the finger millet plant is diverse and is widely used without restriction in our different multi-ethnic, multi-cultural and multi-religious groups (Shinggu *et al.*, 2016). It has been observed to have different names which vary with location as it is referred to as Tamba (Nigeria), Ragi (India), Mandua Winbi (Swahili) Bulu (Uganda), Kurakan (Sri Lanka), Fingerhirse (German). Epidemiological evidence has shown that the plant is widespread and well adopted to diverse regions of the world (Gupta *et al.*, 2010).

Table 1: Global production of millets in thousands per ton

Country	2010	2011	2012	2013
India	13293000	12660000	10750000	10910000
Nepal	2999523	302691	315067	305588
Nigeria	5170430	2711000	5000000	5000000
Sudan	471000	634000	378000	1090000
Uganda	267973	292000	244000	228000
South Africa	6900	7000	6500	6700
Ethiopia	634826	651851	742297	807056
Senegal	813295	480759	661673	572155
USA	261610	207500	70084	418145
Zimbabwe	50999	60000	44000	5500

Source: FAO (2013)

Potential Utilization of Finger Millet in the Food Industry

Composite Flour

Composite flour technology referred to process of mixing wheat flour with cereal and legume flour for making bread and biscuits. However, the term can also be used with regard to mixing of non-wheat flours, roots and tubers or other raw materials (Dendy, 1992). Composite flour technology makes it possible to blend, mix or fortify one food material with others so that the resulting fortified mix has not only better nutritional quality but also the necessary

attributes for consumer acceptance (Lupien, 1990). Fortification of finger millet in chapattis not only improves the taste but also helpful in controlling glucose levels in diabetic patients very efficiently (Kang *et al.*, 2008). The bulkiness of the fibers and the slower digestion rate makes us feel fuller Its high fiber content is further helpful to the individuals having the problem of constipation (Cade, 2007).

Popping

Popping or puffing is a simple processing technique of cereals to prepare ready to eat products. Popped grain is crunchy, porous and a

precooked product. Popped grains especially of finger millet possess a pleasant aroma and acceptable taste. This process improves the nutritional value by inactivating some of the anti-nutritional factors and thereby enhancing the protein and carbohydrate digestibility (Nirmala 2000). For puffing, the whole finger millet grain is conditioned by mixing additional water so as to reach its moisture content in the range of 18-20% and tempered for about 4-6 hours under shed.

The conditioned grains are puffed by agitation on the hot sand surface maintained at about 230 - 250°C for short time following HTST (high temperature and short time) process. During this process, the sugars present in the aleurone layer react with amino acids of the millet causing Millard reaction and as a result, a pleasant and highly desired aroma is developed.

Malting (Weaning Foods)

Malting of finger millet is a common technique in India and malted finger millet is considered superior to malted sorghum and malted maize. Studies have shown that finger millet develops higher amylase activity than sorghum and other millets (Malleshi and Desikachar, 1986; Senappa, 1988). Malleshi and Desikachar (1986) reported that finger millet malt has highly agreeable flavour with adequate starch hydrolyzing enzymes.

Malting of finger millet improves its digestibility, sensory and nutritional quality as well as has pronounced effect in lowering the anti-nutrients. The inherent qualities of Finger millet make it superior compare to other cereals and also qualify for malting and preparation of malted foods.

As it is resistant to fungal infection and elaboration of alpha and beta amylase during germination and during desirable aroma is developed during roasting/kilning makes it an ideal grain for malt foods.

Noodles

The changing food habits of children and teen aged groups have created a good market of noodles in India and even Nigeria. The demand for millet noodles particularly the noodles made out of finger millet is growing due to awareness of its nutritional properties. Noodles are the pasta products also known as convenience foods prepared through cold extrusion system which become hard and brittle after drying. The cooking of these noodles is very convenient and requires few minutes. Noodles of different combinations are prepared such as noodles exclusively made of finger millet, finger millet and wheat in the ratio of 1:1 and finger millet blended with wheat and soy flour in the ratio of 5:4:1. In case of exclusive millet-based noodles, pretreatment to the millet flour is given to facilitate extrusion and smooth texture which should retain while drying and cooking.

Roasting

Roasting and grinding processes render the grain digestible, without the loss of nutritious components (Krantz *et al.*, 1983). The puffing and roasting are almost similar processes, but the volume expansion in puffing is higher (Srivastava *et al.*, 1994). Roasting of cereals, pulses and oilseeds is a simpler and more commonly used household and village level technology which is reported to remove most anti nutritional or toxic effects such as trypsin inhibitor, hemagglutinin, giaterogenic agents, cyanogenic glycosides, alkaloids and saponins and increase storage life (Gopaldas *et al.*, 1982; Huffman and Martin, 1994

Fermentation

Fermentation can be spontaneously initiated without the addition of microorganisms or controlled by the use of specific cultures of

starters from previous batch of fermented products (Frazier and Westhoff, 1986). Changes that take place during fermentation include increase in amino nitrogen, the breakdown of proteins and destruction of any inhibitors that may be present (Davidek *et al.*, 1990). Traditionally, finger millet is consumed in the form of thick porridge (mudde or dumpling), thin porridge (ambali), fried and baked pancake (roti, dosa) and beverages (chang/ jnard). Most of these involve fermentation step (Madhavi and Vaidehi, 1990; Hadimani and Malleshi, 1993; Gomez, 1993). Fermentation of finger millet using different cultures has been shown by Antony *et al.* (1996), Antony and Chandra (1999), and Mbithi *et al.* (2000). Lactic acid fermentation has been found to affect the amount of amino acids in cereals and legumes. Hamad and Fields (1979) observed that fermentation increased the lysine content in millets. Fermenting finger millet with *Lactobacillus salivarius* caused an increase in tryptophan and lysine by 17.8 and 7.1%, respectively. Also, the leucine to lysine ratio, which is an indicator of pellagrogenic character of protein, decreased significantly during fermentation (Mbithi *et al.*, 2000).

Bakery Products

Incorporation of finger millet flour in the preparation of bakery products like biscuit, nankhatai, muffins and bread has been attempted and efforts are being made to standardize the recipe and product quality. The use of millets in bakery products will not only be superior in terms of fiber content, micronutrients but also create a good potential for millets to enter in the bakery world for series of value added products. In a recent study, attempts have been made to improve the nutritional quality of cakes with respect to the minerals and fiber content by supplementing with malted finger millet flour (Desai *et al.*, 2010). In recent years, finger millet

has received attention and efforts are under way to provide it to the consumer's inconvenient forms (Singh *et al.*, 2012).

Finger millet crop management

Finger millet provides farmers with a reliable access to food and nutrition in environments with erratic and scanty rainfall, and low soil fertility levels. This is attributed to its wide genetic adaptation and ability to grow successfully in diverse soils, varying rainfall regimes, diverse photoperiods, in marginal, arid and mountainous terrains where major cereals have low success (Padulosi *et al.*, 2009). Additionally, it is often the grain left in storage after the major cereal grains have been destroyed by storage pests. Indeed, studies have determined that finger millet stores for 10 years or more without damage by storage pests (United States National Research Council, 1996; Adekunle, 2012), a major limiting factor for food security in Africa. Despite these desirable qualities, finger millet yields in Africa have steadily declined in countries such as Uganda, Ethiopia and Kenya (Kidoido *et al.*, 2002; FAO, 2006; Dida *et al.*, 2008; Oduori, 2008).

Finger millet production constraints in Eastern Africa include low soil fertility, environmental and nutrient stresses, pests and diseases, including blast disease (*Magnaporthe grisea*), and Striga weed (*Striga hermonthica* (Del.) Benth) (Wanyera, 2007; Oduori, 2007), among other constraints. Adoption of improved varieties and management practices such as use of fertilizers could improve finger millet yields (Oduori, 2008). Application of NPK along with micronutrients and FYM at the rate of 7.5 – 12.5 tha^{-1} increases yield of finger millet (Thilakarathna and Raizada, 2015). Finger millet is also known to benefit from residual fertility from the previous crop. Therefore, recommendations should consider crop management systems that include rotations with high-residue producing crops. Maintenance of

surface residue cover combined with reduced tillage results in greater soil organic carbon and nitrogen, and has the potential of improving soil productivity (Mahli and Lemke, 2007).

Other soil fertility replenishment approaches have been developed based on naturally available resources and cropping systems. Zapata *et al.*, (2002) recommended direct application of indigenous rock phosphates which are potentially important locally available

phosphorus (P) sources for resource-poor farmers in extremely P deficient soils in Africa, Asia and Latin America. Studies have also shown that incorporation of green manure including *Tithonia diversifolia* could increase the availability of N, P and K (Partey *et al.*, 2010). Tens of thousands of farmers in east and Southern Africa who have adopted these technologies have become food secure (Sanchez, 2002).

Table 2: Nutrient composition of finger millet and other cereals (per 100 g edible portion; 12% moisture)

Component	Rice (brown)	Wheat	Maize	Sorghum	Pearl Millet	Finger Millet
Energy (kcal)	362	248	358	329	363	336
Carbohydrate (g)	76	71	73	70.7	67	72.6
Protein (g)	7.9	11.6	9.2	10.4	11.8	7.7
Fat (g)	2.7	2	4.6	3.1	4.8	1.5
Ash (g)	1.3	1.6	1.2	1.6	2.2	2.6
Crude fibre (g)	1	2	2.8	2	2.3	3.6
Ca (mg)	33	3	26	25	42	350
Fe (mg)	1.8	3.5	2.7	5.4	11	3.9
Thiamin (mg)	0.41	0.41	0.38	0.38	0.38	0.42
Riboflavin (mg)	0.04	0.1	0.2	0.15	0.21	0.19
Niacin (mg)	4.3	5.1	3.6	4.3	2.8	1.1

All values except protein are expressed in dry weight basis (Saleh *et al.*, 2013)

FOOD SECURITY

Food security occurs when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (Carletto *et al.*, 2013 and FAO, 2014).

The latest FAO estimates indicate that World hunger increased in 2020 under the shadow of the COVID-19 pandemic. After remaining virtually unchanged for five years, the prevalence of undernourishment (PoU) equally increased from 8.4 to around 9.9 percent in just one year, heightening the challenge of achieving the Zero Hunger as targeted by 2030. While the global prevalence of a moderate or severe food

insecurity (measured using the Food Insecurity Experience Scale) has been slowly on the rise since 2014, this estimated increase in year 2020 was equal to that of the previous five years combined. Nearly one in every three people in the world (2.37 billion) did not have access to adequate food in 2020 this has resulted to an increase of almost 320 million people in just one year (FAO, 2020)

In Nigeria, the poor macroeconomic conditions and high levels of conflict in northern Nigeria are the key drivers of acute food insecurity. This is compounded by the fact that there has been a continuous widespread flooding and below-average income, which drove low access to agricultural inputs, resulting in a below-average harvest (Shinggu *et al.*, 2016).

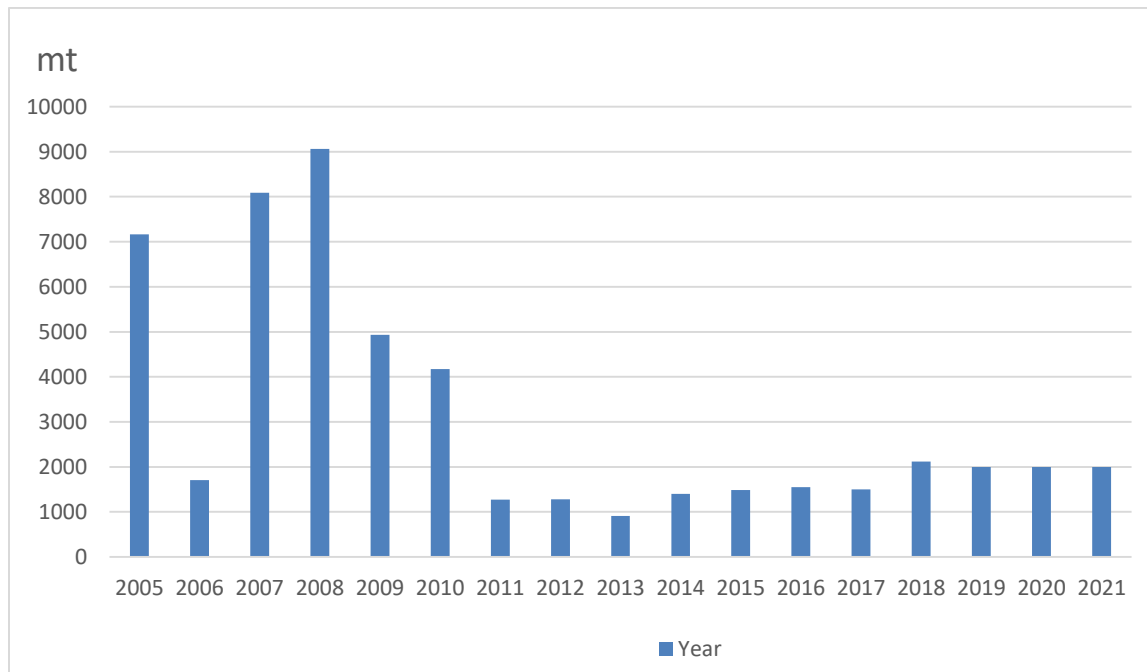


Figure 1: Status of millet production between 2005 and 2021 in Nigeria
Source: FAO 2021

FINGER MILLET CULTIVATION IN NIGERIA

Glew *et al.* (2008) reported that finger millet is cultivated in Southern part of Kaduna state in the Northern Guinea savanna and in the highlands of Jos Plateau in the north central Nigeria. From a survey of Umar and Kwon-Ndung (2014), the crop has also been found to be cultivated in Kano, Gombe, Bauchi, Nasarawa and some part of Abuja. Further studies reviewed that finger millet is also cultivated in Niger and Adamawa states (Tsado1 et al., 2016)

CHALLENGES OF MILLETS CULTIVATION IN NIGERIA

Finger millet is a rich source of food, fodder, and revenue that is mostly farmed by small holder farmers. Unfortunately, there are a number of obstacles to finger millet production that limit its potential to improve food security and reduce poverty. The primary obstacles to finger millet farming in Nigeria are stated below

- i. Lack of high yielding variety: One of the main challenges of finger millet cultivation is the lack of access to improved varieties and production technologies. Most of the millet varieties grown in Nigeria are local landraces.
- ii. Decreasing cultivable land: There are significant natural and human-made are worrying issues that must be address. Due to urbanization, serious deterioration of environmental assets like soil, water, climate, etc., the reoccurring onset of disastrous flood and drought, and the impending threat of salinity increase in the coastline, the amount of arable land is declining at an alarming rate ($0.1\% \text{ yr}^{-1}$) (AIS)
- iii. Low productivity: FAO (2015), reported that millets are typically regarded as low-yielding crops with

lesser productivity as comparing to other crops like rice and wheat. Low productivity is caused by a number of factors, including the absence of better varieties, insufficient inputs, and poor agronomic techniques. Inadequate crop, soil, and water management combined with ongoing land degradation result in a significant yield gap between farmers' practices and crops' potential yields.

- iv. Labour intensive: Crop compared to other major cereals, requiring high labour input mainly during transplanting, weeding, harvesting, threshing and grinding. This increases the workload of farmers, especially women, throughout the whole process of cultivation and preparation of finger millet food items. The crop is mostly grown in the sloped or bench terraces in the hills, with limited possibility of mechanization to reduce the drudgery associated with production and postharvest operations.
- v. The view that the crop is considered 'low status food' or 'food of marginalized communities: Although it is consumed by the majority of households in the mid and high hill regions in varying quantity, irrespective of ethnicity.
- vi. Lack of awareness on the nutrient composition and value of finger millet on human health: This present the obvious fact why there is a low rate of consumption especially among the younger generation.
- vii. Neglect by research and development sectors. Finger millet has received inadequate policy support for variety development,

cultivation, value addition and promotion. Information on area and cultivation of finger millet is scanty and it's grown and consumed by a few farmers in different parts of the country.

NUTRITIONAL IMPORTANCE OF FINGER MILLET

Finger millet grains can be seen as the most nutritious cereal crop. They are rich in essential minerals such as calcium (Ca) and phosphorus (P). The grains contain the highest amount of Ca, ranging from 162.0-358.0 mg/100g when compared to other millet species (Manjula *et al.*, 2015). Calcium which is predominantly present in finger millet, plays vital role in growing children, including pregnant women and the elderly (Jideani, 2012; Chappalwar *et al.*, 2013) as well as in people suffering from obesity, diabetes and malnutrition (Jayasinghe *et al.*, 2013; Manjula *et al.*, 2015). Deficiency of Ca in the body can be put to a halt by consuming finger millet food products in the daily diet of both young and elderly people (Towo *et al.*, 2006). Phosphorus is another mineral that is present in finger millet responsible for the development of body tissue and energy metabolism, with concentration of P in finger millet ranging from 130.0-283.0 mg/g. Other minerals present in FM grains include iron with a concentration of 3-20% (Rajiv *et al.*, 2011; Shukla and Srivastava, 2014) and magnesium implicated for the reduction of high blood pressure, severity of asthma, frequency of migraines and the risk of heart attack (Saleh *et al.*, 2013; Verma & Patel, 2013; Prashantha & Muralikrishna, 2014). In comparison with other millet species, FM grains are more nutritious (Upadhyaya *et al.*, 2011; Adhikari, 2012; Shobana *et al.*, 2013; Devi *et al.*, 2014; Dlamini & Siwela, 2015), with higher mineral content and proximate composition,

though the grain is still extremely neglected and widely underutilized (Roopa & Premavalli, 2008).

Nutraceutical Importance of Finger Millet:

The genus *Eleusine* is derived from the name of Greek goddess of cereals, “Eleusine” while the common name finger millet comes from “finger-like” branching of the panicle of the crop. It may be one of the oldest indigenous domesticated cereal in tropical regions of Africa. It is a highly productive crop that can tolerate many types of stressful environmental conditions, and is also organic by default. It can be cultivated on marginal and less fertile soils and is independent of the use of chemical fertilizers, hence, is a boon for the vast arid and semi-arid regions (Gull *et al.*, 2014). The different species of finger millet have genes for early maturity, vigorous growth, increased size and number of panicles and branching as well as high-density grains. Some of the species have higher water use efficiency with higher carbon dioxide fixation rates with minimal leaf area and hence could perform excellent in semi-arid climates. It is one of the most efficient utilizer of nitrogen (Gupta *et al.*, 2014). Finger millet seeds are known to be resistant to storage pests for as long as 10 years, that ensures year round food supply or even during a crop failure, that’s why it is also called as ‘famine crop’ (Mgonja *et al.*, 2007).

Finger millet is a vital component in the diets during pregnancy and lactating stage of women, and children as well as for the economy of marginal farmers. It is relatively rich in protein, vitamins, minerals, fiber content and energy than other cereals (Vadivoo *et al.*, 1998). Few varieties of finger millet are found to contain about 450 mg of Calcium per 100g of grains (Gupta *et al.*, 2011). It also contains higher amount of manganese, phosphorus, iron, copper, chromium, magnesium, molybdenum, zinc and

selenium (Tripathi and Platel, 2010). Therefore, it can be used as preventative drug for many diseases and also used as good quality animal fodder because of higher amount of easily digestible nutrient. Its seed coat contains higher amount of phytochemicals like dietary fibres, polyphenols and is also rich in minerals especially calcium. The seed coat is also having anti-cancerous and antidiabetic properties, because of its higher polyphenol content, which shows the anti-oxidant activity and high fibre content results in slow digestion and stability in blood sugar level (Devi *et al.*, 2014).

The finger millet grains are rich in essential amino acids like methionine and tryptophan as compared to common staple crops such as rice and wheat (Fernandez *et al.*, 2003). Finger millet is having amino acids in such a concentrations that exceeds the level recommended by those of WHO/FAO. It is rich in methionine and lysine (Mbithi-Mwikya *et al.*, 2000). Supplementation of finger millet along with lysine, proteins or legumes like chick pea, green gram and soybeans improves its protein quality even further (Belton & Taylor, 2004). Finger millet slow digestibility, thereby providing energy throughout the day. The plant itself is found to be diaphoretic, diuretic, and vermifuge, and juice of its leaves has been given to women in childbirth (Dida and Devos, 2006). Due to its medicinal property, it has been used for treatment of wide ailments among which are leprosy, liver disease, measles, pleurisy, pneumonia, and small pox etc. as a folk remedy (Dida and Devos, 2006). Finger millet is having higher level of fiber, which prevents diseases like constipation, high cholesterol formation, diabetes and intestinal cancer etcetera (Devi *et al.*, 2014). Finger millet based diet also helps in reducing blood sugar level when compared with rice and wheat based dietary system due to the abundance of fibre, which is good for the diabetic people (Kumari and Sumathi, 2002). Due to the presence of few anti-nutritional

factors in the flour of whole finger millet, it reduces the digestion and absorption of starch that creates a lower glycemic response (Shobana *et al.*, 2007). In this way finger millet is having an excellent nutraceutical properties.

CLIMATE RESILIENCE OF FINGERMILLET

Climate change is today a major threat to global food security now a days, which has been adversely affecting the agricultural crop production system, because without conducive climatic condition there will be decrease in productivity as well as total food production. All the crop species are not susceptible to adverse climatic condition, the degree of susceptibility differs from species to species (Dida and Devos, 2006). Stress adaptability is a complex phenomenon that is managed at different levels including physiological, cellular and molecular. Determining the stress tolerance mechanisms of plant and adaptation to adverse condition has long been the area of interest to agricultural scientists. Finger millet is given more importance for its growth under limited resources along with higher nutritional value (Gull *et al.*, 2014). Despite its many resistance and nutritional properties, the crop has been neglected for reasons yet unknown.

Ever increasing global concerns over food and nutritional insecurity and reduction of agricultural productivity due to climate change has resulted to an increased in the demand of climate resilient crops. As per the data of World Summit on Food Security at least 70% more food production is required by 2050 to feed the ever increasing population (Tester and Langridge, 2010). Because of this scenario, finger millet has become a satellite for scientific research for its unique quality of growing under less moisture and higher temperature condition. Finger millet is considered as an abiotic stress tolerant plant, even then to identify newer sources in this crop that can be used for the

purpose of crop improvement. For the assessment of genetic diversity for both abiotic and biotic stress tolerance in finger millet, germplasm collections is of major importance. A large number of finger millet accessions have been preserved in the national and international Gene Banks in Asian, African, and European countries as well as USA. India has the largest collection of finger millet germplasm followed by Ethiopia (Dwivedi *et al.*, 2012). There may be a lot of morphological and genetic diversity among different finger millet accessions or their core collections. Molecular markers is required to describe functional diversity in this crop (Kumar *et al.*, 2015). Dynamics of Calcium content (Yadav *et al.*, 2014), accumulation of tryptophan and its association mapping (Babu *et al.*, 2014) and the resistance towards different diseases (Babu *et al.*, 2014) have been described by the use of molecular markers (Babu *et al.*, 2014). Though, description of abiotic stress resistance of finger millet using molecular markers is yet very limited and offers a scope of exploring the vast collections of cultivated and wild accessions of this crop.

FINGER MILLET GERMPLASM EVALUATION AND VARIETY IMPROVEMENT

Successful crop improvement requires the ability to identify and access genetic diversity including new or improved variability for target traits. Plant genetic resources are basically the raw materials for the development of improved cultivars (Upadhyaya *et al.*, 2007). In crops with large germplasm collections such as finger millet, mini core collections (10% of core or 1% of the entire collection) have been suggested (Upadhyaya and Ortiz, 2001). These are composed of a smaller number of well characterized accessions which are given priority for use in crop improvement (Upadhyaya *et al.*, 2009). A finger millet mini

core collection of over 80 accessions has been developed at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India. Accessions ranked highly for desirable traits including grain yield are recommended for adoption in areas where finger millet is commonly grown, after undergoing multi-location testing to verify their agronomic and utilization potential. Enhanced germplasm evaluation for targeted traits would be of enormous importance as will help breeders to develop high yielding cultivars with a broad genetic base (Upadhyaya *et al.*, 2006).

To date, small millets have been improved through conventional breeding due to their self-pollinating nature. Despite all these, there is need to assess the efficacy of other types of breeding procedures including biotechnology, so as to develop resistance against biotic and abiotic stresses and continue to improve quality for wider consumer acceptance and utilization. Studies to determine field performance potential of finger millet germplasm may be complemented by marker assisted selection for rapid trait identification and incorporation into improved germplasm. In a study employing Random Amplified Polymorphic DNA (RAPD), a higher genetic diversity was observed among 12 wild finger millet accessions, indicating that they contain a large proportion of genetic variation (Fakurdin *et al.*, 2004) which may be exploited for genetic improvement of finger millet in Africa.

MOLECULAR MARKERS FOR ASSESSING GENETIC DIVERSITY, SPECIES RELATIONSHIP AND ORIGIN OF FINGER MILLET

Genetic diversity refers to the variations within the individual gene loci/among alleles of a gene, or gene combinations, between individual plants or between plant populations. The morphological diversity present within finger

millet is immense. For example, a range of seed colors can be produced, which are correlated with protein and calcium content (Vadivoo *et al.*, 1998). Landraces with different attributes (e.g., time to maturity, bird tolerance, drought tolerance) are valued by farmers based on local agricultural complexities that reflect their productivity across multiple agro-economic zones (Tsehaye *et al.*, 2006). Genetic diversity offers opportunities to utilize various genomic resources and technologies to manipulate desirable traits. Studying genetic diversity using molecular markers such as random amplification of polymorphic DNA (RAPDs), inter-simple sequence repeats (ISSRs), simple sequence repeats (SSRs), restriction fragment length polymorphisms (RFLPs), amplified fragment length polymorphisms (AFLPs), and expressed-sequenced tags (ESTs) etc. provide unique opportunities to quickly and accurately access the genetic variability in a given population. Compared to rice and other common cereals, there are very few reports on diversity studies of finger millet using molecular markers. However, the design and use of molecular markers in finger millet genomic studies are now beginning to appear in the literature.

Early marker-assisted research suggested that there was little sequence diversity in finger millet populations (Muza *et al.*, 1995; Salimath *et al.*, 1995). Since, finger millet is grown in different parts around the world and is adapted to diverse climatic conditions, the possibility of the existence of considerable genetic diversity among the finger millet germplasm/population cannot be neglected. Subsequent development of molecular markers has enabled linkage map of the finger millet genome to be assembled (Dida *et al.*, 2007). With the recent progress, the availability of a published genomic sequence would accelerate the development of markers to assist genotypic classification and breeding practices.

CONCLUSION

In view of all above mentioned qualities, it is hard to believe why finger millet remain neglected. Compared to the ample researches related to wheat, rice, and maize, there were very few attempts that have been made in the past related to this very important but neglected orphan crop. Throughout the world, this important crop is still unknown to the common populations of developing countries and even many countries that grow it have left this crop as a "poor person's crop"; a "famine food"; or, even worse, just designated as a "bird seed." But the reason is simple, people are neglecting it because of their attention towards maize and sorghum. The cultivation is relatively tedious, which is another reason for lesser production of the crop. However, the reality is that finger millet have a great potential to fulfill the ever increasing demand for food and indeed nutritious food for mankind. Thus dedication and proper strategies are needed to popularize these important crop for better investment and cultivation.

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ANIMAL PRODUCTION

GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF WEANER RABBITS FED
DIETS CONTAINING AFRICAN WILD GRAPE LEAF (*Oryctolagus cuniculus*) MEAL AT
DIFFERENT LEVELS OF INCLUSION.

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ABSTRACT

Feeding trial for 70 days was conducted to evaluate meat quality characteristics of rabbits fed diet containing African wild grape leaf meal at different levels of inclusion. A growth performance and carcass characteristic of rabbit's meat was assessed. Five diets were formulated, comprising treatment 1(control), 2, 3, 4 and 5 at 0%, 5%, 10%, 15% and 20% levels of African wild grape leaf meal respectively. Forty (40) bucks Exotic breed weaner rabbits of 700±60g consisting five treatments with four rabbits per replicates and eight rabbit per treatment allotted in a Completely Randomized Design (CRD). Data generated were subjected to the analysis of variance (ANOVA), where significant differences exist; Duncan's Multiple Range Test was used to compare the means. Results showed that the growth performance of the rabbits was not significant across the treatments, except for the final body weight and daily feed intake. The objective of this study is to determine the growth performance of weaner rabbit and evaluate the carcass and organs percentage of weaner rabbit's meats fed diets containing African wild grape leaf meal at different levels of inclusion. *Lannea microcarpa* can safely be included in rabbit diets for up to 20% compromising productivity.

Keywords: weaner rabbit, growth, carcass and African wild grape

INTRODUCTION

Rabbit production has been identified as a possible means to mitigate the protein shortage of the malnourished average third world population (Ahamefule *et al.*, 2008). Rabbit's meat contains high protein level (about 20.8%) and its consumption is bereft of cultural and religious biases and it also has excellent quality attributes (Jibir *et al.*, 2014) such as having great potential in boosting the protein supply in Nigeria (Owen *et al.*, 2008). Accentuated growth of both world population and life expectancy could lead to a future "food crisis" whilst the

demand for animal protein increases, the conventional sources are insufficient, and areas for agriculture and fodder crop usage have become less available (Krunz *et al.*, 2022). Designing food products containing rabbit meat could be a response to increasing consumers' repeatable satisfaction when buying such products (Petracci *et al.*, 2018). Rabbit meat is considered a functional food due to its high nutritional properties (Pogany *et al.*, 2022). Rabbit meat is generally considered to be a healthier alternative to beef and pork however, the actual nutritional composition of rabbit meat can be affected by intrinsic and extrinsic factors,

including genotype, sex, age, husbandry and diet (Luchyn, 2022).

The use of forages and other agricultural by-products such as *Tridax precumbens* (Taiwo *et al.*, 2005), *Moringa oleifera* (Odeyinka *et al.*, 2008), *Acacia nilotica* (Abdu *et al.*, 2011), composite cassava meal, *Commelina benghalensis*, *Leucerna leucocephala*, *Boerhavia diffusa* and *Impomia triloba* (Ukachukwu *et al.*, & 2011 Yakubu *et al.*, 2012) have been documented. Non-conventional feed resources refers to all those feeds that have not been traditionally used in animal feeding or are not normally used in commercially produced ration for livestock. In several African countries, natural tree products constitute an important part of human diets and are also an important source of income (Thiombiano *et al.*, 2014). African grapes (*Lannea microcarpa*) or wild grapes commonly known as 'Faaru' in Hausa, belongs to the family *Anacardiaceae*. It has proximate composition of protein 15.313%, fat 5.295%, moisture 9.082%, fibre 14.45% and available carbohydrate of 61.133% and its found in the savannah zone of West Africa, in Nigeria, it is commonly found in the Northern states of Sokoto, Kebbi, Zamfara, Kaduna, Katsina, Kano, and Jigawa. The tree is cultivated commercially on a small scale and can be seen in and around villages. The leaves are used as feed to ruminant animals and the fruit makes an excellent jam or can be made into wine while the pulp is fermented into a potent alcoholic drink (Yunus *et al.*, 2013). This study was conducted to determine the effect of graded levels of African wild grape leaf meal on growth performance, carcass traits and organ characteristics of weaner rabbits.

MATERIALS AND METHODS

Location of the Experiment

The research was conducted at the Teaching and Research Farm of Federal University Dutse,

Jigawa State, Nigeria. Dutse is located between latitude 11° 45' 22.25" and longitudes 9° 20' 20.26" E, at an altitude of 485 m above sea level (Encarta, 2007). The state is situated within the Sudan Savannah Vegetation Zone, but there are traces of Guinea savannah in the southern region of the State (Olofin *et al.*, 2008). Prior to the commencement of the experiment, the housing together with the cages were thoroughly disinfected and allowed to dry. Each cage was provided with a feeder and a drinker for daily provision of feed and fresh water.

Experimental Design

Forty (40) mongrel weaner rabbits, of about six (6) weeks of age weighing averagely 750g±50 were randomly allotted to five (5) dietary treatments, replicated four (4) times with two (2) rabbits per replicates in a completely randomized design (CRD). Five (5) diets of 16% crude protein consisting of *Lannea microcarpa* leaf meal at 0, 5, 10, 15, and 20% were formulated as treatments 1, 2, 3, 4 and 5, respectively.

Source of Experimental Materials

African wild grape leaves were sourced from Jahun Local Government Area, Jigawa State. The leaves were collected and transported in jute bags to the Teaching and Research Farm of Federal University Dutse, where they were air-dried and later milled with a milling machine Abro (P 207) and bagged for diet formulation.

Data Collection and Statistical Analysis

The rabbits were fed in the morning (7.15 – 8.15am) daily, the quantity of feed supplied to them were weighed every morning and the left over from the previous day weighed to compute feed intake. Twenty (20) rabbits (4 from each treatment) were used for carcass analysis. Organs such as heart, liver, kidney, lungs and

spleen were weighed. The gut characteristics (small intestine, large intestine and caecum) were also weighed. Data collected were subjected to analysis of variance technique (ANOVA) as described by Steel and Torrie (1984), where significant differences existed between treatments, Duncan's Multiple Range Test was used to separate the mean.

Carcass Measurements

At the end of the experiment, rabbits whose weights were nearest to the average in each replicate were selected, slaughtered and eviscerated. The live weight were taken prior to slaughtering and the dressed weight was also been recorded. The carcass such as hind limbs, fore limbs, ribs, loin, neck, were weighed and recorded while organs including spleen, kidney, lungs, liver, heart and guts such as caecum, small intestine and large intestine were also weighed and recorded using a sensitive digital

electronic scale. The weights were expressed as percentage of respective live weights.

$$\text{Dressing percentage} = \frac{\text{Carcass weight}}{\text{Live weight}} \times 100,$$

$$\% \text{ Cut part} = \frac{\text{Cut part}}{\text{Live weight}} \times 100$$

RESULTS

Growth Performance of Weaner Rabbit Fed Diet Containing African Wild Grape Leaf at Different Levels of Inclusion

Table shows the Growth Performance of Weaner Rabbit Fed Diet Containing African Wild Grape Leaf at different Levels of Inclusion. The result indicated no significant difference ($P>0.05\%$) between treatments on initial body weight, live weight gain, feed conversion ratio, average daily gain, however there were significant differences ($P<0.05$) in daily feed intake, final body weight, daily feed intake, total feed intake and average daily gain were all reported in T5 while T3 had the least.

Table 1: Composition and calculated analysis of the experimental diet (%)

Ingredient	Treatments				
	(T ₁)0%	(T ₂)5%	(T ₃)10%	(T ₄)15%	(T ₅)20%
Maize	43.00	43.00	43.00	43.00	43.00
Soya bean cake	15.90	15.90	15.90	15.90	15.90
African wild grape leaf	0.00	5.00	10.00	15.00	20.00
Wheat offal	36.60	31.60	26.60	21.60	16.60
Bone meal	3.50	3.50	3.50	3.50	3.50
Table salt	0.30	0.30	0.30	0.30	0.30
Lysine	0.20	0.20	0.20	0.20	0.20
Methionine	0.20	0.20	0.20	0.20	0.20
Vitamin premix	0.30	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00	100.00
Calculated Analysis					
Crude protein (%)	16.00	16.00	16.00	16.00	16.00
Metabolized energy(kcal/kg)	2270	2267	2263	2259	2256
Crude fibre (%)	15.23	19.17	17.90	16.63	15.34
Ether extract (%)	4.56	4.45	4.98	5.33	5.12
Ash (%)	6.32	6.19	5.34	6.02	5.88

Table 2: Growth Performance of Weaner Rabbits Fed Diets Containing African Wild Grape Leaf at Different Levels of Inclusion

Parameter	Treatments					P Value
	T ₁	T ₂	T ₃	T ₄	T ₅	
Daily Feed Intake	87.50 ^b	85.75 ^b	80.50 ^b	82.25 ^b	109.75 ^a	0.0307
Initial body weight (g)	770.50	755.50	760.00	745.00	760.75	0.9423
Final body weight (g)	1320.0 ^b	1349.00 ^b	1394.80 ^a	1352.50 ^b	1397.30 ^a	0.0433
Total Weight gain	549.50	593.50	634.80	607.50	636.50	0.1183
Average Daily gain(g)	7.85	8.479	9.068	8.679	9.093	0.1183
Total Feed intake (g/day)	6125	6003	5635	5758	7683	0.3681

Note: ^{abc} Means with different superscripts within the same row are significantly different (P< 0.05).

Table 3: Carcass Characteristics and Cut Organs of Weaner Rabbit Fed Diet Containing African Wild Grape Leaf at Different Levels of Inclusion

Parameters	Treatments					P- value
	T ₁	T ₂	T ₃	T ₄	T ₅	
Live weight (g)	1320.0 ^b	1349.0 ^a	1394.75 ^a	1355.0 ^a	1397.25 ^a	0.0009
Bladed weight (g)	1308.00 ^b	1331.00 ^b	1370.25 ^a	1333.25 ^b	1376.75 ^a	0.0089
Carcass weight (g)	622.50	652.50	680.75	685.00	673.00	0.1243
Carcass dress (%)	49.46	48.35	49.46	50.61	48.16	0.2280
Cut up (%)						
Head	9.26	9.25	8.46	9.18	8.84	0.2449
Neck	2.13 ^c	2.93 ^a	2.82 ^a	2.92 ^a	2.77 ^b	0.0001
Hind limbs	10.31 ^a	6.58 ^b	6.40 ^b	6.80 ^b	6.48 ^b	0.0001
Fore limbs	7.42	7.10	7.12	7.36	7.38	0.8294
Ribs	9.01 ^a	9.40 ^a	7.47 ^b	8.18 ^a	8.12 ^a	0.0444
Loin	7.58 ^a	5.63 ^b	5.85 ^b	5.74 ^b	5.60 ^b	0.0019
Organ weight (g)						
Spleen	1.35	1.38	1.38	1.42	1.35	0.5224
Kidney	10.75 ^b	11.75 ^a	11.75 ^a	13.00 ^a	13.25 ^a	0.0850
Lungs	12.25 ^b	14.25 ^a	15.00 ^a	15.25 ^a	14.50 ^a	0.0152
Liver	39.25 ^b	46.25 ^a	45.50 ^a	44.50 ^a	45.75 ^a	0.0437
Heart	4.23	4.28	4.33	3.88	4.12	0.4723
Guts (cm)						
Caecum	47.25 ^a	34.25 ^b	35.00 ^b	37.25 ^a	37.25 ^a	0.010
Small intestine	238.00	252.00	253.25	246.25	251.50	0.4819
Large intestine	62.00 ^b	79.75 ^a	87.50 ^a	86.00 ^a	87.00 ^a	0.0008

Note: ^{abc} Means with different superscripts within the same row are significantly different (P< 0.05).

DISCUSSION

Growth Performance of Weaner Rabbit Fed Diet Containing African Wild Grape Leaf at Different Levels of Inclusion

The daily feed intake recorded in all the dietary treatments were below the range of 136.3 and 149.9 g as reported by Gidenne *et al.* (2019) and higher than the range of 78.7- 87.90 g as reported by Baba (2017). There is slight increase with increasing level of test materials across all the treatment except in T4 in daily feed intake of

rabbits fed African wild grape. The daily weight gains of the experimental rabbits were within the range of 7.48 to 10.91 g as reported by Mohammed *et al.* (2011).

The higher weight gain of rabbit on T3 and T5 diets could be due to efficient utilization of nutrients by the animals which is similar with report of Ajagbonna *et al.* (2013). The Feed Conversion Ratio of the experimental animals were lower than the range of 5.01- 16.25 as reported by Bello and Mikail (2021). However, the values were similar to (5.38 -5.39 g) reported by Jokthan *et al.* (2013), this may be attributed to the different experimental materials and might be a good indication of better utilization of African wild grape leaf by the experimental animals. Higher total weight gain reported across the treatments showed a better acceptability of the diets.

Carcass Characteristics and Cut Organs of Weaner Rabbit Fed Diet Containing African Wild Grape Leaf at Different Levels of Inclusion

Carcass Characteristics and Cut Organs of Weaner Rabbit Fed Diet Containing African Wild Grape Leaf at different Levels of Inclusion were presented in table 7. The Result showed significant difference between the treatments in terms of live weight, slougher weight, hind limbs, liver, lungs, loin, ribs, neck, weight of kidney, Caecum and large intestine ($P<0.05$), however significant difference does not exist in carcass dressing, head, fore limbs, spleen, heart and small intestine ($P>0.05$). Live weight, kidney, liver and large intestine in T5 had the highest score and T1 has the least score statistically.

Carcass Characteristics and Cut Organs of Weaner Rabbit Fed Diet Containing African Wild Grape Leaf at Different Levels of Inclusion

DISCUSSION

Carcass weight increased with increasing levels of African wild grape leaf across the diets, except in T5. These values were comparable to the 649.00 to 794.00 g as reported by Abubakar *et al.* (2015) for weaner rabbits fed red sorghum based diets. The dressing percentage in this finding scored higher in treatment 4; the dressing percentage range obtained in this study was lower than the range of 55.30-67.45% as reported by Bello and Mikail (2021). The values obtained for weight of the heart were similar to the range of 3.90-4.15g as reported by Ozung *et al.* (2019). The weight of liver in this study is comparable to the 42.30-53.40 g reported by Odeyinka *et al.* (2011) for weaner rabbits fed soybean milk residue, cowpea testa and corn starch residue in diets. Higher values of liver weight could be an indication of the extent of its involvement in feeds digestion and metabolism. The weight of lungs, heart and kidney were comparable to the values reported by Abubakar *et al.* (2015). Other measurements which include small and large intestine, caecum, stomach, hind limbs, ribs and loin were not affected by the dietary treatments (Joseph *et al.*, 2014).

CONCLUSION

Based on the results of this study, it was concluded that weaned rabbits can utilize varying levels of African Wild Grape Leaf at up to 20% level in diets without any adverse effects on growth performance, carcass yield, organ and gut characteristics.

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HAEMATOLOGICAL AND SERUM BIOCHEMISTRY PROFILES OF RED SOKOTO BUCK KIDS SUPPLEMENTED WITH SELECTED BROWSE PODS IN A SEMI-ARID ENVIRONMENT.

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ABSTRACT

This study evaluated the effects of supplementing four browse pods on the hematological and serum biochemical parameters of twenty growing Red Sokoto buck kids (GRSBK). Twenty GRSBK were randomly assigned to five dietary treatments in a completely randomized design: T1 (control), T2 (*Faidherbia albida*), T3 (*Vachellia tortilis*), T4 (*Acacia nilotica*), and T5 (*Piliostigma reticulatum*) for 12 weeks. Hematological parameters, except for mean corpuscular hemoglobin (MCH) and platelets (PLT) which differed significantly ($p < 0.05$), were similar ($p > 0.05$) across treatments. Similarly, most serum biochemical parameters (albumin, creatinine, total protein, alkaline phosphatase, alanine aminotransferase, aspartate aminotransferase, and bilirubin) were not significantly different ($p > 0.05$) among treatments, although cholesterol levels varied. Serum electrolytes (chloride, potassium, and sodium) also showed no significant differences ($p > 0.05$). These results suggest that the tested browse pods can be safely used as dry season supplements for growing Red Sokoto buck kids to mitigate seasonal productivity fluctuations.

Keywords: Buck kids, Browse pods, Hematological, serum biochemical, and Semi-Arid

INTRODUCTION

Small ruminant production, particularly of goats, plays a significant socio-economic role in Nigeria, especially for rural populations and women (Garba & Halliru, 2019). Goats are integral to the cultural life of many Nigerian communities and are used in religious festivals and ceremonies (Adekunle et al., 2020). While goats are distributed throughout Nigeria, they

are concentrated in the north, where two major breeds, the red Sokoto and the Sahelian, are found. Goat rearing in Nigeria and much of sub-Saharan Africa is primarily traditional and subsistence-based, relying heavily on natural rangelands with diverse grasses and browse species. However, these rangelands' nutritional quality and quantity decline rapidly during the dry season due to grazing pressure (Sikosana et al., 2014). This seasonal feed scarcity is a major

constraint limiting goat production in Nigeria and other African countries (Aruwayo & Maigandi, 2013). Browse pods, such as those from *Piliostigma reticulatum* and *Faidherbia albida*, have been identified as potential nutritional supplements to address this challenge (Khanyileet al., 2014).

Hematological and serum biochemical parameters are valuable indicators of an animal's physiological state and health status, reflecting the influence of stress, nutrition, and environmental factors (Kurechiyaet al., 2021). Blood analysis can complement physical examinations and medical history, providing a basis for diagnosis, assessing tissue and organ damage, evaluating the animal's defense mechanisms, and aiding in clinical predictions (Njidda et al., 2014). Therefore, this study investigated the hematological and serum biochemical profiles of growing Red Sokoto buck kids supplemented with selected browse pods in a semi-arid environment.

MATERIAL AND METHODS

Experimental Location

The research was conducted at the Teaching and Research Farm of the Department of Animal Science, Federal University Dutse, Jigawa State, Nigeria. Dutse is located between latitude 11° 45' 22.25" and longitudes 9° 20' 20.26"E, at an altitude of 485 m above sea level. The state is situated within the Sudan Savannah vegetation zone, but there are traces of Guinea savannah in the southern part of the state. (Olofin, 2008).

Experimental Materials and Processing

Four browse pod species—*Faidherbia albida*, *Vachellia tortilis*, *Acacia nilotica*, and *Piliostigma reticulatum*—were collected from rangelands in Jigawa and Yobe states. The pods were transported in 50 kg jute bags to the

Animal Science Laboratory, Federal University Dutse, where they were sun-dried and crushed for nutritional and anti-nutritional analysis.

Experimental Animals and Management

Twenty growing Red Sokoto buck kids, aged 6–8 months and weighing 10 ± 1.5 kg, were purchased from local markets (Shuwarin, Hammayayi, and Sakwaya) in the Kiyawa and Dutse local government areas of Jigawa State. Experimental pens were thoroughly cleaned before the kids arrived. Feed and water were provided two hours before their arrival. Upon arrival, the kids were acclimatized for three weeks and tagged for individual identification. During acclimatization, they received prophylactic treatment with oxytetracycline (5%) and multivitamins to prevent bacterial infections and stimulate appetite, respectively. They were also dewormed with a broad-spectrum anthelmintic (A. Zole) and treated against ectoparasites with ivermectin (Ivomec 1%), both administered according to the manufacturer's instructions. The kids were individually housed in 1.25 m² pens with sloped concrete floors in a well-ventilated room.

Experimental Design and Treatments

Twenty (20) growing Red Sokoto kids were randomly assigned to five treatment groups in a randomized complete block design. The control group (T1) received wheat offal supplementation, while groups T2, T3, T4, and T5 were supplemented with *Faidherbia albida*, *Vachellia tortilis*, *Acacia nilotica*, and *Piliostigma reticulatum* pods, respectively. Crushed sorghum stalk was provided *ad libitum* as a basal diet daily between 10:00 am and 12:00 pm. The supplements (200 g/head/day) were offered daily between 8:00 am and 9:30 am for 12 weeks. Fresh drinking water was available *ad libitum* throughout the 12-week experimental period.

Blood Sampling and Analysis

At the end of the 12-week study, blood samples were collected from three animals per treatment. Approximately 10 mL of blood was drawn from the jugular vein of each kid between 7:00 and 8:00 am using a 10 mL disposable syringe and a 23-gauge needle. Five milliliters of blood were transferred to a tube containing EDTA, and the remaining 5 mL were collected in a plain tube and allowed to clot at room temperature for three hours to separate the serum. All samples were immediately placed in a cooler with ice packs and transported to the laboratory for hematological and serum biochemical analyses.

Hematological Indices Determination

Hematological parameters, including packed cell volume (PCV), hemoglobin (Hb), red blood cell count (RBC), and white blood cell count (WBC), were measured using a Sysmexhematology analyzer following the methods described by Baker and Silverton (1985). Erythrocyte indices (mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) was calculated using standard formulas (Jain, 1986).

Serum Biochemical Analysis

Plasma total protein was measured using the biuret method (Savory & Sunderman, 1968), and albumin was analyzed calorimetrically using a Sigma diagnostic kit (Reinhold, 1953). Globulin concentration was calculated by subtracting albumin from total protein. Aspartate aminotransferase (AST) and alanine aminotransferase (ALT) activities were determined calorimetrically (Duncan *et al.*, 2004). Total cholesterol was measured following the method described by Baker and Silverton (1976), and blood urea nitrogen (BUN) and

creatinine levels were measured calorimetrically (Hosten, 1990).

Data Analysis

All data generated were subjected to analysis of variance (ANOVA) according to standard procedure of the General Linear Model (GLM) procedures of Statistical Analysis System (SAS, 2013). Duncan's multiple range test was used to separate means that might exist.

Proximate Composition of Selected Browse Pods in Semi- Arid Environment.

The proximate composition of the selected browse pods in semi- arid environment is presented in table 1. The results revealed significant differences ($P < 0.05$) in all the parameters analyzed.

RESULTS AND DISCUSSION

Hematological Profile of Growing Red Sokoto Buck Kids

Table 2 presents the levels of hemoglobin (Hb), packed cell volume (PCV), red blood cell count (RBC), white blood cell count (WBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and platelet (PLT) count. Most hematological parameters did not differ significantly ($p > 0.05$) among treatments, except for MCH and PLT, which varied significantly ($p < 0.05$). Hemoglobin values fell within the normal range of 5–13 g/dL for goats (Merck, 2016). These levels are consistent with those reported by Abdurrahmanet *al.* (2015) (8.03–9.80 g/dL) and Iliyasuet *al.* (2022) (9.10–11.73 g/dL) in studies on goats fed various diets. The normal hemoglobin values observed in this study suggest that the browse pods provided adequate nutrition and did not pose any health risks to the

buck kids. Generally, higher hemoglobin concentrations are associated with greater disease resistance, while lower levels may indicate infection or poor nutrition (Njidda *et al.*, 2013). Packed cell volume (PCV) values were higher than the $25.7 \pm 3.1\%$ reported by Tambuwalet *al.* (2002) for Red Sokoto goats but consistent with the $28 \pm 0.17\%$ reported by Njidda *et al.* (2013) for buck kids in a semi-arid environment. The observed PCV values fell within the normal physiological range of 22–38% for healthy goats (Krammer, 2000). Elevated PCV is often associated with dehydration, diarrhea, or other conditions causing fluid loss (NseAbasiet *al.*, 2013). Red blood cell (RBC) counts ($4.15\text{--}5.30 \times 10^{12}/\text{L}$) were lower than the $12.55\text{--}16.55 \times 10^{12}/\text{L}$ reported by Olocheet *al.* (2018) and the normal range of $8.00\text{--}18.00 \times 10^{12}/\text{L}$ for healthy goats (Plum, 1999). These lower RBC counts may indicate a predisposition to anemia-related conditions. RBC counts correlated positively with PCV, consistent with previous reports (Chinekeet *al.*, 2006; Anya *et al.*, 2018). White blood cell (WBC) counts were within the normal range of $4.00\text{--}13.0 \times 10^9/\text{L}$ for goats (Plum, 1999) and comparable to those reported by Olocheet *al.* (2015) ($5.30\text{--}7.40 \times 10^9/\text{L}$) and Olocheet *al.* (2018) ($5.70\text{--}9.95 \times 10^9/\text{L}$) for goats. These values contrast with the higher WBC counts reported by Okunlola (2015) for Red Sokoto goats fed baobab fruit meal. Normal WBC counts generally indicate the absence of disease. Mean corpuscular volume (MCV) values ($66.50\text{--}71.00 \text{ fL}$) were slightly lower than those reported by Abdurrahmanet *al.* (2015) for Red Sokoto goats but higher than the normal range of 28–40 fL for sheep (Banerjee, 2007). This difference may be due to species variation. Elevated MCV can also result from the release of immature red blood cells (Garba & Halliru, 2019). Mean corpuscular hemoglobin (MCH) and mean corpuscular hemoglobin concentration (MCHC) values were lower than the 38.7 ± 1.21

and 35.2 ± 0.2 , respectively, reported by Njidda *et al.* (2013). MCV, MCH, and MCHC are important indices for diagnosing anemia and assessing bone marrow function (Saleh, 2017; Garba & Halliru, 2019; Njidda *et al.*, 2013; Ajagbeet *al.*, 2019). Platelet counts ($138.00\text{--}232.00 \times 10^3/\text{L}$) were similar to the $200.19\text{--}300.61 \times 10^4/\text{L}$ reported by Anya *et al.* (2018) but slightly lower than the $300\text{--}600 \times 10^3/\mu\text{L}$ reported by Fielder (2016) for healthy goats. The lack of significant differences ($p > 0.05$) in RBC, WBC, MCH, and MCHC between the supplemented groups and the control suggests that the browse pods are safe for growing Red Sokoto buck kids.

Serum Biochemistry Profile of Growing Red Sokoto Buck Kids

Table 3 presents the serum biochemical indices of growing Red Sokoto buck kids supplemented with selected browse pods in a semi-arid environment. Most biochemical parameters (albumin, creatinine, total protein, alkaline phosphatase (ALP), alanine aminotransferase (ALT), aspartate aminotransferase (AST), and bilirubin) did not differ significantly ($p > 0.05$) among treatments. However, cholesterol levels varied significantly ($p < 0.05$). Serum biochemical indices are valuable for assessing heart and liver health, as well as protein quality and amino acid requirements (Njidda & Enoch, 2020). Albumin values were comparable to those reported for buck kids in a semi-arid environment (Njidda *et al.*, 2013) and consistent with findings that normal serum albumin levels indicate adequate protein nutrition (Ewulola&Egbunike, 2008; Muhammad, 2014). Creatinine concentrations were within the normal range reported by Njidda *et al.* (2013) and Anya *et al.* (2018) ($58.67\text{--}91.67 \mu\text{mol}/\text{L}$) for West African Dwarf bucks. Elevated creatinine can indicate impaired renal function, cardiac issues (Yakubuet *al.*, 2017),

Table1 Proximate Composition and Fibre Fractions of the Selected Browse Pods in Semi- Arid Environments.

Parameter (%)	Browse		Pods		P- Value
	<i>Faidherbia Albida</i>	<i>Vachellia Tortilis</i>	<i>Acacia Nilotica</i>	<i>Piliostigma Reticulatum</i>	
DM	87.79±3.46 ^b	91.60±0.01 ^a	91.09±0.03 ^{ab}	90.83±0.04 ^{ab}	0.0098
CP	18.18±0.02 ^b	16.33±0.08 ^c	15.46±0.05 ^d	24.86±0.01 ^a	0.0001
ASH	6.65±0.03 ^a	6.52±0.02 ^b	5.83±0.01 ^c	4.89±0.01 ^d	0.0001
EE	9.67±0.02 ^a	3.38±0.01 ^c	3.89±0.02 ^b	3.15±0.02 ^d	0.0002
CF	10.41±0.01 ^d	17.17±0.01 ^c	18.18±0.03 ^b	21.70±0.04 ^a	0.0001
NFE	44.88±0.09 ^c	48.19±0.07 ^a	47.70±0.07 ^b	36.21±0.10 ^d	0.0001
NDF	9.73±0.00 ^d	16.05±0.00 ^c	16.99±0.01 ^b	23.86±0.02 ^a	0.0003
ADF	7.96±0.00 ^d	13.13±0.00 ^c	13.90±0.01 ^b	19.52±0.01 ^a	0.0001
ADL	4.57±0.00 ^d	7.54±0.00 ^c	7.97±0.00 ^b	11.20±0.00 ^a	0.0001

SEM: standard error of mean^{abcd}. Means on the same row with different superscripts are significantly (P<0.05) different. DM- dry matter, CP-crude protein, EE- ether extract, CF- crude fibre, NFE- nitrogen free extract, NDF- nitrogen detergent fibre, ADF- acid detergent fibre, ADL- acid detergent lignin.

Table 2 Hematological Profile of Growing Red Sokoto Buck Kids Supplemented with Selected Browse Pods

Parameters	Treatments					P-values
	Wheat offal	<i>Faidherbia Albida</i>	<i>Vachellia Tortilis</i>	<i>Acacia Senegal</i>	<i>Piliostigma Reticulatum</i>	
Hb (g/L)	7.95±0.3	8.50±1.0	7.65±1.5	8.10±0.3	10.05±14.4	0.4256
PCV (%)	28.00±2.0	31.50±3.5	28.50±3.5	30.00±10	33.50±4.5	0.733
RBC (×10 ¹² /L)	4.25±0.5	4.90±0.4	4.15±0.9	4.60±0.3	5.30±0.4	0.492
WBC (×10 ⁹ /L)	5.10±1.5	4.85±0.5	5.65±0.7	6.35±2.0	6.15±0.2	0.877
MCV (fl)	66.50±2.4	67.50±0.1	70.90±3.8	69.45±2.4	71.00±1.2	0.661
MCH (pg)	18.60±0.5 ^{ab}	17.40±0.5 ^b	18.25±0.5 ^{ab}	17.50±0.4 ^b	19.70±1.0 ^a	0.015
MCHC (g/dl)	26.25±1.6	25.70±0.8	25.75±1.4	25.20±0.3	27.75±0.9	0.602
PLT (×10 ³ /L)	205.0±21.00 ^{ab}	145.50±23.5 ^b	138.00±15.0 ^b	190.50±18.5 ^{ab}	232.00±19.0 ^a	0.007

SEM: standard error of mean a,b, c Means on the row with different superscripts are significantly (p<0.05) different. Hb (Haemoglobin), PCV (packed cell volume), RBC (red blood cell), WBC (white blood cell), MCV (mean corpuscular volume), MCH (mean corpuscular haemoglobin), MCHC (mean corpuscular haemoglobin concentration) and PLT (platelets), T₁ = Wheat offal, T₂ = *Faidherbia albida*, T₃ = *Vachellia tortilis*, T₄ = *Acacia nilotica*, T₅ = *Piliostigma reticulatum*

or tannin toxicosis (Garget *al.*, 1992).

Total protein levels (6.50–7.75 g/dL) were within the normal range of 6.37–8.85 g/dL

(Daramola *et al.*, 2005) and consistent with other reports (Koloet *al.*, 2021). Elevated blood protein can indicate infection or inflammation

(Mayo Clinic, 2019).Cholesterol concentrations were comparable to those reported by Njidda *et al.* (2013) and Taofik (2018) (3.7 ± 0.03 mmol/L and 4.5–4.8 mmol/L, respectively). High cholesterol levels can increase the risk of cardiac arrest and heart failure (Alabi, 2012).ALP, ALT, and AST activities (103–148 U/L, 19.50–35.50 U/L, and 19.00–33.5 U/L, respectively) were within normal ranges, suggesting no liver or kidney damage and no adverse effects on organ function (Vakiliet *al.*, 2013). Elevated serum enzyme levels can indicate liver and/or kidney damage (Olafadehanet *al.*, 2014).Bilirubin

values were consistent with those reported by Yakubu (2017) and fell within the normal physiological range of 0.0–1.2 mg/dL (Susan, 1998), indicating the absence of hemolysis (Sirois, 1995).Blood urea nitrogen (BUN) values were slightly lower than the 5.83–9.53 mg/dL reported by Abdurrahmanet *al.* (2015). Low BUN can result from low protein intake or liver disease (Njidda & Enoch, 2020) and in ruminants can be influenced by dietary nitrogen-to-energy ratio, forage intake, and rumen protein degradability (Turner *et al.*, 2005).

Table 3 Serum Biochemistry Profile of Growing Red Sokoto Buck Kids Supplemented with Selected Browse Pods in a Semi-Arid Environment

Parameters	Treatments					P-Value
	Wheat offal	<i>Faidherbia albida</i>	<i>Vachellia tortilis</i>	<i>Acacia Senegal</i>	<i>Piliostigma Reticulatum</i>	
Albumin (g/dl)	33.00±5.0	31.00 ±7.0	41.50 ±1.5	27.00±2.0	33.00 ±1.0	0.280
Creatinine (µmol/l)	41.00±9.0	88.50±29.5	43.00±0.0	48.50±10.5	51.00±8.0	0.288
Total protein (g/dl)	6.50±9.5	7.50±5.5	7.50±5.5	7.50±3.5	7.50±1.5	0.690
Cholesterol (mmol/l)	4.05±0.25 ^{ab}	3.40±0.5 ^{ab}	2.75±0.8 ^b	4.65±0.1 ^a	3.05±0.25 ^{ab}	0.0158
ALP (µ/l)	106.50±8.5	148.00±35.0	103.50±0.5	120.50±0.5	147.00±15.0	0.327
ALT (µ/l)	20.00±3.0	22.00±11.0	19.50±1.5	22.50±3.5	35.50±1.5	0.332
AST (µ/l)	19.50±8.5	19.00±1.0	23.50±9.5	33.5±4.5	23.50±4.5	0.558
Billurubin (mmol/l)	0.75±0.55	1.55±0.75	0.90±0.00	2.25±0.95	1.85±0.25	0.450
Urea (mmol/l)	4.70±0.1	4.80±0.6	4.65±2.0	6.50±1.1	5.65±2.6	0.897

SEM: standard error of mean a,b, c Means on the row with different superscripts are significantly (p<0.05) different. ALP (Alkaline Phosphate), ALT (Alanine Aminotransferase,) and AST (Aspartate aminotransferase, T₁ = Wheat offal,T₂= *Faidherbia albida*, T₃= *Vachellia tortilis*, T₄= *Acacia nilotica*, T₅= *Piliostigma reticulatum*

Table 4 Serum Electrolytes of Growing Red Sokoto Buck Kids Supplemented with Selected Browse Pods in a Semi-Arid Environment

Parameters	Treatments					P – values
	Wheat offal	<i>Faidherbia albida</i>	<i>Vachellia tortilis</i>	<i>Acacia Senegal</i>	<i>Piliostigma reticulatum</i>	
Chloride (mmol/l)	94.50±1.5	100.00±0.0	91.00±2.0	101.00±1.0	112.00±6.0	0.250
Potassium(mmol/l)	4.65±0.3	5.30±0.6	4.25±0.3	4.60±0.7	4.05±0.3	0.491
Sodium (mmol/l)	135.00±1.0	144.00±1.0	144.50±5.4	146.56±3.5	146.56±1.5	0.177

T₁ = Wheat offal, T₂= *Faidherbia albida*, T₃ = *Vachellia tortilis*, T₄ = *Acacia nilotica*, T₅ = *Piliostigma reticulatum*

Serum Electrolytes of Growing Red Sokoto Buck Kids

Table 4 presents the serum electrolyte profiles of growing Red Sokoto buck kids supplemented with selected browse pods in a semi-arid environment. Chloride, potassium, and sodium concentrations did not differ significantly ($p > 0.05$) among treatments. Electrolytes regulate osmotic pressure, maintain membrane potentials and acid-base balance, and transmit nerve impulses. Sodium and potassium deficiencies can impair kidney function and urine concentration (Njidda & Enoch, 2020).

Chloride values were consistent with the 106 ± 2.33 mmol/L reported by Njidda *et al.* (2013) for Red Sokoto buck kids and the 97.8–99.7 mmol/L reported by Olafadehan *et al.* (2017) for Red Sokoto goats. However, they were lower

than the 120.00–153.25 mmol/L reported by Abdurrahman *et al.* (2015) for Red Sokoto bucks, possibly due to differences in animal age or season.

Potassium concentrations were within the normal range of 5.2–5.3 mmol/L for buck kids (Bhat *et al.*, 2011) and comparable to the 4.39–5.73 mmol/L reported by Njidda and Enoch (2020) for Red Sokoto bucks.

Sodium values were comparable to the 124.00–146.00 mmol/L reported by Anya *et al.* (2018). Potassium and sodium regulate osmotic pressure, maintain membrane potential, acid-base equilibrium, and nerve impulse transmission. Low concentrations can lead to altered gastric secretions, sluggishness, kidney disease, and reduced nerve response (Muhammad, 2014).

CONCLUSION AND RECOMMENDATION

In conclusion, supplementing growing Red Sokoto buck kids with the selected browse pods (*Faidherbia albida*, *Vachellia tortilis*, *Acacia nilotica*, and *Piliostigma reticulatum*) did not negatively affect hematological indices, serum biochemistry, or serum electrolytes. Observed values for these parameters were comparable to those reported in previous studies. Therefore, these browse pods appear to be a safe and suitable dry season supplement for growing Red Sokoto buck kids to mitigate seasonal productivity fluctuations.

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FEEDING VALUE OF SESBANIA SESBAN FODDER AND NAPIER GRASS HAY MIXTURE DIETS ON THE NUTRIENT INTAKE AND DIGESTIBILITY OF WEST AFRICAN DWARF GROWING BUCKS

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ABSTRACT

This study was conducted to evaluate the nutrient intake and digestibility of West African dwarf growing bucks fed *Sesbania sesban* with Napier grass hay mixture diet for 90days feeding trial. A total of sixteen (16) growing WAD bucks between 6 - 9 months of age with an average body weight of 6.00-10.00kg were randomly allocated to four treatments with 4 bucks per treatment and 2 bucks per replicate in a completely randomized design, and were fed daily with varied experimental diets (T_1 = 100%NG hay (100NG); T_2 = 25%NG + 75%SS hay (25NG75SS); T_3 = 50%NG+50%SS hay (50NG50SS); T_4 = 100%SS hay (100SS)) with a 500g concentrate diet at 3% body weight of individual animals. . There were significant ($P<0.05$) differences in all parameters determined on nutrient intake and digestibility across the dietary treatments. Buck fed diet T_4 recorded highest value (255.25g/d) of DM intake while lowest value (197.31g/d) for DM intake was recorded in buck fed T_3 diet. Highest CP intake(58.75g/d) and CFI intake (77.53g/d) values was observed in buck fed diet T_4 and T_1 respectively while the least CP intake (21.29g/d) and CF intake (55.70g/d) was recorded in buck fed diets T_1 and T_3 respectively. The highest Ash intake (33.64g/d) and NFE intake (96.59g/d) was observed in buck fed diet T_4 and T_1 respectively while the least value for Ash intake (22.06g/d) and NFE intake (65.76g/d) was noted for buck fed T_2 and T_3 diet. The highest value for CF digestibility (66.54%) were recorded in buck fed T_4 diet while the least value (62.78%) was recorded in buck fed T_1 diet. It can be concluded that the combination of grass based diet (Napier grass) with selected browse fodders enhanced nutrient intake and digestibility in WAD growing bucks fed 50% Napier grass hay + 50% *S. sesban* fodders combination.

Keywords: Tropical browse legume fodders, Napier grass, WAD bucks, intake and digestibility of nutrients.

INTRODUCTION

A major problem facing livestock producers in tropical countries is how to provide a proper nutrition for their animals, especially during the dry season when pasture and cereal residues are

limiting in quantity and nutritional quality (Michalk *et al.*, 2018; Kebede 2020). Sheep and goats constitute the majority of the ruminant population in developing countries and contribute significantly to the household economy. In developing countries, small

ruminants are mainly kept under the traditional grazing system with low feed inputs (Hango, *et al.*, 2007). Goats are kept in a wide range of agro-ecological zones and management systems in Africa. They are widely distributed and are of great importance as a major source of livelihood of the small farmer and the landless in rural communities in tropical Africa (Belete, 2013).

Small ruminants in particular West African dwarf goats are useful to humans during periods of cyclical and unpredictable food shortages (Birteeb *et al.*, 2012). They have the ability to convert poor quality feedstuffs, such as grasses, legumes, farm wastes and crop residues that are unsuitable for human body tissue to meat (Fajemisin *et al.*, 2010). The production system in Tropical and Sub-tropical regions is characterized by poor feeding, housing, breeding, and health management and consequently very low (Gurmesa *et al.*, 2011) returns from sale.

When the quality of the fodder is low, animals are not able to eat what is required to put on weight. Because of the slow growth rate, the animals become old before they reach the desired live weight for sale. Shortage of feed is also one of the limiting factors for increasing production and productivity of small ruminant in most agro-ecological zones of Nigeria.

Ruminants have abundance of forage to feed on in the rainy season, and as such, animals are well fed and fattened due to availability of highly nutritive forage materials. Consequently, in the dry season, they usually experience significant loss of weight and remarkable decline in milk production as a result of low quality feed resources (Lamidi and Ologbose, 2014).

Meanwhile, agro-industrial by-products have been adopted as alternative feed resource for ruminants feeding during dry season (Andrew *et al.*, 2014; Mamine *et al.*, 2020). These materials are known to have poor nutritive quality and low digestibility unless they are further processed

before presenting to animals which will, in turn, increase the cost of production of animals.

Intake of this agro-industrial by products in the raw state by ruminants is usually too low to maintain body weight due to their tough texture, poor digestibility and low nutrient content (Sindhu, 2002). In view of the demerits of crop residues and industrial waste materials as dry season feed resource for ruminants, therefore, conservation forage still remains the best approach to ensure year round production. Due to abundance of high quality forages during dry season, hay and silage making have been recommended, on the premise that farmers can use these conservation techniques on farm provided they have sufficient man power and can obtain forage during the late wet season from any available pasture field (Ewetola, 2018). In this regard, legume forages and tree leaves are receiving increasing attention due to their potential to supply high CP and minerals and palatable fodder during periods of reduced accessibility to good-quality fodder (Abebe *et al.*, 2012; Khan and Habib, 2012).

Therefore, there is a need to look for protein sources that farmers could get from their own farm with minimum cost. One potential way for increasing the availability of feeds for smallholder farmers could be through the use of fodder trees and shrub legumes. Hence, this study was made to focus on identifying the best grass-legume supplementation option that can promote better feed utilization and animal performance by combining varying proportion of air dried *S. sesban* and Napier grass hay mixture on nutrient intake and digestibility of West African dwarf growing bucks.

MATERIALS AND METHODS

Experimental Site and Animals

The experiment was conducted at the Sheep and Goat Unit, Teaching and Research Farm, Oyo

State College of Agriculture and Technology, Igboora. Sixteen (16) growing West African dwarf bucks weighing between 6.00 – 10.00 kg and of 6 – 9 months of age were used. The bucks were dewormed with anthelmintics (Albendazole®) to control endoparasites; oxytetracycline and multivitamin preparations were administered at rate of 1mL per 10 kg body weight through intramuscular route for prophylactic treatment. Homologous *Pesti des petit* ruminant (PPR) vaccine was administered against PPR disease and acclimatized for 28 days before the commencement of the experiment. Guinea grass and cassava peels were offered to the animals during the adaptation period. Fresh and clean water was also made available throughout the experiment.

Harvesting and Processing of Experimental Diets

Napier grass and *Sesbania sesban* forage were harvested around the College farm, chopped at 3 cm long, wilted for 2 – 3 hours in the sun, and air-dried under shade for 4 - 5 days to prevent bleaching and loss of nutrients before baled and stored for the experiment.

Experimental Layout, Design and Feeding Method

The animals were allocated by weight into four treatments of four bucks per treatment and two bucks as a replicate in a completely randomized design (CRD). The air-dried *Sesbania sesban* forage and Napier grass were mixed in varying proportions as the experimental diets, and thoroughly mixed to eliminate/minimize selection by the animal before being fed at 3% body weight to the bucks per day. The animals in each treatment group were offered their respective experimental diet (forage hay) at 8.00 am, a formulated low-cost concentrate (Table 1) of 500g per buck per day at 2.00 pm, and 3 litres of fresh and clean water daily. The compared

experimental diets were: T₁ (100%NG hay only), T₂ (25%NG+75%SShay), T₃ (50%NG+50%SShay) and T₄ (100%SS hay only), and their proximate composition shown in Table 2.

Table 1: Composition of formulated low-cost concentrate for experimental West African Dwarf growing bucks

INGREDIENTS	LEVEL (%)
Palm kernel cake	60.00
Wheat offal	20.00
Corn bran	9.75
Groundnut cake	8.00
Bone meal	2.00
Salt	0.25
TOTAL	100

DATA COLLECTION AND ANALYSIS

Nutrient Digestibility Study

After 90 days feeding trial, two bucks from each treatment were transferred into clean metabolic cages for separate collection of faeces and urine. There was a 7-day acclimatization followed by 7days' collection of faeces. Urine and faeces were collected separately from each animal daily throughout the last seven days of the experiment in metabolic cages. Total faecal output was collected daily in the morning, weighed and mixed thoroughly. The faeces sample collected was bulked and oven dried at 80°C until constant weight was reached. Twenty percent (20%) formaldehyde was added to prevent further bacterial activity and the faecal samples were stored at -4°C. A total urine output for 24 hours was collected. Plastic containers containing 10mls 0.1N H₂SO₄, were placed under the metabolic crates. Ten percent (10%) of daily urine output was taken from each buck and stored in a refrigerator at -20°C for subsequent

analysis. The fecal samples were chemically analyzed using A.O.A.C procedure (AOAC, 1995) while the fiber fractions (NDF, ADF and ADL) were determined using Van-Soest (1991) procedure. All nutrient intake and digestibility data obtained were subjected to one-way analysis of variance (SAS, 2013). Differences among the means were separated using Duncan's multiple range test (Duncan, 1955).

Statistical Analysis

Data were subjected to one-way Analysis of Variance (ANOVA) procedure of SAS version 9.4 (SAS, 2013). Differences among treatment means were assessed using Duncan's Multiple Range Test (DMRT, Duncan 1955).

RESULTS AND DISCUSSION

The proximate composition and fibre fractions of varied mixture of air-dried *Sesbania sesban* legume forage and Napier grass hays and concentrate diets fed growing bucks is presented in Table 2. High dry matter (DM) contents observed in this study which ranged from 71.59 to 87.63% was in consonance with the report of Oyewole and Aderinola (2022) for mixtures of *P. maximum* with either *Stylosanthes hamata* or *S. guianensis*. The higher dry matter values for grass-legume mixtures could be averred to higher dry matter percentage in Napier grass. Thus, the increase in the inclusion levels of Napier grass in the grass-legume mixture diets had significant influence on their dry matter. Also, high DM of the diets in this study suggested good shelf-life of leaves during the drying process (Alalade et al., 2019). The percentage crude protein (CP) contents, ranging from 8.12 – 18.67%, were recorded for different inclusion levels of *Sesbania sesban* and Napier grass hay mixture. The observed values of CP contents in this current study was close to that of *Cajanus cajan* foliage (21.16%) recently

reported by Adebisi et al. (2022). The CP contents of all treatments were high as they were well above the 8%CP requirement for ruminant animals which will provide ammonia requirement for the rumen microbial activity (Norton, 2003).

The differences in CP contents of browse legume hay among the various studies could be due to the factors like the species composition of the hay, environmental factors in which the hay was grown, and stage of maturity at which the hay was harvested (Chrenkova et al., 2006; Dereje, 2015). The *Sesbania* foliage could serve as potential protein supplement which enhances the feed intake and utilization of low quality grass and fibrous crop residues by ruminants. Since the importance of protein to animal and human health cannot be over emphasized, *S. sesban* foliage could, therefore, be used as feed protein supplements. This agreed with the submission of Alalade et al. (2017) that *S. sesban* foliage had better nutrient values due to high content of protein.

The crude fiber contents of the treatment feeds ranged from 19.01 to 29.57%. The observed crude fiber content value obtained in this current study will aid digestion and absorption of water in favour of animals (Ayoola and Adeyeye, 2000). The values recorded for each sample showed that the higher the percentage of Napier grass in the inclusion level, the higher the values recorded for crude fiber content. The fiber contents for 75% *Sesbaia*+25% Napier grass and solely 100% Napier grass were above the 15-20% recommended for improved intake and production in finishing ruminants (Buxton, 1996). The higher crude fiber content values will aid digestion and absorption of water which is in favour of ruminant animal (Ayoola and Adeyeye, 2000). The ash contents of the treatments at varied inclusion levels of *S. sesban* and Napier grass ranged from 7.06- 11.95%.

The values obtained were in line with range values of 9.65- 9.87% reported for different cultivars of *L. purpureus* leaf by Alalade *et al.* (2017). The highest values of 11.95% ash content in the present study was above the 5.08% recorded for *Psophocarpus tetragonolobus* leaf (Alalade *et al.*, 2016) and also higher than the 3.70% reported for *Mucuna utilis* leaf (Ujowundu *et al.*, 2010). The proportion of ash content present is a reflection of mineral contents present in the feed material (Omotosho, 2006). This suggests that these feed samples could be a better source of essential valuable and useful minerals needed by ruminant, for good body development. The ether extract value, which represented crude fat, was higher in forage samples. However, it showed that they contained adequate crude fat that will satisfy the energy requirement of ruminant animals for productive purpose. Feed stuffs having a crude fat value of 1-2% have been found sufficient to maintain good health in ruminant by reducing the risk of disease and ageing caused by its excess consumption (Sodamade *et al.*, 2013).

The NDF concentration of the treatment sample ranged from 41.65 and 51.50%. Increase inclusion level of Napier grass in the samples

resulted higher values of NDF concentration. The NDF concentrations of the different varied mixtures of legume-grass were below 60% which has been reported as the threshold level of NDF in tropical plants beyond which feed intake of ruminants is affected (Meissner *et al.*, 1991). The NDF content is the best indicator to predict fodder quality as it is related to the intake potential of the fodder. Low energy value and the low NDF contents of all treatment samples, suggested it contained potential and important available fermentable carbohydrate in ruminant feeds.

ADF concentrations ranged from 30.17 to 40.09% in this current study. These values agree with the values reported by Olajumoke (2003) that 30.6-40.20% was recorded for ADF on elephant grass at age of 4-8weeks. Forage with high ADF value is classified as low quality roughage (Rusdy, 2016). According to Kellems and Church (1998), roughage with less than 40% ADF is categorized as high quality and those with greater than 40% as poor quality. Based on this assertion, the varied mixtures of grass-legume hay and sole Napier grass samples used in this study can be classified as high quality forage because their ADF values were below 40%.

Table 2: Proximate composition of air dried *Sesbania sesban* and Napier grass hay mixture and concentrate diets fed to bucks

Parameters (%)	T ₁ 100NG	T ₂ NG25SS75	T ₃ NG50SS50	T ₄ 100SS	Concent rate
DM	87.63	73.52	71.59	81.12	94.48
CP	8.12	15.28	15.61	18.67	17.57
CF	29.57	20.34	20.12	19.01	8.75
EE	1.15	2.28	2.33	2.37	10.39
Ash	11.95	7.06	9.67	10.69	5.85
NFE	36.84	28.64	23.86	30.38	50.21
NDF	51.50	45.18	48.16	41.65	30.34
ADF	40.09	30.17	31.78	32.07	16.05
ADL	14.03	10.60	11.03	10.27	5.65
*ME(Kcal/Kg)	1702.33	1676.15	1615.19	1963.15	3282.45

DM= Dry Matter, CP= Crude Protein, CF= Crude Fibre, EE= Ether Extract, NFE= Nitrogen Free Extract, NDF= Neutral detergent fibre, ADF= Acid detergent fibre, ADL= Acid detergent lignin, *ME= Calculated Metabolizable energy,). SS=*Sesbania sesban*, NG=Napier grass

The mean daily total DM and nutrient intakes for WAD bucks are presented in Table 3. In the current study, dry matter intake (DMI) was significantly different ($P < 0.05$) among treatment groups. But there was, highly significant difference ($P < 0.05$) in total dry matter intake (DMI) among treatments with the highest value (283.19g/d) recorded for T_4 and the least values (235.98g/d) and (248.05g/d) were recorded for T_1 and T_3 , respectively. Generally, total daily DMI showed an increasing trend with increasing the level of *S. sesban* treated Napier grass hay mixture from T_1 to T_4 . This trend is in line with the report of Deribe *et al.* (2017) who reported that the total DM intake of animals was increased with increasing level of effective microorganism (EM).

In contrast to the current finding, Chernet (2012) reported that there was a fall in total DM intake as EM-Bokash inclusion in the diets increased from 1 to 5%. Higher total DM intake in the supplemented groups is related to the favorable rumen environment, such as microbial growth, production of fiber degrading enzymes, which could have been resulted in enhanced fermentation, rate of break down and rate of digestion of the feed and resulted in a greater DM intake (McDonald *et al.*, 2010). The DM intake value (235.98 – 283.19g/d) recorded in this current study was lower than intake range of 433 - 443g/d reported for Savanna brown goat fed graded levels of *Gmelina arborea* leaf meal in complete diets (Abdu *et al.*, 2013) and also lower than the value (683.10- 767.31g/d) reported by Adebisi (2021) fed WAD growing rams with different proportions of *Cajanus cajan* foliage hay and *Panicum maximum*. The least total DM intake recorded for the WAD bucks kept on natural grass hay (T_1) was probably due to the low colonization of microorganisms in the rumen and the retention of fiber contents in the rumen for long time which is likely depressing both feed intake and digestibility. One of the

factors that affect forage and concentrate intake and digestibility is the microbial density in the rumen. Effective fiber colonization of microbes in the rumen reduces the retention time of fiber components due to production of fiber degrading enzymes (Walker, 2007; Seo *et al.*, 2010).

The higher and lower CP intake obtained from T_4 (58.75g/d) and T_1 (21.29g/d), respectively was in part due to greater and lower DM intake. The CP intake value observed in this current study was lower than the values ranged from 85.50 to 129.72 g/day reported by previous studies (Bishaw and Melaku, 2008; Bekele *et al.*, 2013; Haymanot *et al.*, 2019). The higher CP intake in the present study could be expressed due to the higher intake of dry matter which is closely associated with body weight. This indicates that all treatment groups have no negative impact on overall feed intake as their CP intake was above 8% of DM intake (Van Soest, 1994).

According to Minson (1990), the lowest energy density at which sheep does not lose weight is between 8 and 10 MJ ME/kg DM and the minimum protein level required for maintenance is about 8% CP in DM, which indicates that the result of the current study is above the satisfactory energy and protein requirement for maintenance and growth of WAD bucks. Moreover, the feed consumption could be explained by the fiber intake which was observed to be higher in T_1 and T_2 than that of T_3 and T_4 . Feed intake is negatively impacted by the number of indigestible fractions (such as lignin) or fractions with low digestibility like NDF and ADF content due to the need for more retention time in the rumen for further fermentation (Bruinenberg *et al.*, 2003).

The highest nitrogen free extract (NFE) intake (96.59g/d) was obtained in bucks fed on T_1 diet while the lowest value for NFE intake (65.76g/d) was recorded in bucks fed on T_3 diet. ARC (1984) reported that supplementation of protein

based supplement enhances intake and growth performance. Supplementation of poor quality forages was reported to increase dry matter intake and performance of animals. The increase in dry matter intake by bucks was due to increased protein intake as a result of browse plants supplementation which gave higher live weight gain (Ferdous *et al.*, 2011).

On the other hand, significantly ($P < 0.05$) higher intake values of CP, NDF and ADF were observed in bucks fed diets T_4 , T_2 and T_1 respectively compared to the rest of the treatments. The higher microbes contend in the supplemented feeds compared to the basal diet in T_1 that contained solely Napier grass (NG)

might be result higher microbial protein synthesis in the supplemented groups. According to Ranjhan (1997), the average daily protein and energy requirement for maintenance of the goat weighing 10 kg was reported to be 36 g and 4.017 MJ ME, respectively. This indicated that both the supplemented and control goats in this study had CP intake beyond their maintenance requirement above which protein being used for body weight gain purposes. Significant differences were also observed in CP and NDF intake among the supplemented groups with the highest value for CP (58.75g/d) and NDF (141.19g/d) recorded for T_4 and T_2 respectively.

Table 3: Nutrient intake of WAD bucks fed air dried *Sesbania sesban* and Napier grass hay mixture with concentrate diets (g/day)

Parameters(g/day)	T_1 100NG+500g concentrate	T_2 NG25SS75+500g concentrate	T_3 NG50SS50+500g concentrate	T_4 100SS+500g concentrate	SEM ($\pm$)
DFI	235.98 ^{cd}	281.26 ^b	248.05 ^{bc}	283.19 ^a	10.28
DMI	229.77 ^{ab}	229.76 ^c	197.31 ^{cd}	255.25 ^a	10.27
CPI	21.29 ^{cd}	47.75 ^{ab}	43.02 ^c	58.75 ^a	6.80
CFI	77.53 ^a	63.56 ^{ab}	55.70 ^d	59.82 ^c	4.10
EE intake	3.02 ^{cd}	7.13 ^b	6.42 ^c	7.46 ^a	0.88
Ash intake	31.33 ^{ab}	22.06 ^{cd}	26.65 ^{bc}	33.64 ^a	2.22
NFE intake	96.59 ^a	89.50 ^c	65.76 ^{cd}	95.59 ^b	6.24
NDF intake	135.03 ^{ab}	141.19 ^a	132.73 ^{bc}	131.05 ^d	1.92
ADF intake	105.12 ^a	94.28 ^{bc}	87.59 ^{cd}	100.91 ^{ab}	3.32
ADL intake	36.79 ^a	33.13 ^{ab}	30.40 ^{cd}	32.32 ^c	1.15

^{abcd} Means on the same row with different superscript are significantly different ($P < 0.05$). DMI= Dry Matter intake, CPI= Crude Protein intake, CFI= Crude Fibre intake, EEI= Ether Extract intake, NFEI= Nitrogen Free Extract intake, NDFI= Neutral detergent fibre intake, ADFI= Acid detergent fibre intake, ADLI= Acid detergent lignin intake, *ME= Calculated Metabolizable energy,). SS=*Sesbania sesban*, NG=Napier grass

Table 4 indicates the nutrient digestibility values of WAD bucks fed air dried *Sesbania sesban* and Napier grass hay mixture with concentrate diets. The result showed that nutrient digestibility values were significantly ($p < 0.05$) different among the treatment groups. Dry matter digestibility (%) was higher for the bucks fed mixture of NG50SS50 + 500g concentrate in diet T_3 (74.68%) and the least value in T_1

(68.45%), which suggests that combining legume forage hay species with concentrate diet promotes dry matter digestibility.

The values obtained were lower compared with Tona *et al.*, (2014) who reported a range value of 77.47 to 81.67% for goats fed *Panicum maximum* with concentrate diets containing graded level of *Moringa olerifera* leaf meal and also lower than the value (86.87– 88.24%)

reported by Adebisi, (2021), fed WAD growing rams with different proportions of *Cajanus cajan* foliage hay and *Panicum maximum*. In the present study, DM digestibility (%) in the group supplemented with 500g concentrate diet with NG25SS75 hay mixture in T₂, 500g concentrate diet + NG50SS50 hay mixture in T₃ and 500g concentrate + solely 100SS hay in T₄ were 71.82%, 74.68% and 72.92% respectively as compared to 68.45%% in the control group T₁. The DM digestibility below 55% was considered poor based on studies of weaned Dorper sheep (Norhayati, 2020). Hence, all treatment groups had moderate digestibility as their DM digestibility was above 55%.

It was owing to the feeding of the protein-rich formulated legume forage hays which enhanced intake and digestibility of the nutrients. The activity of microorganisms may perhaps increase due to enhance protein intake (Jolly, 2013) and believed that the tropical legume forage hay supplementation might improve the metabolism of nutrients such as CP (Taheri et al., 2018), where the availability and utilization of metabolic N caused the reduction of N loss via urine. Significant differences ($P < 0.05$) were observed in digestibility of crude protein (CP) among dietary treatments. Bucks fed T₃ diet had higher CP digestibility (86.52%) than those on T₁, T₂ and T₄ while bucks fed diet T₁ recorded the lowest CP digestibility value of 79.06%. Mulligan et al., (2001) reported that increasing dietary CP content increased the digestibility of low quality hay. In this study, increased CP intake with increasing levels of *Sesbania sesban* in the hay mixture with 500g concentrate diets was followed with increase in DM, CP and ether extract (EE) digestibility.

In agreement with the present study, significantly different digestibility of CP was reported by Berhanu et al., (2014) in Washera sheep fed *Milletia ferruginea* (Birbra) foliage

with natural pasture grass hay basal diet. Firisa et al., (2013) also reported significantly improved CP digestibility in Horro lambs supplemented with graded levels of *V. amygdalina* leaves and sorghum grain mixture. Furthermore, Abuye et al., (2018) reported that digestibility of CP for sheep fed basal diets of natural grass hay were improved when supplemented with Gebisa-17 and Beresa-55 cultivars of *Lablab purpureus* and concentrate mixture.

There were significant differences in crude fibre (CF) digestibility among treatments. Bucks fed on solely 100%SS hay +500g concentrate diet had significantly higher CF digestibility (66.54%) while the least value for CF digestibility was recorded in bucks fed diet T₁. This result indicated that the higher the CP level of the legume forage hay mixture diets positively influenced CF digestibility which agrees with the reports of Fasaie et al., (2005) and Okah et al., (2012) that CF digestibility and CP digestibility increase with increasing level of CP in diet. The value of Ash digestibility content recorded from the result ranged from 41.90 to 46.68%.

This indicated that ash digestibility content is useful in assessing the quality grading of diets and also gives an idea of the amount of mineral elements present in the leaves (Smart, 1996). The value obtained in this study fell above (10.90%) the value reported by Ibeawuchi et al., (2002) and also higher than the value (6.29%) reported by (Mecha and Adegboola, 1980). This suggested that the *Sesbania sesban* hay could be a better source of essential valuable and useful minerals needed for good metabolic that will enhance good production of small ruminants. The significant increase in the digestibility of Nitrogen free extract (NFE) as a result of *Sesbania sesban* hay supplementation is in agreement with the findings of Abule et al.,

(1995). This can be attributed to an increasing level of the crude protein that was ingested. It agrees with the previous study on the effect of increasing dietary crude protein level on nitrogen or crude protein digestibility (Sahlu *et al.*, 1993).

The NDF and ADF digestibility were significantly ($p < 0.05$) influenced as the inclusion levels of *S. sesban* fodder hay increased. Nutrient digestibility has been reported by Weiss *et al.*, (2009) to increase with dry matter intake; this was also established in this present study as the dry matter digestibility of the goats was significantly high in T₃ with a

corresponding significantly high dry matter intake. This study showed a positive relationship between protein intake and digestibility as the treatment (T₂) with the highest protein intake, also produced the highest protein digestibility. This is in consonance with the report of McDonald *et al.*, (1995) who revealed a positive relationship between digestibility of diets and protein intake. ADL digestibility was best for goats in T₃ in comparison with other groups. The lower ADL digestibility observed T₁ may be attributed to the lower ADL content and ADL intake observed in the respective treatment.

Table 4: Nutrient digestibility of WAD bucks fed air dried *Sesbania sesban* and Napier grass hay mixture with concentrate diets (%)

Parameters (%)	T1 100NG+500g concentrate	T2 NG25SS75+500g concentrate	T3 NG50SS50+500g concentrate	T4 100SS+500g concentrate	SEM (±)
DMD	68.45 ^d	71.82 ^c	74.68 ^a	72.92 ^{ab}	1.14
CPD	79.06 ^{cd}	83.10 ^{bc}	86.52 ^a	84.75 ^{ab}	1.38
CFD	62.78 ^{cd}	65.51 ^{ab}	64.30 ^{bc}	66.54 ^a	7.01
EED	80.62 ^d	81.15 ^{bc}	85.09 ^a	83.26 ^{ab}	8.89
Ash D	41.90 ^{cd}	43.16 ^{bc}	44.75 ^{ab}	46.68 ^a	8.94
NFED	59.25 ^{cd}	60.32 ^{bc}	62.70 ^a	61.20 ^{ab}	6.38
NDFD	52.68 ^{cd}	53.76 ^{bc}	56.81 ^a	55.36 ^{ab}	7.84
ADFD	20.14 ^{cd}	22.95 ^b	22.19 ^{bc}	23.57 ^a	6.46
ADLD	14.76 ^{cd}	15.48 ^{bc}	18.03 ^a	17.62 ^b	6.92

^{abcd} Means on the same row with different superscript are significantly different ($P < 0.05$). DMD= Dry Matter Digestibility, CPD= Crude Protein Digestibility, CFD= Crude Fibre Digestibility, EED= Ether Extract Digestibility, NFED= Nitrogen Free Extract Digestibility, NDFD= Neutral detergent fibre Digestibility, ADFD= Acid detergent fibre digestibility, ADLD= Acid detergent lignin digestibility, SSH= *Sesbania sesban* Hay, NGH= Napier grass Hay

CONCLUSION

The results of the study indicates that the combination of grass based diet (Napier grass) with selected browse fodder plants promoted dry matter and nutrient intake, and also enhance digestibility in growing West African Dwarf growing bucks fed 50% Napier grass hay + 50% *S. sesban* hay combinations with 500g concentrate diet.

RECOMMENDATION

It is, therefore, recommended that the tropical grass (Napier grass) be supplemented with browse fodder in diets of growing bucks to enhance the performance of the animals. The combination ratio might, however, depend on the production status of the animal and the quality of both the basal grass diet and the browse plant species. It might be necessary, however, to further investigate the ratio of grass:

browse fodder that will be best for different production statuses of bucks with different qualities of both basal grass diet and browse fodders.

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PERFORMANCE, ECONOMICS OF PRODUCTION, PROTEIN AND NITROGEN UTILIZATION
OF GROWING BROILER CHICKENS FED MAIZE-PAP RESIDUE MEAL BASED DIETS WITH
ACIDIFIER SUPPLEMENTATION

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ABSTRACT

The present study was conducted to evaluate the replacement effects of maize-pap residue meal (MPRM) for maize with acidifier supplementation in the diet of growing broiler chickens from 7 to 35 days of age on growth performance, economics of production, and protein/nitrogen utilization. Two hundred and twenty-four (224), 7-day-old *Arbor Arce* broiler chicks were randomly distributed into seven (7) dietary treatments of four replicates with eight birds each using a Completely Randomized Design (CRD). The diets were formulated to be iso-nitrogenous (23% CP) and iso-caloric (3000 kcal ME/kg) to comprise the following treatment groups: Group T₁ served as the control maize-soybean meal-based diet, groups T₂, T₃ and T₄ contained 25, 50 and 75% MPRM respectively, while groups T₅, T₆ and T₇ contained 100 mg/kg acidifier supplementation to diet T₂, T₃ and T₄, respectively. On day 35, performance, protein/nitrogen utilization, and economic indices were evaluated. Results showed that there were significant ($p < 0.05$) differences recorded in all performance, cost, and protein/nitrogen utilization indices of the birds fed MPRM without or with acidifier supplementation. Birds fed 50% MPRM diets without acidifier showed improved ($p < 0.05$) performance and efficiency of protein and nitrogen utilization with lower ($p < 0.05$) nitrogen excretion; whereas the improvement in these parameters increased to 75% with the addition of acidifier at a significant ($p < 0.05$) higher profit margin. Therefore, it was concluded that 50% of MPRM can be tolerated in the diet of growing broiler chickens and up to 75% with the addition of an acidifier for improved performance and protein/nitrogen utilization attributes at a higher profit margin.

Keywords: Acidifier, maize-pap residue, growth, protein/nitrogen utilization, cost, broilers.

INTRODUCTION

In developing countries like Nigeria, there is an extreme shortage and insufficiency of animal

protein. The lack of animal protein has become so severe that it needs to be fixed immediately to prevent people from becoming malnourished. Poultry production has been identified as one of the fastest ways to avert malnutrition because of its quick turnover and genetic improvement (Bohrer, 2017; Korver, 2023). However, the high cost of feeds in poultry production has impaired the advantage of poultry over other livestock species. Feed constitutes the primary expense in poultry production, accounting for about 70-80% of the total cost of production (Zampiga *et al.*, 2021; Wongnaa *et al.*, 2023). Raw material for poultry feed has different components such as energy, protein, vitamin, and mineral components. Poultry birds usually consume feed to meet their energy needs first, which determines how much they eat (MacDonald *et al.*, 2002). However, energy concentrates are very expensive because they are staple food for our ever-increasing human population; hence, the need for alternative energy sources in poultry diets (Aguihe *et al.*, 2017; Ilaboya *et al.*, 2018; Abd El-Hack *et al.*, 2019; Aguihe *et al.*, 2021). Reducing energy costs without compromising quality would translate to a reduced price of feeding livestock (Martin *et al.*, 2023; Baris, 2023). The increased expense of conventional feed components has necessitated the urgent pursuit of economical and accessible local feed alternatives. One potential option is maize-pap residue meal, a by-product of processed maize floor used to make the traditional carbohydrate food known as “pap” in Nigeria. The pap is the residue in the form of a paste that results from fermenting, grinding, and sieving maize grains. The processing methods used to prepare pap through fermentation of maize grain have an impact on the product's color, taste, odor, microbial load, and consumer acceptability. Using suitable fermentation techniques and sanitary processing methods for maize grains can improve and fortify the quality of pap; and the residue has been reported to contain significant feed

nutrients required by farm animals (Isirima and Ukpong, 2018).

One of the challenges facing the poultry industry is how to effectively use these alternative feed resources for better poultry performance and production efficiency. Since the European ban on using in-feed antibiotics in animal feeding programs, there has been a global effort to find alternative growth promoters free from antibiotics. This has resulted in adding eubiotic feed additives, a meaningful way to enhance feed efficiency and improve the performance of monogastric animals (Kim *et al.*, 2015; Aguihe *et al.*, 2021; Qui, 2023). Some viable alternatives include probiotics, prebiotics, phytochemicals, enzymes, and organic acids. Among these options, organic acids, or acidifiers, are crucial in supporting gut health and improving nutrient digestibility and utilization (Sabour *et al.*, 2019; Pearl *et al.*, 2020; Chukwudi *et al.*, 2025). Dietary acidifiers have attracted significant interest due to their antibacterial properties against pathogenic bacteria and their ability to lower pH in the gastrointestinal tract (GIT), hence enhancing nutrition absorption in chickens (Yang *et al.*, 2018; Vinolya *et al.*, 2021). In light of the increasing recognition of the need to prohibit antimicrobial growth promoters (AGPs) in chicken feed due to the potential for cross-resistance of pathogens to antibiotics, acidifiers have emerged as a viable alternative (Fernandez Miyakawa *et al.*, 2023; Peng *et al.*, 2024; Abreu *et al.*, 2024). Currently, the use of acidifiers can increase feed quality and utilization, safety conditions, and production performance in poultry (Khan *et al.*, 2016; Syrovatko *et al.*, 2021; Chukwudi *et al.*, 2025). However, there is a paucity of information on the use of maize-pap residue meal as a novel alternative partial replacement for maize in poultry diet with the addition of an acidifier. Therefore, this study was conducted to examine the response of growing broiler chickens fed a maize-pap residue meal-based diet with or without acidifier

supplementation on growth performance, protein/nitrogen utilization and economics of production.

MATERIALS AND METHODS

Description of Experimental Site and Facility

The study was conducted in the Poultry Unit of the Research Farm under the Department of Animal Production Technology at the Federal College of Wildlife Management, New Bussa, Niger State. The college is situated in longitudes 9° 81' 95" N and 9° 49' 10" N, and latitudes 4° 58' 05" N and 4° 34' 49" N (Google Map), encompassing an area of 2.5 km² marked by the Northern Guinea Savanna zone of Nigeria.

Ethical Approval

The current study and its experimental methods received approval and were conducted following the parameters set out by the Animal Welfare Ethics Committee of the Federal College of Wildlife Management, New Bussa, Nigeria.

Procurement of Test Ingredients:

The maize-pap residue was obtained in substantial quantities from several local producers in Bodija, Ibadan, Oyo State, Nigeria.

Experimental birds, Experimental Design and Management

Two hundred and twenty-four (224) 7-day-old *Arbor Arce* broiler chicks were randomly distributed into seven (7) dietary treatments of four replicates with eight birds each using a Completely Randomized Design (Table 1). The birds were reared in an open-sided deep litter management system for 28 days. Experimental diets were provided *ad libitum* in the form of dry mash for the duration of the trial. All appropriate biosecurity protocols were rigorously followed throughout the study duration.

Experimental Diets and Treatment Layout

Seven isocaloric meals were developed following NRC (1994) recommendations, as detailed in the following menus, with the experimental treatment diets shown in Table 2.

Diet 1 is the control diet containing 0% maize pap residue meal and 0% acidifier.

Diet 2 contained 25% of maize pap residue meal.

Diet 3 contained 50% of maize pap residue meal.

Diet 4 contained 75% of maize pap residue meal.

Diet 5 contained 25% maize pap residue meal with the inclusion of a 100mg/kg acidifier.

Diet 6 contained 50% maize pap residue meal with inclusion of 100mg/kg acidifier.

Diet 7 contained 75% maize pap residue meal with inclusion of 100mg/kg acidifier.

Composition of the Acidifier:

The acidifier used in the research is a commercial product from CIFEK INTERNATIONAL, Lagos, Nigeria.

Growth Performance Evaluation

Broilers were weighed collectively at the commencement of the study and thereafter every week at ages 7, 14, 21, and 28 days. The weighing was conducted using an electronic balance before the provision of feed each afternoon of the week. The average weight increase of broilers in each replication was determined by subtracting the beginning body weight from the end body weight. The feed intake of the experimental broilers in various treatment groups was determined weekly by subtracting the retained quantity from the provided amount for that week. The feed conversion ratio was determined as the amount of feed ingested per unit of body weight increased.

Table 1: Layout of experimental dietary treatments

Replication	Dietary Treatments							Total birds
	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	
R ₁	8	8	8	8	8	8	8	
R ₂	8	8	8	8	8	8	8	
R ₃	8	8	8	8	8	8	8	
R ₄	8	8	8	8	8	8	8	
Birds/ treatment	32	32	32	32	32	32	32	224

Table 2: Gross ingredient composition of experimental diets

Ingredients	WITHOUT ACIDIFIER				WITH ACIDIFIER		
	0%	25%	50%	75%	25%	50%	75%
	MPRM	MPRM	MPRM	MPRM	MPRM	MPRM	MPRM
	T1	T2	T3	T4	T5	T6	T7
Maize	55.50	41.63	27.75	13.88	41.63	27.75	13.88
Soybean	34.60	34.60	34.60	33.60	34.60	34.60	33.60
Fishmeal	3.00	3.00	3.00	3.00	3.00	3.00	3.00
MPRM	0.00	13.87	27.75	41.62	13.87	27.75	41.62
Oil	2.50	2.00	1.00	1.00	1.00	1.00	1.00
Acidifier	0.00	0.00	0.00	0.00	0.10	0.10	0.10
DCP	1.70	1.70	1.70	1.70	1.70	1.70	1.70
Limestone	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Inert filler	0.00	0.50	1.50	2.50	1.40	1.40	2.40
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Methionine	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Lysine	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Premix	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Monensin	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total	100.00	100	100	100	100	100	100
Nutrient composition							
CP %	22.66	23.13	23.60	23.63	23.13	23.60	23.63
ME, kcal/kg	3069.71	3099.12	3089.59	3129.04	3021.12	3089.59	3129.04

*Vitamin-trace mineral premix/kg diet: vitamin A: 12 000 IU, vitamin D3: 1 500 IU, vitamin E: 50 mg, vitamin K3: 5 mg, vitamin B1: 3 mg, vitamin B2: 6 mg, vitamin B6: 5 mg, vitamin B12: 0.03 mg, niacin: 25 mg, calcium-d-pantothenate: 12 mg, folic acid: 1 mg, D-biotin: 0.05 mg, apo-carotenoic acid ester: 2.5 mg, choline chloride: 400 mg, manganese: 80 mg, iron: 60 mg, zinc: 60 mg, copper: 5 mg, cobalt: 0.2 mg, iodine: 1 mg, selenium: 0.15 mg

Economics of Production

The prevailing market prices of ingredients during the experiment were used to determine the cost of feed per kilogram (₦), total feed consumption cost (₦), cost of feed per kilogram weight gain (₦), production cost (₦), total revenue generated (₦), and profit margin (₦) for the experimental birds, following the

methodology of Medugu *et al.* (2010) as adopted by Oguntoye *et al.* (2018).

Evaluation of Protein and Nitrogen Utilization Indices

For each pen (n = 18/treatment), total nitrogen intake (N_{intake}, g) was determined by multiplying the total feed intake (FI) of the pen by the crude protein (CP) content of the diet and dividing by

6.25. Whole-body nitrogen retention (N_{ret} , g) was calculated by multiplying the total body weight gain of the pen by a constant for whole-body nitrogen content ($N_{\text{body}} = 29 \text{ g/kg}$; ITAVI, 2013), consistent with prior research (Aletor *et al.*, 2000; Bregendahl *et al.*, 2002) indicating that whole-body nitrogen content remained unaffected by a decrease in dietary crude protein content, even under limiting conditions. Nitrogen retention efficiency (N_{effi} , %) was determined by dividing nitrogen retention by nitrogen intake and multiplying the result by 100.

Chemical Analysis

Determination of the proximate composition of the experimental test ingredient was according to the method of AOAC (2016).

Statistical Analysis

The bird pen was the experimental unit for all data collection. The gathered data were evaluated using the Statistical Package for the Social Sciences's generalized linear model (GLM) function (SPSS Statistics for Windows, Version 21.0, Armonk, NY: IBM Corp). The changes in means were analyzed using Duncan's multiple range tests, with all variations deemed significant at a 5% probability threshold ($p \leq 0.05$).

RESULTS

Nutrient Composition of the Processed Maize-Pap Residue:

The proximate composition results of the processed maize-pap residue meal (MPRM) are shown in Table 3. The MPRM exhibited a dry matter content of 90.78% and a crude protein content of 13.17%, surpassing maize, which had values of 88.00% and 10.60%, respectively. The MPRM exhibited a carbohydrate content of

72.41%, indicating its potential as a viable carbon source for animal feed formulation. The crude fat level of MPRM was 7.98%, while the crude fiber content was 3.35%, both of which were somewhat greater than maize, which had 4.00% crude fat and 3.00% crude fiber, respectively. The ash content of the MPRM and maize is comparable, with values of 3.09% and 3.00%, respectively.

Growth Performance

The response of broiler starter chickens to diets with or without an acidifier-supplemented MPRM on growth performance is detailed in Table 4. The data analysis indicated that the dietary treatments with the acidifier-treated MPRM-based meals significantly ($p < 0.05$) influenced all evaluated parameters. The final body weight and average weight gain of the broilers exhibited a consistent trend, with significantly higher ($p < 0.05$) mean values observed in birds fed 50% and 75% MPRM without acidifier and those fed 25% and 75% MPRM diets with acidifier, compared to the control group. The feed intake of birds was significantly greater ($p < 0.05$) in the group receiving a diet composed of 75% acidified MPRM, followed by other groups given MPRM diets with or without an acidifier, compared to the control group. A significant ($p < 0.05$) increase in feed conversion ratio (FCR) was seen in birds consuming 25% and 75% MPRM without acidifier, followed by those on 75% MPRM diets with acidifier, in comparison to birds on the control diet and other MPRM diets, which exhibited the lowest ($p < 0.05$) FCR.

Protein and Nitrogen Utilization Efficiency:

Table 5 illustrates the response of experimental broiler starting chickens fed MPRM based diets with and without acidifier addition. The results indicated that dietary interventions significantly ($p < 0.05$) influenced the measured parameters.

Birds consuming a 75% MPRM diet exhibited significantly greater ($p<0.05$) protein and nitrogen intake than those in the non-supplemented 25% MPRM and control diet groups. The protein efficiency ratio and nitrogen efficiency of the birds were significantly greater ($p<0.05$) in the groups receiving the control and non-supplemented 50% MPRM diets, followed by those on the acidifier-supplemented 75% MPRM diet, in comparison to the group on the 50% MPRM diet with acidifier. Nitrogen retention was significantly greater ($p<0.05$) in the MPRM diet groups without supplementary acidifier at the 50% level and in the MPRM groups with acidifier supplementation at the 25% and 75% levels, compared to the control diet group.

Economics of Production:

The economic characteristics of the birds subjected to experimental diets are shown in Table 6, revealing that all economic indicators assessed exhibited significant differences ($p<0.05$) across the dietary treatments. The feed cost per kilogram for the birds was elevated in the control diet group and declined numerically as the degree of MPRM inclusion increased with or without acidifier supplementation. The feed cost per bird consumption was considerably ($p<0.05$) cheaper in the group receiving a 75% MPRM diet without acidifier compared to the groups receiving 25% MPRM diets, regardless of acidifier supplementation. The feed cost per gain considerably increased ($p<0.05$) in birds consuming the control, non-supplemented 25% MPRM, and acidifier-supplemented 25% and

50% MPRM diets in comparison to other experimental diet groups. The cost of production and feed cost were considerably ($p<0.05$) lower in the group receiving a diet with a greater inclusion level of MPRM (75%) compared to the 25% MPRM diet. The profit margin of birds was considerably ($p<0.05$) elevated in groups devoid of acidifier at 50% and 70% MPRM, as well as in groups with acidifier at 75% MPRM meals, in comparison to control and 25% MPRM diets.

DISCUSSION

The proximate composition of the MPRM recorded in this study is in accordance with the findings of Isirima and Ukpong (2018), who reported that pap meal contains substantial feed nutrients required by farm animals. This result corroborates the fact that maize is rich in carbohydrates, essential minerals, and vitamins (IITA, 2011). The present study suggests that the increased crude protein level and similar crude fiber, ash, and carbohydrate contents of the MPRM relative to maize reveal its applicability as a novel feed element in chicken diet composition. The crude protein of MPRM obtained in this study showed that the protein composition is higher than 10% standard crude protein content of harvested maize grain (Singh *et al.*, 2012) and 11.76% crude protein of processed pap (Isirima and Ukpong, 2018). The nutrient contents of MPRM in this research are significant as they indicate an improvement in the nutritional quality of the MPRM sample material.

Table 3: Proximate Composition of maize-pap residue meal and maize meal

Parameters	MPRM	Maize
Dry Matter (%)	90.78	88.00
Crude Protein (%)	13.17	10.60
Ash (%)	3.09	3.00
Crude Fiber (%)	3.35	3.00
Ether Extract (%)	7.98	4.00
Nitrogen-free extract (%)	72.41	79.40

*MPRM: Maize-pap residue meal

Table 4: Growth performance of broiler chickens (7-28 days) fed experimental diets.

Indices	<u>Without Acidifier</u>				<u>With Acidifier</u>			SEM	P-values
	0% MPRM	25% MPRM	50% MPRM	75% MPRM	25% MPRM	50% MPRM	75% MPRM		
Ave. Initial Weight, g/bird	220.00	220.00	220.00	220.00	220.00	220.00	220.00	0.00	NA
Ave. Final weight, g/bird	1020.00 ^c	1070.00 ^{bc}	1210.00 ^a	1130.00 ^{ab}	1190.00 ^a	1205.00 ^{bc}	1210.00 ^a	18.64	0.002
Ave. weight gain, g/bird	800.00 ^c	850.00 ^{bc}	990.00 ^a	910.00 ^{ab}	970.00 ^a	985.00 ^{bc}	990.00 ^a	18.64	0.002
Ave. daily gain, g/bird	38.10 ^c	40.48 ^{bc}	47.14 ^a	43.33 ^{ab}	46.19 ^a	46.91 ^{bc}	47.14 ^a	0.89	0.002
Ave. feed intake, g/bird	1710.00 ^d	2060.00 ^c	2170.00 ^b	2160.00 ^b	2130.00 ^{bc}	2180.00 ^b	2260.00 ^a	38.17	0.000
Ave. daily Feed Intake, g/bird	81.43 ^d	98.10 ^c	103.33 ^b	102.86 ^b	101.43 ^{bc}	103.81 ^b	107.62 ^a	1.82	0.000
Feed:gain	2.15 ^b	2.42 ^a	2.19 ^b	2.38 ^a	2.21 ^b	2.21 ^b	2.29 ^{ab}	0.04	0.010

^{abcd}: Mean values with different superscripts within rows are significantly (p<0.05) different

*MPRM: Maize-pap residue meal

Table 5: Economic attributes of broiler starter chickens (7-28 days) fed experimental diets

Indices	<u>Without Acidifier</u>				<u>With Acidifier</u>			SEM	P-values
	0% MPRM	25% MPRM	50% MPRM	75% MPRM	25% MPRM	50% MPRM	75% MPRM		
Protein Intake	380.65 ^d	463.50 ^c	481.09 ^{bc}	478.87 ^{bc}	472.22 ^{bc}	482.87 ^b	500.59 ^a	8.31	0.000
Protein Efficiency Ratio	2.10 ^a	1.83 ^{bc}	2.06 ^a	1.90 ^{abc}	2.05 ^a	1.76 ^c	1.98 ^{ab}	0.03	0.017
Nitrogen Intake	60.90 ^d	74.16 ^c	76.97 ^{bc}	76.62 ^{bc}	75.56 ^{bc}	77.26 ^b	80.09 ^a	1.33	0.000
Nitrogen Retention	23.20 ^c	24.65 ^{bc}	28.71 ^a	26.39 ^{ab}	28.13 ^a	24.65 ^{bc}	28.71 ^a	0.54	0.002
Nitrogen Efficiency	38.13 ^a	33.25 ^{bc}	37.30 ^a	34.44 ^{abc}	37.19 ^a	31.91 ^c	35.85 ^{ab}	0.61	0.017

^{abcd}: Mean values with different superscripts within rows are significantly (p<0.05) different

*MPRM: Maize-pap residue meal

Table 6: Economic attributes of broiler chickens (7-28 days) fed experimental diets

Indices	<u>Without Acidifier</u>				<u>With Acidifier</u>			SEM	P-values
	0% MPRM	25% MPRM	50% MPRM	75% MPRM	25% MPRM	50% MPRM	75% MPRM		
Feed Cost/kg, ₦	1022.25	941.61	844.20	744.95	940.96	845.58	746.34	21.64	---
Feed Cost/kg Intake, ₦	1748.05 ^c	1939.72 ^a	1831.92 ^b	1609.10 ^d	2004.25 ^a	1843.37 ^b	1686.72 ^c	29.71	0.000
Feed Cost/kg gain, ₦	2195.23 ^a	2281.31 ^a	1851.73 ^b	1769.53 ^b	2075.17 ^a	2168.87 ^a	1709.46 ^b	51.27	0.000
Cost of production, ₦	2898.05 ^c	3089.72 ^a	2981.92 ^b	2759.10 ^d	3154.25 ^a	2993.37 ^b	2836.72 ^c	29.71	0.000
Feed cost %	60.32 ^{bc}	62.76 ^{ab}	61.43 ^b	58.32 ^d	63.54 ^a	61.58 ^b	59.46 ^{dc}	0.39	0.000
Revenue, ₦	4590.00 ^a	4815.00 ^{bc}	5445.00 ^a	5085.00 ^{ab}	5355.00 ^a	4815.00 ^{bc}	5445.00 ^a	83.86	0.002
Profit Margin, ₦	1091.95 ^c	1125.28 ^c	1863.08 ^a	1725.90 ^a	1600.75 ^{ab}	1221.63 ^{bc}	2008.28 ^a	87.56	0.001

^{abcd}: Mean values with different superscripts within rows are significantly (p<0.05) different

*MPRM: Maize-pap residue meal

A potential way to enhance the quality of these feedstuffs for broiler diet suitability is the fermentation method (Sugiharto *et al.*, 2019). The activity of microbes during the fermentation of organic materials resulted in changes in nutritional content, palatability, and physicochemical qualities (Sharma *et al.*, 2020; Sawant *et al.*, 2025).

This often indicates an improvement in the nutritional composition of the products, particularly the protein derived from accumulating microbial protein (Kazimierz, 2010; Garba *et al.*, 2022). The reduction in crude fiber content resulting from the fermentation process that yielded the MPRM aligns with the findings of other studies (Adeleke *et al.*, 2017; Doughan and Dzogbefia, 2018).

Broiler birds given an acidified MPRM diet up to 75% have shown improvements in weight growth, feed intake, and feed conversion ratio compared to the control and MPRM diets without acidifier addition. Previous studies indicate that the enhanced growth performance in birds receiving acidifier-supplemented diets may be ascribed to the low pH in the diet and digestive tract, which functions as a microbial barrier, diminishes buffering capacity, and enhances nutrient digestibility (Brzoska *et al.*, 2013; Khalil *et al.*, 2020). Earlier research seems to indicate that dietary acidification can improve growth performance by lowering the acidity of the feed and gastrointestinal tract, therefore eradicating detrimental bacteria sensitive to low pH or selectively promoting *Lactobacillus* (Liu *et al.*, 2017; Heidari *et al.*, 2018; Gao *et al.*, 2021). According to Chukwudi *et al.* (2025), the positive impact of acidifiers on the gut microbiota is likely the main cause of improved body weight growth. In addition, the supplementation of acidifier in MPRM-based diets of broiler chickens resulted in an improved FCR compared with that of the control group. It was observed by previous works of Pearlin *et al.*

(2020) and Chukwudi *et al.* (2025), who reported that better nutrient utilization leading to higher body weight gain could cause an improvement in the FCR. The rationale for enhancing intestinal microflora is that pathogenic bacteria thrive in a neutral pH environment, whereas helpful bacteria like *Lactobacillus* flourish in acidic conditions (Sabour *et al.*, 2019). Acidifiers enhance performance by decreasing gut pH, inhibiting the growth of detrimental microbes, hence boosting enzyme activity and optimizing digestion and vitamin and mineral absorption (Sun *et al.*, 2022, Elnaggar and El-kelawy, 2024).

The current findings indicate that the enhancement in protein and nitrogen intake attributed to acidifier supplementation is associated with the regulation of microbial competition for host resources, endogenous nitrogen losses, and ammonia generation (Omogbenigun *et al.*, 2013). The protein utilization efficiency in birds fed acidifier-treated MPRM was superior to that of the control diet group, accompanied by considerably reduced nitrogen excretion, as reported in this research.

The reduced protein intake may be offset by enhanced protein absorption due to acidifier supplementation (Sukemi *et al.*, 2013). The use of an acidifier in broiler feed may enhance protein consumption, growth, and feed efficiency (Kopecky *et al.*, 2012; Sabour *et al.*, 2019). Protein intake is intricately linked to protein metabolism, particularly the mechanisms of protein deposition, which facilitate growth acceleration. The current study demonstrates that incorporating acidifier supplements positively affected performance, evidenced by improved protein efficiency ratio and nitrogen utilization efficiency, consistent with previous field trials conducted by Hashemi *et al.* (2012) and Sedghi *et al.* (2024). The current study's findings align

with previous research (Suthama, 2006), indicating that protein availability plays a crucial role in enhancing the rate of protein synthesis, hence promoting avian development. Nitrogen efficiency indicates nitrogen waste, a critical factor in assessing the environmental implications of feeding high-protein diets to animals. The enhanced nitrogen efficiency resulting from the acidification of MPRM diets found in this research aligns with the results of Sedghi *et al.* (2024). The increased level of protein and nitrogen utilization efficiency is associated with the advancement of gastrointestinal ecology and morphology (Mahfudz *et al.*, 2020). Previous studies demonstrated that dietary organic acid may inhibit the proliferation of pathogenic bacteria and enhance intestinal architecture, particularly the duodenal villi, hence boosting protein digestion and absorption (Waghmare *et al.*, 2025; Sharifuzzaman *et al.*, 2025).

The current findings indicated that the cost of feed was inversely related to the inclusion of MPRM, regardless of the presence of an acidifier. The data indicated that the cost of producing 1 kg of feed decreased when the level of MPRM, with or without acidifier addition, rose in the experimental diets.

This finding may be ascribed to the lower cost per unit of MPRM compared to maize. This aligns with the primary goals of using unconventional feedstuffs in monogastric feeding, as shown by previous studies (Aguihe *et al.*, 2015a; Ilaboya *et al.*, 2018). The cost-benefit analysis indicated that birds receiving higher amounts (50 and 75%) of MPRM, with or without the addition of an acidifier, achieved optimal production economics, likely attributable to enhanced feed consumption efficiency. The current results align with those of Aguihe *et al.* (2015b), who recorded a significant decrease in feed cost per kilogram of growth when the proportion of yam peel meal in the diet of growing Japanese quails increased.

The significant reduction in production costs and percentage feed costs in birds consuming a 75% MPRM diet may be ascribed to the decreased cost per kilogram of feed associated with the higher MPRM levels, hence indicating a more significant profit margin. The elevated profit margin seen in the non-supplemented groups of 50% and 75% MPRM and the acidifier-supplemented 75% MPRM group may be ascribed to reduced mean values for food cost per kg and enhanced growth performance. Furthermore, consistent with our findings, earlier research indicated that a reduction in feed costs is only required when production outcomes are equivalent to the control (Lamidi *et al.*, 2008; Sola-Ojo *et al.*, 2011; Oguntoye *et al.*, 2018). Therefore, the main aim of sustainable poultry farming is to achieve efficient performance at minimal cost to enhance profitability potential.

CONCLUSIONS

This study has shown that MPRM possesses substantial nutrient levels that make a potential alternative for maize in the diet of broiler chicken. The addition of acidified MPRM as a partial substitute for maize in the diet of broiler chickens (7-28 days) influenced the birds' growth performance, protein/nitrogen utilization, and economic attributes. Consequently, the incorporation of MPRM at 50% without an acidifier and up to 75% with acidifier supplementation enhanced growth performance and, protein and nitrogen utilization in broiler starter chickens while simultaneously reducing production costs and increasing profit margins.

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PROXIMATE AND PHYTOCHEMICAL COMPOSITION OF HAY MADE FROM THREE DIFFERENT PASTURE SPECIES

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ABSTRACT

Laboratory analysis was conducted to determine the proximate and phytochemical contents of three grass pasture species; *Pennisetum pedicellatum*, *Andropogon gayanus* and *Chloris biflorus* used in hay making. The plants were harvested at bloom stage, shade-dried for ten (10) days, milled into 2 mm particle size and stored in airtight polythene bags until needed for analysis. Samples for each specie were analyzed in triplicates and results subjected to descriptive analysis (Mean and Standard Deviation) using SPSS. Results obtained for proximate composition revealed that *A. gayanus* had higher mean value for crude protein (10.62 g/100g) followed by *P. pedicellatum* (8.94 g/100g) then *C. biflorus* (6.81 g/100g). Nitrogen free extract was highest in *C. biflorus* (50.53 g/100g) and lowest in *A. gayanus* (36.70 g/100g). Phytochemical analysis showed that the concentration of flavonoids in *P. pedicellatum* (0.15 g/100g) was slightly higher than the respective values of 0.07 and 0.04 g/100g obtained in *A. gayanus* and *C. biflorus*. Similarly, *P. pedicellatum* (0.26 g/100g) had higher tannin level than both *A. gayanus* (0.04 g/100g) and *C. biflorus* (0.02 g/100g). The mean concentration of saponins in the three grass species was 0.09 g/100g (*A. gayanus*), 0.10 g/100g (*P. pedicellatum*) and 0.16 g/100g (*C. biflorus*) while that of alkaloids fell within the range of 0.14g/100g in *C. biflorus* and 0.25g/100g in *A. gayanus*. Based on the Crude protein and phytochemical content of these pasture species, it was concluded that they are suitable for hay making in the following ranking order, *A. gayanus*, *P. pedicellatum*, *C. biflorus*.

Keywords: Grass, Crude protein, Hay quality, Tannin, Saponin, Alkaloid

INTRODUCTION

Nigeria, Africa's most populous country, has one of the largest livestock populations on the continent, contributing 9 and 1.7% to the agricultural and national Gross Domestic Product (GDP), respectively (FAO, 2019). The sector constitutes the major source of dietary animal protein in the form of meat and milk. Three outstanding systems of production, namely; extensive, semi-intensive and intensive systems are in use. The extensive system, also

known as pastoralism, is the most adopted and comprises of over 15 million pastoralists and 82% of cattle (Ayodele, 2022). This system, thus, is the main source of milk of animal origin, national reservoir of genetic trait of indigenous animals, source of draft power and meat. The pastoral system of livestock husbandry is characterized by transhumance and grazing of range for free. In addition, sedentary livestock rearers also leverage on forage grasses and legumes from range lands in order to meet the nutritional needs of their animals. In essence,

most ruminant livestock owners depend on grazed and conserved forage as basic feed resource (Ayodele, 2022).

The main advantages of forage as feed resource are informed by its low unit cost and high availability compared to other animal feed materials. Forage grasses and legumes provide all the nutrients required for maintenance, production and reproduction. However, the low level of animal production experienced, particularly, in the Savannah zones of Nigeria, is generally associated with the inability to get enough, high quality forage, especially during the dry season. This has been the main cause of southward migration of herdsmen and the seemingly unending cases of farmers-herder clashes, cattle rustling and banditry that have claimed several lives (Abdena, 2013).

In order to meet the nutrient requirements of livestock, particularly ruminants, knowledge of the nutritive value or chemical composition of pasture and forage crops is key (Muftau and Musa, 2020). *In vivo* digestibility analysis together with proximate analysis has been hitherto used in determining the chemical composition of feeds. However, modern techniques such as *In vitro* digestibility analysis and Near-Infrared Reflectance Spectroscopy (NIRS) which are cheaper, more rapid and cost-effective are now being used in most developed countries (Corson *et al.*, 1999; Samadi and Munawar, 2018 and Marica *et al.*, 2021).

Some of the most available and popularly used forage grasses in ruminant feeding in Northern Nigeria include *Pennisetum pedicellatum* (kyasuwa- Hausa), *Andropogon gayanus* (Gamba - Hausa), *Cenchrus biflorus* (karangiya - Hausa), *Chloris gayana* (kanarin doki - Hausa), *Digitaria horizontalis* (harkiya - Hausa), among others (Garba *et al.*, 2022). However, available data on their chemical composition in the Sahel

which is valuable in assessing their nutritional value for animals and possible utilization in folklore medicine remain scanty. *Pennisetum pedicellatum*, *Cenchrus biflorus* and *Andropogon gayanus* are some of the most available and used grass pastures for ruminants feeding in the study area. Results obtained in this study will help animal scientists, pasture agronomists, extension agents and livestock farmers in making informed decisions on effective and optimal utilization of these forage species. The results will also help compound ruminant feed millers and livestock farmers who practice intensive and semi-intensive ruminant production properly mix concentrates/supplements with chopped forage in order to obtain balanced rations that could meet the nutrient requirements of their animals.

Apart from nutritive value vis a vis nutritional requirement of livestock, assessment of chemical composition of forages is also useful in the area of phytomedicine. Phytochemicals are plant-based bioactive compounds produced by plants for their protection. They can be derived from various sources such as whole grains, fruits, vegetables, nuts, and herbs, and more than a thousand phytochemicals have been discovered to date. Some of the significant phytochemicals are carotenoids, polyphenols, isoprenoids, phytosterols, saponins, dietary fibers, and certain polysaccharides.

Therefore, the aim of this research work is to evaluate the proximate composition and some phytochemical profile of three grass species; *Pennisetum pedicellatum*, *Andropogon gayanus*, and *Cenchrus biflorus* in Yobe State.

MATERIALS AND METHODS

Experimental Site

The study was conducted at Federal Polytechnic, Damaturu, Yobe State. The area is located

within latitude 11° North and longitude 13.5° East. The state shares common boundaries with Borno to the East and South-East, Jigawa to the Northwest and Bauchi and Gombe states to the Southwest. It also shares an international border with the Republic of Niger. According to the population census conducted in 2006, the state has a population of about 2.6 million people (NPC, 2006).

Sample Collection and Processing

Forage plants of *Pennisetum pedicelatum*, *Cenchrus biflorus* and *Andropogon gayanus* were harvested at bloom stage, shade-dried for 10 days, milled into 2 mm particle size and stored in polythene bags ready for laboratory analysis. Materials used for the proximate analysis includes; Forage samples, Hot Air Oven, Air Tight Container, Crucible, Conical Flask, Soxhlet Apparatus, Muffle Furnace, Milling Machine, Weighing Balance, Desiccator, Pipette, Water, Sodium Hydroxide, Petroleum Ether, Sulphuric acid, Sodium Sulphate, Hydrochloric acid, Sodium Hydroxide, Standard solution of Sodium chloride.

Laboratory Analysis and Data Collection

The nutrient analysis was done at a laboratory in Federal Polytechnic, Damaturu, Yobe State using the procedure of AOAC (2005). The moisture content and ash were determined using weight difference method while the crude protein composition of the forages was determined using kjeldahl method of the sun-dried sample (AOAC, 2005). The nitrogen value which is the precursor for protein and was determined by micro kjeldahl method. The nitrogen value was converted to protein by multiplying to a factor of 6.25. Determination of Ether Extract was done using soxhlet type of direct solvent extraction method. The solvent is petroleum ether (boiling range 40-60°C) and the proximate values were reported in percentage.

Total Ash content was determined by igniting the sample in a muffle furnace at 550°C for 5 hours. The ether extract content of the sample was determined by adding distilled water to one hundred grams of the sample material placed in a flask. The flask was incubated in water at 50°C for 48hrs after which the obtained extract was filtered using filter paper. The filtrate was stored in a deep freezer at 80°C overnight and then subjected to freeze drying at 50°C for 48hrs to obtain extract.

Samples for each forage were analyzed for proximate analysis in triplicate using standard laboratory methods and procedures of AOAC (2005) while Nitrogen Free Extract (NFE) was obtained by calculation using the following formula;

$$NFE \% = 100\% - (\% CP + \% EE + \% CF + \% Ash + \% moisture)$$

Phytochemical Analysis

Test for alkaloids

Five (5) ml of the extract was added to 2 ml of hydrochloric acid (HCl). To this acidic medium, 1 ml of Dragendorff's reagent was added. An orange or red precipitate was obtained, denoting the presence of alkaloids.

Test for Tannins

About 0.5 g of the dried powdered samples were boiled in 20 ml of water in a test tube and filtered. A few drops of 0.1% ferric chloride were added and observed for brownish green or a blue-black coloration.

Test for Saponins

About 2 g of the powdered sample was boiled in 20 ml of distilled water in a water bath and filtered. Ten 10ml of the filtrate was mixed with 5 ml of distilled water and shaken vigorously for a stable persistent froth. The frothing was then mixed with 3 drops of olive oil

and shaken vigorously. The formation of an emulsion confirmed the presence of saponins.

Test for Flavonoids

Three methods were used to determine the presence of flavonoids in the samples (Sofowara, 1993). Five (5) ml of diluted ammonia solution was added to a portion of the aqueous filtrate of the sample followed by addition of concentrated H_2SO_4 . A yellow coloration was obtained, indicating the presence of flavonoids. The yellow coloration disappeared on standing.

Data Analysis

All data obtained from laboratory analysis were analysed for mean and standard deviation (Descriptive Statistics) using the SPSS v. 25.

RESULTS AND DISCUSSION

Proximate Composition of *Pennisetum pedicellatum*, *Androgodon gayanus* and *Cenchrus biflorus*

The results for proximate analysis of *Pennisetum pedicellatum*, *Androgodon gayanus* and *Cenchrus biflorus* are presented in Table 1. Values for moisture content (g/100g sample) were 7.11 g for *Androgodon gayanus*, 4.27 g for *Pennisetum pedicellatum*, and 3.65 g for *Cenchrus biflorus*. Ash content ranged between

11.79 and 21.03 g in *A. gayanus* and *P. pedicellatum* respectively. Crude fibre level was highest in *A. gayanus* (31.23 g) followed by *P. pedicellatum* (21.03 g), then *C. biflorus* (16.42 g). The crude fibre content for *A. gayanus* obtained in this study is lower than 40.70 g/100g reported by Salah *et al.* (2014) and 34.32g/100g (Amada *et al.*, 2020). This could be attributed to the stage of growth at which the grass was harvested. Usually, plants harvested late in their growth cycle may contain higher amount of crude fibre than those cut at earlier stage. On the contrary, Rahman *et al.*, (2020) reported a lower mean value (18.00 g/100g) for crude fibre in *P. pedicellatum* than obtained in the present study. Furthermore, the mean crude fibre value for *C. biflorus* obtained in this study is slightly lower than 20.80g/100g (Hassan *et al.*, 2018). Ether extract was higher in *P. pedicellatum* (3.87 g) than in *A. gayanus* and *C. biflorus* which were the same (2.54 g). Values for crude protein were 10.62, 8.95, and 6.81 g for *A. gayanus*, *P. pedicellatum* and *C. biflorus*, respectively. These values are comparable with 9.81 g/100g for *P. pedicellatum* (Salah *et al.*, 2014), 2.60 – 19.0 g/100g for *A. gayanus* (Evitayani *et al.*, 2004) and 3.70 – 22.00 g/100g for *C. biflorus* (Ahmed *et al.*, 2003). Nitrogen free extract which had values between 36.70 g and 50.53g was highest in *C. biflorus* and lowest in *A. gayanus*. However, the value for *A. gayanus* is comparable with 37.84g/100g reported by Salah *et al.* (2014).

Table 1: Proximate composition of selected pasture grass species

Parameter (g/100g)	Grass specie					
	<i>A. gayanus</i>		<i>P.pedicellatum</i>		<i>C. biflorus</i>	
	Mean	SD	Mean	SD	Mean	SD
Proximate Composition						
Moisture	7.11	0.01	4.27	0.03	3.65	0.07
Ash	11.79	0.02	21.03	0.11	16.42	0.02
Crude fibre	31.23	0.17	18.93	0.10	20.06	0.11
Ether extract	2.54	0.03	3.87	0.02	2.54	0.19
Crude protein	10.62	0.02	8.95	0.06	6.81	0.13
Nitrogen free extract	36.70	0.17	42.96	0.31	50.53	0.15

SD = Standard deviation

Phytochemical Contents of *Pennisetum pedicellatum*, *Androgogon gayanus* and *Cenchrus biflorus*

The results for phytochemical analysis of *A. gayanus*, *P. pedicellatum*, and *C. biflorus* are presented in Table 2. Mean values for flavonoids were; *A. gayanus* (0.07 g), 0.15 g (*P. pedicellatum*) and 0.04 g (*C. biflorus*). The widespread distribution of flavonoids, their variety and their relatively low toxicity compared to other active plant compounds (for instance alkaloids) mean that many animals, including humans, could ingest significant quantities in their diet. Tannin content was higher in *P. pedicellatum* (0.26 g), followed by *A. gayanus* (0.04 g), then *C. biflorus* (0.02 g). This disagrees with 10.25 g/100g reported by FAO (2016) and Sulaiman *et al.* (2020) for *A. gayanus* and *P. pedicellatum* respectively. Tannins can reduce feed intake when found in high concentration in feed. They also precipitate proteins in the gut, reducing their digestibility (Mavromichalis, 2020). Saponin values were; 0.09 g (*A. gayanus*), 0.10g (*P. pedicellatum*) and 0.16 g (*C. biflorus*). These values are lower than 0.85 g/100g for *P.*

pedicellatum (Chaney *et al.*, 2006), 4.01 g/100g for *A. gayanus* (FAO, 2016) and Cirade *et al.*, (1991) for *C. biflorus*. Saponins are glycosides present in plants. The effect of saponins at a lower concentration of 10 µg/mL or less on the transverse tubular system and sarcoplasmic reticulum was also observed to be effective (Desai *et al.*, 2009). Mean values for alkaloids ranged from 0.14 g (*C. biflorus*), to 0.25 g for *A. gayanus*. Grinkevich and Safronich (1983) stated that alkaloids content in plants is usually within a few percent and is inhomogeneous over the plant tissues. Depending on the type of plants, the maximum concentration is observed in the leaves. This study provides an insight into the distribution of phytochemicals in *A. gayanus*, *P. pedicellatum*, and *C. biflorus* pasture grasses which are usually dependent on species, growth period, growth stage and plant part. The results of phytochemicals obtained in this study which were low and indicated a very slight presence could be used to develop a good grass management strategy such as selection of species for healthy animal nutrition without any detrimental effect on livestock fertility (Butkute *et al.* 2018)

Table 2: Phytochemical Contents of selected pasture grass species

Parameter (g/100g)	Grass specie		
	<i>A. gayanus</i>	<i>P. pedicellatum</i>	<i>C. biflorus</i>
Phytochemical Content			
Flavonoids	0.07	0.15	0.04
Tannins	0.04	0.26	0.02
Saponins	0.09	0.10	0.16
Alkaloids	0.25	0.20	0.14

CONCLUSION AND RECOMMENDATION

Based on the results obtained in this study it was concluded that the three grass pasture species *P. Pedicellatum*, *A. gayanus* and *Cenchrus biflorus* harvested at bloom stage of growth or life cycle contain appreciable levels of nutrients and secondary metabolites may be required ruminant

animals especially during periods of forage and feed scarcity.

Hay made from *Pennisetum Pedicellatum*, *A. gayanus* and *Cenchrus biflorus* is hereby recommended for ruminant animals feeding. However, hay from *Androgogon gayanus* and *Pennisetum Pedicellatum*, should be given

preference due to their relatively higher crude protein contents.

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QUALITY ASSESSMENT OF MEAT AND MILK PRODUCTS FROM VENDORS IN PARTS OF KADUNA STATE

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ABSTRACT

This study evaluated the proximate composition, total bacterial and total fungal counts of processed meat products (*Tsire* and *Balangu*) and milk products (plastic yoghurt, carton yoghurt and *Nono*) obtained from vendors in Kaduna State. A total of fifteen (15) samples of each product type were purchased. Five samples each from three different sport of Sabon Tasha, Central market and Zaria were used for this study. Samples were analysed for dry matter, crude protein, lipid, ash, nitrogen free extract and microbial loads. *Balangu* had significantly higher crude protein ($P>0.05$) were found in microbial loads across all the products. The results underscore the nutritional variation between meat products and highlight the limited impact of packaging on milk quality. The results indicated that the crude protein was significantly higher ($P<0.05$) while the nitrogen free extract was lower ($P<0.05$) for *Balangu* compared to *Tsire*. For milk products, the dry matter for yoghurt packaged in carton was higher ($P<0.05$) than the yoghurt packaged in plastic and *Nono*. There was no difference ($P>0.05$) in dry matter, crude lipid, crude ash, total bacterial and total fungi count between *Balangu* and *Tsire*. Also, no difference was observed in the proximate composition, total bacterial and total fungi count among the plastic yoghurt, carton yoghurt and *Nono*. In conclusion, *Balangu* has higher crude protein but lower nitrogen free extract compared to *Tsire* with no difference in the total microbial counts while for the milk products, no difference was noted in both proximate composition and total microbial counts among plastic yoghurt, carton yoghurt and *Nono*. The findings in this study suggest that product type influences nutritional component, while microbial quality is uniformly affected by vendor handling.

Keywords: Meat, milk, spoilage

INTRODUCTION

Meat and milk products are essential component of a balance diet, providing vital nutrients and energy for human growth and development (FAO, 2013). In Northern Nigeria, particularly in Kaduna and Zaria, many people rely on vendors for these products (Egwaikhiden *et al.*, 2013). However, the quality and safety of these

products have become a major concern in recent years, particularly in informal markets where vendors play a significant role in the food supply chain. (Moshood *et al.*, 2012). Informal markets often lack proper quality control measures, raising safety concerns (Addis ans Sisay, 2015). In Kaduna and Zaria environs both of Kaduna state Northern Nigeria, the majority of population relies on vendors for their daily

supply of meat and milk products. (Egwaikhide *et al.*, 2013). However, the lack of effective quality control majors and inadequate regulation has raised concerns about the safety and quality of these products. According to Addis and Sisay (2015), the risk of foodborne illnesses, nutritional deficiencies and exposure to contaminants is high, particularly among vulnerable populations such as children, pregnant women and the elderly. Despite the nutritional importance of meat and milk, their quality in informal markets remains uncertain. Vendors may sell products contaminated with pathogens such as *Salmonella*, *E. coli* and *Campylobacter*, potentially causing foodborne illness (FAO,2023). This study addresses the gap in data concerning the nutritional and microbial quality of these vendor-supplied products in Kaduna State.

The objectives of this study were to evaluate the nutritional contents of meat and milk products from vendors, and to assess the microbial safety of meat and milk products from vendors.

MATERIALS AND METHODS

The study was conducted in Sabon Tasha, Central Market and Zaria environs, all part of Kaduna state. Kaduna is on latitude 10.45° N and latitude 7.47°E. The annual rain fall in this area varies between 1000mm and 1500mm per annum and raining season last for 150 to 200 days and the dry season start from October to early April (40° C) and coolest period (13.20°C) which is between December and January during severe harmattan. Kaduna State falls within the northern guinea savanna zone of Nigeria (GPS, 2025).

A total of fifteen (15) samples of *Tsire*, *Balangu* (meat), *Nono*, yogurt (plastic bottle) and yogurt (carton bottle) were purchased, five samples each from three different sport of Sabon Tasha, Central market and Zaria environs of Kaduna state. Each sample was labelled with the name of

the location collected. The samples were then transported to Ahmadu Bello University Zaria for analysis. Each of the samples was shared into two equal halves. One of the halves were taken for microbiological analysis where it was processed immediately to avoid further contamination while the remaining half of the sample conveyed to the animal science laboratory for proximate analysis to ascertain the composition of each product or samples.

Each sample (10 g for meat and 10 ml for milk) was diluted in 90 ml of 0.1% sterile peptone water and serially diluted to 10⁻⁴. Plate Count Agar (PCA) was used for bacterial enumeration, while Potato Dextrose Agar (PDA) was used for fungal isolation and bacterial isolation

The distinct colonies that develop in the pure culture plate were observed for the morphological and cultural characteristics including the nature of margin, elevation, shape, color and transparency and Gram staining and set of biochemical characteristics by standard methods given by Sherm and Holt *et al.* (2005).

Using a sterile knife, 10gm each of meat sample (*Tsire* and *Balangu*) and 10ml each of the milk samples (yogurt and *Nono*) were cut and transferred aseptically into 90ml of 0.1% sterile peptone water (stock solution). It was allowed to soak to about 10minutes after which 1ml was transferred into a bottle containing also 0.1% sterile peptone within (10⁻¹ dilution). Thus was obtained with the aid of a sterile syringe 0.1ml of 10⁻⁴ dilution of aseptically transferred into a surface of a sterile plate, aseptically poured a sterile potato dextrose agar (P.D.A) gently mixed, it was allowed to solidify and incubated at room temperature (27° – 30°) for period of seven days. At the end of the incubation period the fungi colonies grown on the media were counted and the result was expressed as colony forming unit per gram (CFU/gm) by using the formula below:

$$\frac{\text{Total number of colony counted} \times \text{dilution factor}}{\text{Volume of inoculums} = 1\text{ml.}}$$

The fungi were identified using the lactophenol cotton blue technique. Drop lactophenol cotton blue was placed on clean grease free. A straight wire loop was used to pick the organism colony and teased on the drop. A cover slip was placed on the lactophenol cotton blue and examined under x40 objective lens to check for the structure of the organisms.

The samples of meat (*Tsire* and *Balangu*) and milk (yogurt and *Nono*) were analysed for dry matter (DM), crude protein (CP), lipid, ash and nitrogen-free extract (NFE) using the procedures outlined by AOAC (2012).

Data collected on proximate composition and total bacterial and fungi counts were subjected to ANOVA using SAS (2009) version 9.4, means with significant difference were separated using Duncan Multiple Range Test at 5% level of probability.

RESULTS AND DISCUSSION

Table 1 represents the proximate composition of *Tsire* and *Balangu* Sold by Vendors in Parts of Kaduna State. The crude protein content was significantly higher ($P < 0.05$) for *Balangu* compared to *Tsire* why the value for the nitrogen free extract was higher ($P < 0.05$) in *Tsire* when compared to the *Balangu*. However, there were no significant differences ($P > 0.05$) observed for the dry matter, crude lipid and crude ash contents between *Tsire* and *Balangu*. The higher energy content of *Tsire* could be due to the addition of plant-based condiments such as groundnut etc. The crude protein content of

Tsire (44.26%) and *Balangu* (51.48%) as obtained in this study were higher than the 37.44% and 31.42% recorded by Gyang *et al.* (2024) who evaluated the proximate composition and sensory evaluation of different meat products produced from beef. This could be attributed to the type/part of meat used and the processing method.

Table 2 shows the Proximate Composition (%) of some Milk Products Sold by Milk Vendors Using Different Packaging Methods. The dry matter content of carton packed yoghurt is significantly higher ($P < 0.05$) than the plastic packed yoghurt and *Nono* (raw milk). There were no significant differences ($P > 0.05$) noted for the crude protein, crude lipid and crude ash contents among the three forms of milk products. This could probably mean that the packaging does not influence parameters such as crude protein, crude lipid and crude ash contents of milk.

Table 3 illustrates the total bacteria and fungi counts of *Tsire* and *Balangu* sold by Vendors in parts of Kaduna State, while Table 4 represents the total bacteria and fungi counts of some milk products sold by milk Vendors using different packaging methods. There were no significant differences ($P > 0.05$) observed for the bacteria and fungi counts between *Tsire* and *Balangu*, as well as among the three forms of milk packaging methods. This probably indicates that total bacteria and fungi counts are not affected by meat the forms of meat processing as well as by the three forms of milk packaging methods.

Table 1: Proximate Composition (%) of *Tsire* and *Balangu* Sold by Vendors in Parts of Kaduna State

Sample	Dry matter	Crude protein	Lipid	Ash	NFE
<i>Balangu</i>	59.71	51.48 ^a	12.32	4.35	31.84 ^b
<i>Tsire</i>	69.27	44.26 ^b	12.79	5.75	37.15 ^a
SEM	9.96	1.54	0.28	0.64	1.70
P value	0.53	0.03	0.30	0.20	0.03

^{ab} = means with different superscripts differ significantly at $P < 0.05$ across rows, SEM = Standard error of mean. NFE=nitrogen free extract

Table 2: Proximate Composition (%) of some Milk Products Sold by Milk Vendors Using Different Packaging Methods

Sample	Dry matter	Crude protein	Lipid	Ash	NFE
<i>Nono</i> (raw milk)	6.17 ^b	3.92	3.13	3.88	89.07
Plastic Yoghurt	7.77 ^b	3.36	3.15	2.14	91.35
Carton Yoghurt	12.72 ^a	2.83	3.01	3.19	90.97
SEM	1.77	0.75	0.42	1.89	2.03
P value	0.021	0.23	0.76	0.42	0.33

^{ab} = means with different superscripts differ significantly at $P < 0.05$ across rows, SEM = Standard error of mean. NFE=nitrogen free extract

Table 3: Total Bacteria and Fungi Counts of *Tsire* and *Balangu* Sold by Vendors in Par State

Sample	Bacteria(cfu×10 ⁴)	Fungi(cfu×10 ⁴)
<i>Balangu</i>	18.00	5.33
<i>Tsire</i>	27.00	2.67
SEM	5.29	0.88
P value	0.30	0.10

$P < 0.05$ across rows, SEM = Standard error of mean.

Table 4: Total Bacteria and Fungi Counts of Some Milk Products Sold by Milk Vendors Using Different Packaging Methods

Sample	Bacteria (cfu×10 ⁴)	Fungi (cfu×10 ⁴)
<i>Nono</i> (raw milk)	34.33	6.33
Plastic Yoghurt	32.33	4.67
Carton Yoghurt	31.00	4.00
SEM	12.08	3.09
P value	0.79	0.49

$P < 0.05$ across rows, SEM = Standard error of mean.

CONCLUSION

This study concludes that *balangu* had higher crude protein but lower nitrogen free extract as compared to *tsire* with no difference in the total microbial counts, while for the milk products, no difference was observed in both proximate composition and total microbial counts among plastic yoghurt, carton yoghurt and *nono*. It is also suggested that a routine quality control program involving periodic testing of meat and milk products for microbial safety and nutritional content. Meat and milk vendors should be properly trained on handling, storage

and hygiene practices of animal products to reduce microbial contamination and to maintain wholesomeness of products.

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