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General Information about Journal of Agriculture and Agricultural Technology

Background:

The Journal of Agriculture and Agricultural Technology, Minna, was established in the early 90s with Prof T.Z. Adama as the pioneer Editor-in-Chief. It is housed within the School of Agriculture and Agricultural Technology of the Federal University of Technology, Minna, Nigeria. The journal has been a prominent platform for disseminating research and knowledge in the field of agriculture and related technologies.

Philosophy:

The journal operates with the philosophy of advancing agricultural research and technology through the publication of original works and review articles. It aims to foster innovation, promote sustainable agricultural practices, and contribute to the growth of the agricultural sector. By providing a scholarly space for researchers and experts, the journal plays a vital role in the academic and practical development of agriculture and related areas.

Management:

Under various visionary leadership and editorial teams, the Journal of Agriculture and Agricultural Technology, Minna, has maintained a commitment to quality and excellence. The management is dedicated to upholding rigorous editorial standards, ensuring the publication of high-impact research, and facilitating a dynamic platform for collaboration and knowledge exchange within the agricultural community.

Future Prospects:

The journal has demonstrated remarkable growth over the years, evolving from an annual publication to a biannual one. Looking forward, there are ambitious plans to transition to a quarterly publication schedule. This strategic move reflects the journal's commitment to keeping pace with the rapid advancements in agricultural research and technology and providing a more frequent outlet for the dissemination of groundbreaking findings.

The Journal of Agriculture and Agricultural Technology, Minna, aspires to expand its readership and impact, reaching an even larger community at a faster rate. By doing so, it aims to contribute significantly to the global discourse on innovative solutions to the challenges facing agriculture and related areas. The future prospects include leveraging technology to enhance accessibility, collaborating with international researchers, and maintaining a steadfast commitment to excellence in agricultural research dissemination.

The journal has a rich history, a clear philosophical foundation, effective management, and ambitious plans for the future. Its evolution from an annual to a quarterly publication is a reflects its adaptability and commitment to advancing agricultural knowledge and technology.

EDITORIAL

The Editorial Board is delighted to unveil Volume 13 of our esteemed Journal, marking another milestone in our commitment to scholarly excellence. As we look ahead, we anticipate the release of more issues and a special edition in 2024, promising a year of enriched academic discourse and valuable insights.

We are glad to share that our online-first approach is now a permanent feature, ensuring our esteemed readership has swift access to cutting-edge research. Furthermore, we are happy to state that many of our past editions are now online. All hard copies will be made available immediately after the online version has been released. All these are aimed towards a more extensive reach and impact within the academic community.

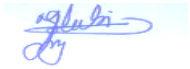
Deepest gratitude is extended to all dedicated members of the Board for their unwavering commitment in bringing forth this edition despite the numerous work load and challenges faced in 2023/2024. The collective effort and perseverance have truly made this achievement possible. Our sincere appreciation goes out to our diligent reviewers who dedicated their time, effort and resources to ensure timely and rigorous review of submitted articles. We value your contribution in upholding scholarly standards. As we navigate a global audience, we encourage our reviewers to adopt a more critical stance by continuously improving the quality and timeliness of their reviews.

We extend our profound appreciation to the Board of School of Agriculture and Agriculture Technology, Federal University of Technology, Minna, Nigeria as well as the entire University Community, for the honour bestowed upon us to serve as Editorial Board members. We recognize the significance of this trust and assure you that we will continue to do our best.

Lastly, we express our gratitude to everyone involved in making Volume 13 a reality. We are eager to continue our journey of academic exploration and look forward to the valuable contributions that will shape the future editions of the Journal.

Warm regards,

Editor-in-Chief



Prof. O.J. Alabi

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FACTORS INFLUENCING PROFITABILITY OF POULTRY EGG PRODUCTION IN IBADAN METROPOLIS, OYO STATE, NIGERIA

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ABSTRACT

This study was executed to estimate the profitability of poultry egg production and its determinants in Ibadan, Oyo State, Nigeria. A two-stage sampling technique was used to survey 120 poultry farmers, and primary data was collected using a structured questionnaire. The data obtained was analyzed using descriptive statistics, cost and returns analysis and multiple regression. Results revealed that the majority (75%) were male, with an average age of 41 years. Many (64.2%) of the poultry farmers had secondary education, and 25.8% had farming experience of 1-4 years. The majority (88.3%) were cooperative society members, and 87.5% operated a battery cage system of poultry management. The cost and returns result showed that poultry egg production was profitable, with a net income of ₦1,823,252.61. The profitability ratio further revealed that for every ₦1 invested in poultry egg production, the poultry farmer earned ₦0.26 as profit. In addition, factors influencing profit level among the farmers include age ($\beta = 0.23$, $p<0.01$), experience ($\beta = 0.71$, $p < 0.05$), feed cost ($\beta = -0.12$, $p < 0.01$), labour cost ($\beta = -1.30$, $p < 0.01$), cost of medication ($\beta = -1.06$, $p < 0.01$), stock size ($\beta = 0.79$, $p < 0.01$), price of crate of eggs ($\beta = 0.90$, $p < 0.01$) and cost of laying birds ($\beta = -0.28$, $p < 0.05$). Based on the findings of this study, it is recommended that policies that will assist poultry egg farmers to attain a drastic reduction in the cost of poultry feed, possibly through subsidies,

should be formulated by the government. In addition, it is essential to encourage the use of locally sourced raw materials in feed formulation to increase profit.

KEYWORDS: Cost and returns, Egg, Poultry, Production, Profitability ratios

INTRODUCTION

Agriculture is a prominent non-oil sector in Nigeria that contributes remarkably to the country's economic growth. In real terms, this industry produced approximately 22.36% of the Gross Domestic Product (GDP) in the first quarter of 2022. According to the National Bureau of Statistics (NBS), the livestock business is one of agriculture's subsectors, as it employs about 85 million Nigerians directly or indirectly and primarily in the poultry industry on a small to medium scale (NBS, 2022). Livestock contributed between 6% and 8% of the nation's GDP (Africa Sustainable Livestock, ASL, 2018). According to FMARD (2021), livestock are tools that can improve the socioeconomic conditions of the rural populace, particularly in developing countries. They can be raised on a small, medium, or big level. Nigerian livestock includes poultry (chickens), cattle, pigs, sheep, and goats. According to the Federal Ministry of Agriculture and Rural Development (FMARD, 2021) report, the annual output of livestock produced in Nigeria was 22 million cattle, 38 million sheep, 57.3 million goats, 7.1 million pigs, 180 million poultry birds and 1.4 million equids (horses, donkeys and so on). According to the Federal Ministry of Agriculture and Rural Development (FMARD, 2021) report, the output realized from the poultry population was 650,000 metric tonnes (MT) of eggs and 300,000MT of meat as against the demand for eggs and meat, which is about 790,000MT and 1,500,000MT respectively, thus creating a huge demand gap which is often met through smuggling from the Benin Republic. There are numerous lucrative prospects in the poultry industry in Nigeria, although chickens are more commonly raised than other poultry birds. For example, a broiler is reared for meat production and layers for egg production under a free-range, semi-intensive or intensive management system.

Poultry offers a wide range of economic opportunities, including egg and meat production, hatcheries and input suppliers, which generate additional revenue for the household. Despite the obstacles, the production of poultry products in Nigeria has increased throughout the years. However, the proportion of increases still falls short of demand as it only caters for 30% of the chicken eggs and meat needs of Nigerians as per capita egg consumption is 60 eggs per annum compared to advanced countries where per capita egg consumption is 250 eggs per annum

(Babban 2021). According to FMARD (2021) and FAO (2019), the main reasons for the low poultry output in Nigeria compared to what is obtainable in other African countries are inadequate capital, diseases and parasite infection, enormous feed costs and the use of poor breeds of birds. The high costs of maize and soybeans have put most poultry producers out of business (Sahel, 2015). The exorbitant cost of foreign-sourced feed has caused most farmers to improvise and reformulate poultry feeds with sub-standard materials such as peanut cake, cottonseed and palm kernel meal, thus exacerbating the input dilemma (World Poultry, 2013). The high cost of inputs is a big problem in the poultry industry because feed purchases consume as much as 70% of the cost of production, leading to a significant reduction in the number of commercial poultry farmers, particularly small-scale ones who are unable to bear the high-cost of egg production (Adebiyi, 2000; Ashagidigbi *et al.,* 2011) and subsequent reduction in the farmer's profit level (Hamzat *et al.,* 2020). The exorbitant input cost would undoubtedly impact the income level of poultry egg producers. The Nigerian government has implemented several programmes both in the past and in the present aimed at addressing the issue of high input costs, bridging the demand-supply gap, creating more job opportunities, reducing hunger and reducing heavy dependency on importation in the poultry industry. These include the Micro-Credit Scheme for Livestock Production and the Community-Based Agricultural and Rural Development Project (African Development Fund, ADF, 2003, FAO, 2019). However, some of these programmes appear to be no longer functional, possibly due to a lack of funding and proper monitoring that would ensure continuity.

Poultry egg farming is crucial in meeting the growing demand for high-quality protein sources. Therefore, ensuring the sustainability and profitability of poultry egg farming is germane given the ongoing population growth. In addition, despite its importance, poultry egg farming confronts numerous challenges that affect its profitability. Poultry egg enterprise is affected by many factors, including high production costs and technical constraints in marketing due to poor infrastructures, among others. Therefore, identifying the critical variables that affect its financial sustainability is necessary. The current study aims to evaluate the profitability of poultry egg production and its determinants in the Ibadan metropolis, Oyo state. The study specifically described the socioeconomic characteristics of poultry farmers and calculated the costs and returns involved in poultry egg farming and its determinants. Findings from this study would enable the relevant stakeholders to make well-informed choices and have in-depth knowledge of these factors, thereby potentially improving the profitability and sustainability of the poultry egg farming industry in Nigeria.

METHODOLOGY

The research was conducted in the Ibadan metropolis, Oyo State, Nigeria, which comprises 11 Local Government Areas (LGAs). It lies between longitude 3°55′0″E and latitude 7°23′47″N and had an estimated population of 6,000,000 as of 2021. Ibadan has a tropical wet and dry climate, with a long wet season and relatively consistent temperatures (between 24^{o}C and 25^{o}C) all year. Because of the favourable weather, poultry farming is popular among the farmers in the study area. A well-structured questionnaire was used to elicit relevant information from the respondents that supported the study objectives. A two-stage sampling procedure was employed to select the respondents. The first stage involved the purposive selection of two (Lagelu and Oluyole) out of the 11 LGAs in the metropolis due to intensive poultry egg farming in the area. The Poultry Association of Nigeria, Oyo state chapter (PANOY) provided a register of all poultry egg farmers in the selected LGAs. The second stage involved a proportionate sampling of 120 poultry egg farmers from the list obtained from PANOY, as the number of registered poultry farmers from the two local governments was different and also, a large number of the registered farmers had deserted the enterprise due to high production cost, thus leaving very few behind in the business. Fifty farmers were interviewed in Lagelu, while 70 were interviewed in Oluyole. Data were analyzed using descriptive statistics in the form of frequency counts and percentages to describe the socioeconomic characteristics of the respondents, cost and return analysis for profitability and multiple regression analysis for determinants of profitability.

Estimation of Net Income

The profitability of egg production was evaluated using the net income estimation approach. Costs incurred and returns from egg farming were estimated, including the cost of all inputs used (fixed and variable), the quantity of output (eggs) produced in crates and the price per crate. This can be specified as shown in equations 1-4.

$$NI_i = TR_i - TC_i \quad (1)$$

$$TR_i = P_i * Q_i \quad (2)$$

$$TC_i = TFC_i + TVC_i \quad (3)$$

$$\text{Therefore, } NI_i = P_i * Q_i - (TFC_i + TVC_i) \quad (4)$$

Where: NI_i = Net income realized from the sale of egg (₦);

TR_i = Total revenue realized from the sale of eggs (₦);

TVC_i = Total variable cost expended on production of eggs (₦);

Qi= Total quantity of eggs produced by the farmer (crates);

Pi= Current price per unit of output (₦/crate);

TFCi= Total fixed cost expended by the farmer (₦)

Returns on Investment (ROI) = NI/TC

Net Profit Ratio = NI/TR

Profitability ratios, such as Net Income (NI), Returns on Investment (ROI), and Net Profit Ratio (NPR), were calculated from the cost and returns analysis.

Following Olaoye *et al.* (2016), poultry egg farming was profitable.

Determinants of Profitability in Poultry Egg Production

Multiple regression analysis was employed in this study to establish the socio-economic factors that influence profitability in poultry egg production. This was represented in equation 5 below:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots \ldots \beta_{10} X_{10} + \varepsilon_{it} \quad (5)$$

Where

Y_i = Profit from poultry egg production (naira)

X_1 = Age (years)

X_2 = Sex (male = 1; 0 otherwise)

X_3 = Experience in poultry farming (years)

X_4 = Level of education (years)

X_5 = Feed cost (naira)

X_6 = Labour cost (naira)

X_7 = Medication cost (naira)

X_8 = Stock size (number)

X_9 = Price of crate of eggs (naira)

X_{10} = Cost of laying birds (naira)

RESULTS AND DISCUSSION

Socioeconomic characteristics of poultry egg farmers

The socioeconomic characteristics of the poultry egg farmers sampled in the study area are presented in Table 1. The majority (75%) of the poultry egg farmers are male, while very few (25%) are female. An average poultry egg farmer in the study area was 41 years old, with a cumulative majority (80%) below 50 years of age. This implies that the farmers were still economically active and productive and, thus, would be able to withstand the arduous tasks involved in poultry egg production. This result is similar to the earlier findings of Adedeji *et*

al., (2017) and Johnson *et al.*, (2020), who reported an average age of 41 years for poultry egg farmers in Oyo State, Nigeria. Most (77.5%) of the poultry farmers are married, while a few (17.5%) are single. Regarding educational qualification, very few (2.5%) had only primary education, 33.3% had secondary education, while more than half (64.2%) attained tertiary education. This high literacy rate among the farmers is a promising sign for the industry, as it could bring about more informed decisions and possibly increase output levels, as reported by Adenuga *et al.*, (2013). About one-quarter (25.8%) of the poultry farmers had 1-4 years of experience, while an average poultry egg farmer in the study area had 12 years of experience. This suggests that there are relatively few new entrants in the business. However, the long years of experience could improve profit levels, possibly due to perfection that sets in following the repetition of production activities over time, as documented by Adeyonu *et al.*, (2016); Oyinbo *et al.*, (2016) and Oke *et al.*, (2022). Many (59.2%) of the respondents had 5-8 persons in their households, while the mean household size was five persons, and the majority (88.3%) of the poultry farmers were cooperative society members, providing a strong support network for the farmers. In addition, (87.5%) of the poultry farms operate a battery cage system of management, while just (12.5%) operate a deep litter system.

Cost and Returns Analysis in Poultry Egg Production

The profitability of poultry egg production was examined using the net income estimation approach. The costs and returns to poultry egg enterprises in the study area are presented in Table 2. The depreciated cost was ₦121,841.30, representing 8.4% of the total cost (TC). The total variable cost (TVC) was ₦1,327,653.42 per annum, constituting about 92.0% of the total cost (TC). A breakdown analysis of the total variable cost (TVC) incurred during production revealed that labour cost, cost of laying birds, medications and feeds accounted for 97.9% of the total cost incurred in egg production.

Table 1: Socioeconomic Characteristics of Poultry Egg Farmers in the Study Area

Variables	Frequency	Percentage	Mean
Sex			
Male	90	75.0	
Female	30	25.0	
Age (years)			
≤30	23	19.2	
31-40	40	33.3	
41-50	33	27.5	
51-60	18	15.0	
61 and above	6	5.0	41.2
Marital status			
Single	21	17.5	
Married	93	77.5	
Widow	3	2.5	
Separated	3	2.5	
Educational Qualification			
Primary	3	2.5	
Secondary	40	33.3	
Tertiary	77	64.2	
Household size (number)			
1-4	47	39.2	
5-8	71	59.2	
9 and above	2	1.6	5
Experience (years)			
1-4	31	25.8	
5-10	36	30.0	
11-15	16	13.3	
16-20	18	15.0	
20 and above	19	15.8	11.6
Membership in cooperative society			
Yes	106	88.3	
No	14	11.7	
Poultry management system			
Battery cage system	105	87.5	
Deep litter system	15	12.5	

Source: Field Survey, 2021

The result also showed that all other variable cost items, including transportation, electricity, fuel, maintenance and repairs, water, and wood shavings, represented 2.1% of the total cost. In terms of revenue, revenue realized from the eggs and spent layer sales was ₦3,272,747.33, although egg sales represented 80.3% of the total revenue. In comparison, revenue from spent poultry birds accounted for about 19.7% of the total revenue, possibly due to the fact that the purpose of raising the birds was to produce eggs and that has been realised and also due to diminishing marginal productivity of the birds. This result is in tandem with the earlier

documentation of Emam and Hassan (2010) and Tanko *et al.* (2014), who reported that egg sales constituted the highest proportion of the total revenue. These findings imply that egg is a significant revenue source in poultry egg production. The profitability result showed that poultry egg production was profitable in the study area, given a net income of ₦1,823,252.61. The profitability ratios computed in this study revealed that the return on investment (ROI) was 1.26, which implied that for every ₦1 invested in poultry egg production, the farmer realised a profit worth ₦0.26.

Similarly, a net profit ratio value of 0.55 generated implied that ₦0.55 will be realized as a gain on every ₦1 expended on poultry egg production. There were disparities in the profit ratios because ROI is not the same as profit but rather the returns on the money invested in the poultry egg enterprise based on the net profit, while the net profit ratio measures the performance of the business. The profitability ratios reported in this study are relatively higher than the Bank of Agriculture (BOA) and Bank of Industry (BOI) lending interest rates of 10%. This implies that the enterprise can conveniently repay any borrowed funds from these sources to increase production output. The result further supports the findings of Afolami *et al.* (2013) that egg production is a profitable enterprise.

Multiple Regression Analysis of the Factors Influencing Profitability in Poultry Egg Production

Multiple regression analysis was used to examine the socioeconomic factors that influence the profitability of poultry egg production in the study area. Table 3 showed that the six explanatory variables (age, experience, feed cost, labour cost, medication cost, stock size, price of crate of eggs and cost of laying birds) substantially impact the profitability of poultry egg production at different probability levels.

The table further showed that the four substantial inputs in the production of poultry eggs were feeds, laying birds, labour and medications. These significant inputs, which took nearly all (97.9%) of the total cost involved in egg production, are the key cost drivers in the poultry egg production process. It was also noticed that about 60.3% of the total cost involved was expended on feeding the birds, thus making it the most expensive variable cost item in egg production. This result is similar to Johnson *et al.*, (2020) who also reported that the cost of feeding poultry birds accounted for the largest share of the total cost of production.

The model is correctly fitted, according to the diagnostic statistics. The coefficient of multiple determination, the R^2 value of 0.73, showed that the explanatory factors (age, experience, cost of feed, labour cost, cost of medication, stock size, price of crate of eggs and cost of laying birds) explained 73.0% of the variation in poultry egg profitability. The obtained coefficients are consistent with the *a priori* expectations. The F-ratio was 10.97 and higly significant ($p \leq 0.01$). This implies that all the included variables had a significant joint effect on egg production.

Table 2: Cost and Returns Outlay in Poultry Egg Production

Items	Mean value (₦/year)	Percentage (%)
Revenue		
Revenue from poultry eggs sold	2,629,559.75	80.34
Revenue from spent layers sold	643,187.58	19.66
Total Revenue (TR)	**3,272,747.33**	100.00
Variable Cost Items		
Laying birds	299,415.77	22.55
Feed	800,078.92	60.26
Medication	42,700.63	3.22
Labour	157,100.00	11.83
Transportation	10,225.00	0.77
Energy (Electricity, Fuel)	9,217.20	0.69
Maintenance and Repairs	5,650.40	0.42
Others (Water, Wood shavings)	3,265.50	0.26
Total Variable Cost (TVC)	**1,327,653.42**	100.00
Fixed Cost Items (Depreciated using Straight-line method)		
Farm Vehicle	34,280.25	28.14
Land and Buildings	78,675.37	64.57
Feeding and Drinking Troughs	1,980.65	1.63
Cages	5,560.81	4.56
Empty egg crates	1,083.86	0.89
Shovels, Buckets etc.	260.36	0.21
Total Fixed Cost (TFC)	121,841.30	100.00
Total Cost (TC)	1,449,494.72	
Net Income (NI)	1,823,252.61	
Returns on Investment	1.26	
Net Profit Ratio	0.55	

Source: Computed from Field Survey, 2021

The coefficient of age (X_1) is positive and highly significant ($p \leq 0.01$). As their age increased, the profit from poultry egg production also increased, possibly due to the efficient utilisation of resources and management practices of the birds. Specifically, a unit increase in the age of the poultry egg farmer will increase the profit of egg production in the study area by 23.0%. This agrees with the earlier submission of Oke *et al.* (2021), who stated that productivity increases

with age, possibly due to knowledge and expertise acquired from years of observations and experimentations with different production techniques. Poultry farming experience coefficient (X_3) is positive and highly significant ($p \leq 0.01$). This suggests that the more experienced the farmer, the more the profit. This agrees with the earlier submission of Rahman (2003) and Adesiyan *et al.* (2011), who opined that the more experienced the poultry egg farmer is, the more efficient the producer becomes. Cost of feed (X_5), cost of labour (X_6) and cost of medication (X_7) were negative and highly significant ($p \leq 0.05$). The negative relationship observed also conforms to the *a priori* expectation. This suggests that the higher the cost of buying feed, medication and farm labour, the lower the profit. This agrees with the earlier submission of Jacob *et al.* (2014).

Stock size (X_8) was highly significant ($p \leq 0.01$). and had a positive relationship with profit level in the study area. This implies that the higher the number of birds reared by the farmers, the more the output realized (eggs), which will increase the profit level. Specifically, a unit increase in stock size will increase the profit level by 79% among farmers in the study area. This conforms to the earlier findings of Valerien *et al.* (2011). The price of a crate of eggs (X_9) was highly significant ($p \leq 0.01$) and had a positive relationship with the profit level in the study area. Specifically, a unit increase in the price of eggs will increase profit by 90 per cent in the study area. This result agrees with the findings of Johnson *et al.* (2020). Also, the cost of laying birds was negative but significantly influenced profitability. This negative relationship implies that the higher the cost of acquiring the birds, the lower the profit. This is also in tandem with the findings of Johnson et *al.* (2020).

Table 3: Factors Influencing Profitability in Poultry Egg Production

Variables	Estimated β values	Standard error	t – values
Age	**0.23*** **	**0.060**	**3.83**
Sex	**19.72**	**15.650**	**1.26**
Experience in years	**0.71****	**0.290**	**2.44**
Level of education	**0.81**	**0.696**	**1.16**
Cost of feed	**-0.12*** **	**0.018**	**6.67**
Cost of labour	**-1.30*** **	**0.340**	**3.82**
Cost of medication	**-1.06*** **	**0.205**	**5.17**
Stock size	**0.79*** **	**0.296**	**2.67**
Price of crate of eggs	**0.90*** **	**0.276**	**3.26**
Cost of laying birds	**-0.28****	**0.120**	**2.33**
Intercept	**6.27**	**5.42**	**1.16**
F-value 10.97, R^2 = 0.73			

Note: **Significant at p<0.05 and ***significant at p<0.01.

CONCLUSION AND RECOMMENDATION

The study concluded that poultry egg production is profitable in the study area, given the net income and profitability ratios, which are positive and more significant than zero. However, efforts and policies that will assist the poultry egg farmers in achieving a drastic reduction in the cost of poultry feed, possibly through subsidies and the need to encourage the use of local materials in feed formulation that will eventually increase profit level, are recommended.

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INVENTORY AND LAND SUITABILITY EVALUATION OF SELECTED SOILS OF NKWESI, IMO STATE, NIGERIA, FOR SUSTAINABLE PRODUCTION OF PINEAPPLE, CASSAVA AND SWEET POTATOES

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ABSTRACT

The study was conducted to inventorize a 54.81 ha farmland at Nkwesi community, Oguta LGA of Imo State, Southeast, Nigeria and evaluate its suitability for sustainable cultivation of pineapple, cassava and potatoes. A flexible grid soil survey method was adopted, and two soil mapping units (NKWE I and II) were delineated with four representative profile pits excavated. The pedons were described in situ for their morphological attributes, and samples collected from the pedogenetic horizons were analyzed for physical and chemical properties. Results showed very deep (> 130 cm), ranging from well-drained (NKWE I) to poorly drained (NKWE II). Textural class ranged from sand and loamy sand surface underlain by sandy loam and clay loam subsoil. The units were moderate to slightly acidic (4.7 – 5.50), moderately high organic carbon (1.38-2.11%), moderate to high (11.50 – 35.70 mg/kg) available P, very low exchangeable K (0.10-0.17 cmol/kg), very low ECEC (4.64 – 6.97 cmolkg-1) and eutric, (78.00-

94.00%) base saturation. Two soil classes were identified: Arenic Kandiustepts (NKWE I) and Arenic Kandiudepts (NKWE II) (USDA) correlated as Arenosols (WRB). Suitability assessment of the farmland classified NKWE I moderate (S2f) and NKWE II marginal (S3wf) for pineapple, cassava and potato cultivation. Identified constraints were low fertility and poor drainage (NKWE II). The optimum performance of the test crops in the area can be enhanced through adequate drainage (NKWE II), liming, organic manuring and efficient use of mineral fertilizers.
Keywords: Interpretation, Soil inventory, Sustainable crop production.

INTRODUCTION

Lack of adequate knowledge of our soils, their potentialities and limitations for various uses has contributed to persistent food insecurity in Nigeria today. Soil surveys have been reported as a veritable tool to gather reliable information about the soil and environmental factors that will help them make judicious decisions about sustainable soil management or land use (Esu, 2004; Lekwa *et al.*, 2004). Soil survey involves a combination of field and laboratory activities intended to identify soil's basic morphological, physical and chemical properties (soil characterization) and establish the distribution of those soils at specific map scales (classification and mapping).

It is pertinent that if the potential of agricultural land should be maximized, land use should not be based primarily on the needs and demands of the users but also on the suitability of such land for the intended use in order to derive maximum benefit and achieve environmental sustainability. Land evaluation is the first step in agricultural planning for sustainable crop production because it will guide decisions on land utilization so that resources are optimally used, resulting in sustainable environmental management (Fasina *et al*., 2015).

Different soils have varying nutrient capabilities, depending on the amount of total nutrient reserves, mobilization and accessibility of the chemically available nutrients to plant roots. Consequently, if the soil is not managed well, crop yield declines over time, accompanied by environmental degradation (Akinrinde and Obigbesan, 2000; Akamigbo, 2010). It is, therefore, important that before an agricultural project is established, mainly where intensive crop production is involved, the soil must be fully characterized through soil testing. Soil characterization will establish the various soil types present in the area and the levels of the different plant nutrients in the soil.

Crops require a wide range of nutrients (N, P, K, Ca, Mg, etc) and in appropriate amounts for optimum growth and yield (Chude *et al*., 2011). Each nutrient element is present in the soil to a certain level. The knowledge of the amounts of the nutrient elements that are required to be added, in the form of fertilizer, to the soil to enable the planted crop or crops to yield optimally is established through soil testing. If the right type and amount of fertilizer are not applied, the expected yield increase will not be obtained, and the return on investment may not be encouraging.

Therefore, understanding the characteristics of soils in an area is crucial for the productive and sustainable management of such soils to better the inhabitants' lives (Oluwatosin *et al*., 2006). Interpretation of soil survey reports (evaluation), as reported by Esu (2004), is a very handy tool for assessing the potential of land for specific purposes and the soils' responses to manipulative management for sustained agricultural production. The correct interpretation of soil and its environment is the basis for rational and sustainable land use for crop production.
In Nigeria, various food and cash crops have contributed largely to the national food basket, among which are pineapple, cassava, and potatoes. Nigeria is ranked 7th in the world in pineapple production and the leading producer in Africa, with an area of 199,891 ha under production and an average yield of 83 t/ha (FAO, 2019).
Similarly, sweet potato and cassava are essential to root crops in tropical and sub-tropical countries like China, India, Japan, Thailand, Nigeria, etc. Among the root and tuber crops grown in the world, sweet potato ranks second after cassava Ravindran *et al*. (2010)

Despite the significant role these crops have played, particularly as raw materials for agro-based industries, little or no organized research has attempted to assess the suitability of soils for sustainable production compared to other contemporary foreign exchange-earning crops (cocoa, oil palm, cashew, and rubber). However, this research presents a potential avenue for improving their productivity through soil suitability assessment, offering hope for the future of the agricultural sector. Therefore, the research work was carried out to inventorize and assess land suitability of selected soils in the community for sustainable production of pineapple, cassava and potatoes.

MATERIALS AND METHODS

Study Area

The research was carried out in the Nkwesi community, located between latitudes 5˚39'10"-5˚39'50" N and longitudes 6˚48'40"-6˚49'25" E, in the Oguta Local Government Area of Imo State, South-eastern Nigeria (Fig. 1). Nkwesi is about 42.7 km from Owerri, the capital of Imo State.

The area has an annual rainfall of 2,500 and 3000 mm distributed over seven months in the rainy season. Annual air temperatures range between 21oC and 31o, with a relative humidity of 64-80 % (NIMET, 2020). The original vegetation of the project site was typical equatorial rainforest. However, a greater percentage of the land is under a cassava-based cropping system, including sole cassava, cassava/maize intercrop and cassava/maize/melon intercrop with few stands of oil palm (*Elaeis guineensis*). The general land use pattern of cultivation in the area is subsistence in characteristics with a bush fallow system of regenerating the soil. Mixed cropping is a common practice. Presently, the study site was under a cassava-based cropping system, and a few stands of rubber trees and bush fallow in the northeastern and southern parts of the farm. The soils of the study area were developed from the Coastal Plain Sands (Benin formation) of the Oligocene Miocene era (Ojanuga *et al.*, 1981; Lekwa, 2002).

Field Work

The study site was reconnoitred to obtain relevant information by physically observing different physiographic features. A perimeter survey of the land area, measuring about 54.49 hectares was traversed at 100 m thereafter geo-referenced using Global Positioning System (GPS) receiver. Soils were examined using auger borings at points where soil changes occurred due to slope, soil colour, vegetation, geology and human influences. At each observation point, soil examination was done at a depth of 50 cm. Soils were examined for texture, colour, consistency, red-oximorphic features, root or water-restrictive layers, and coarse fragment inclusions. Based on the variability of these parameters, two mapping units (NKWE 1 and NKWE 2) were identified and delineated. To describe the mapping units, soil profile pits were located and dug at modal points. Based on the size of the units, one modal pit was established in unit NKWE 1 (5.01 ha), while mapping unit NKWE 2 (49.48 ha) had three profile pits.

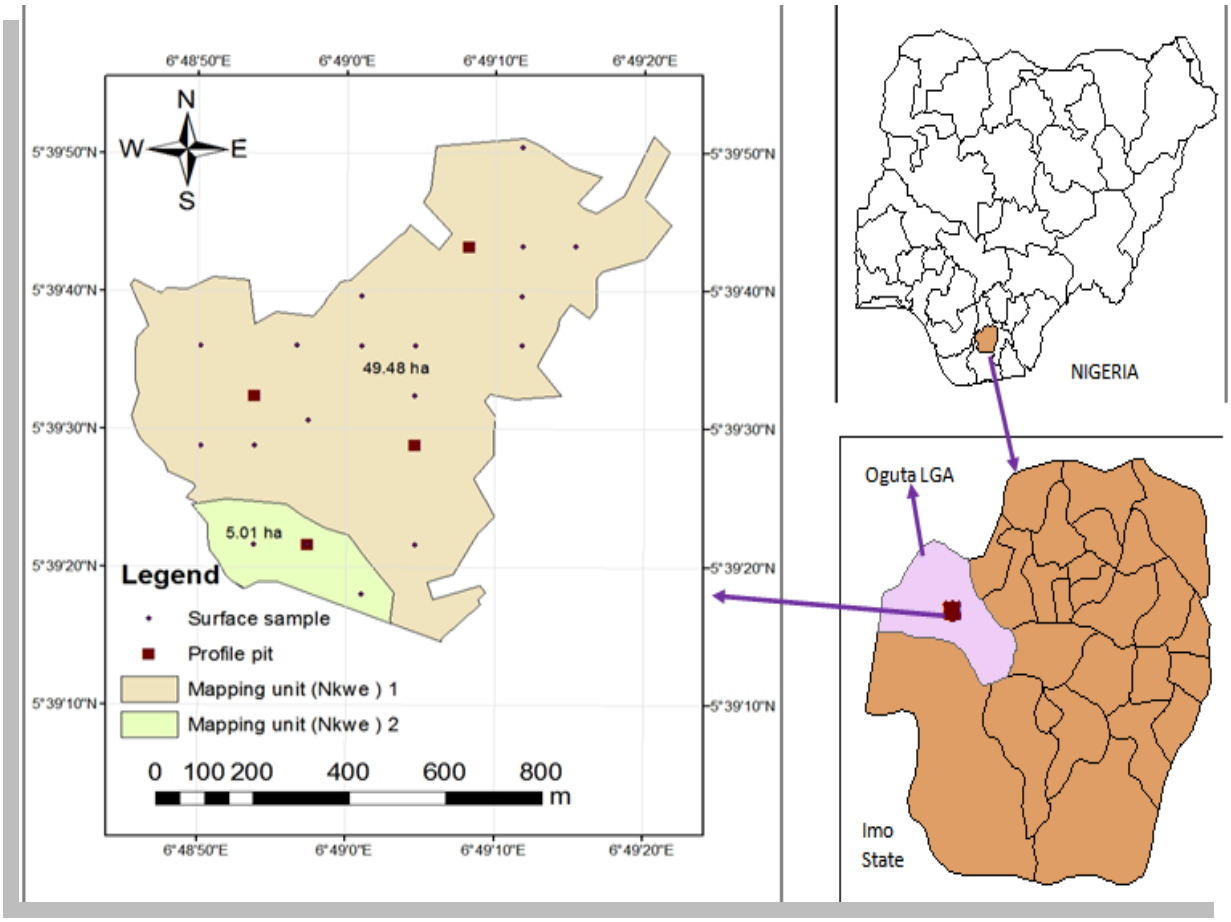

Fig. 1: Map of the Study Site Showing Sample Points

The profile pits were described following the USDA guidelines for soil profile descriptions (FAO 2006). Samples were collected according to the occurrence of identified master and subordinate horizons for detailed laboratory analysis. Surface (0-30 cm) soil samples were also obtained with an auger from soil sampling points across the whole farm to determine the soil fertility status of the farmland. The profile pits and surface soil sampling points were geo-positioned.

Soil Analysis and Data Interpretation

The soil samples were air-dried and ground to pass through a 2 mm sieve. For the determination of total N and organic carbon (OC), a 0.5 mm sieve was used. Analyses of the physicochemical properties followed standard laboratory procedures described by Udo *et al*. (2009). Particle-size distribution and bulk density were determined by Bouyocous hydrometer analysis and core methods, respectively. Soil pH was measured using a 1:2.5 soil-to-water ratio, whereas organic carbon (OC) was determined by the wet digestion method (Walkley and Black method). The

Kjeldahl wet digestion and distillation method and available P by the modified Olsen method determined total N. Exchangeable bases were extracted by saturating the soil with neutral 1N NH4OAc: Na+ and K+ displaced by NH 4+ were determined by a flame photometer.

In contrast, Ca2+ and Mg2+ were determined using the Ethylene Diamine Tetra-Acetic acid (EDTA) titration method. Exchangeable acidity was extracted with 1N KCl and estimated in the extract by titration (Udo *et al*., 2009). The effective cation exchange capacity (ECEC) was determined by summation of all exchangeable cations, including exchangeable acidity (Al3+ and H+), and finally, the base saturation (BS) Percentage was determined using the relationship.

$$BS\ (\%) = \frac{\sum Exchageable\ Bases}{\sum Exchageable\ Bases + \sum Exchangeable\ Acidity} \times 100$$ …… Equation 1

Data were interpreted based on (Chude, *et al*. 2011; Sasseville, 2013 and Hazelton and Murphy, 2016) ratings for soil data interpretation.

Soil Classification

Based on the morphological, physical, and chemical properties obtained, the soils were classified according to the USDA Soil Taxonomy System (Soil Survey Staff, 2014) and correlated with the World Reference Base for soil resources (WRB, 2014).

Suitability Classification of the Soils for Cassava, Sweet Potatoes and Pineapple.

Evaluating the project site for the suitability of the recommended agricultural enterprises will make it possible to identify soil characteristics that require intervention for optimum productivity. The land qualities of the project site were matched with standard land qualities for assessing the suitability of the mapping units for cassava, sweet potatoes and pineapple production based on the guidelines of FAO (2016). The parametric square root method was used to compute the index of productivity (IP) of the soil for the cultivation of the test crops:

$$IP = A\ x\ \sqrt{\frac{B}{100}\ x\ \frac{C}{100}\ x\ \frac{D}{100}\ x\ \frac{E}{100}\ x\ \frac{F}{100}}$$ ……... Equation 2

where: A is the overall lowest characteristic rating, and B, C…, and F are the lowest characteristics rating for each land quality group, such as climate (c), topography (t), soil physical properties (s), wetness (w), and chemical fertility (f). Only one member in each group was used because strong correlations exist among members of the same land quality group (Ogunkunle, 1993). The potential index of productivity (IPp) was calculated without

considering N, P and K in the fertility (f) group because they can easily be changed. In contrast, the current (actual) index of productivity (IPc) considered N, P and K as parts of the 'f' group. Suitability classes such as high (S1), moderate (S2), marginal (S3) and none (N) are equivalent to IP values of 100-75 %, 74-50 %, 49-25 %, and 24-0 %, respectively.

RESULTS AND DISCUSSION

Morphological and Physical Characteristics

Selected morphological and physical properties across the mapping units in the study site are presented in Table 1.

Table 1: Land use Requirements for Sweet Potato Cultivation

Land qualities	Land characteristics	Units	S1 100-95 %	S2 94-85 %	S3 84-40 %	N1 39-20 %
Climate (c)						
Water Availability	Mean annual Rainfall	(mm)	1600-1100	1100-900	900-500	<500
Temperature regime	Mean annual Temp.	(^{O}C)	21-30	>18<21	>12	<12
Wetness (w)						
Oxygen Availability	Soil drainage		Well drained	Moderately drained	Poorly drained	Very poorly drained
Fertility (f)						
Nutrient Availability	Total N	(%)	>0.12	0.1-0.12	<0.1	-
	Avail P	(mgkg^{-1})	>25	6-25.	<6	-
	Exch. K	(cmol/kg)	>0.6	0.3-0.6	<0.3	-
	pH		5.5-6.8	6.8-7.8/ 5.0-5.4	>7.8 <5.0	-
	Organic C (0-15) cm	>1.5	1.0-1.5	<0.4-1.0	<0.4	
Nutrient retention	**CEC**	(cmol/kg)	>16	3-16	<3	-
	Base saturation	(%)	>35	20-35	<20	-
Soil physical characteristics (s)						
	Soil texture		L, SL	LS, CL	S, SCL	C
Rooting Condition	Soil depth	(cm)	>100	100-75	75-50	<50
Topography (t)	Slope	(%)	0-5	5-12	12-20	>20

(Modified from Sys *et al.,* 1991)

Key: S_1 = highly suitable, S_2 = moderately suitable, S_3 = marginally suitable, N_1 = currently not suitable, C = Clay, CL= clay loam, L = loam, SiC = silty clay, LS = loamy sand, SL= sandy loam, SCL = sandy clay loam, S = sand, SC = sandy clay.

Variations were observed in the colour of the horizons across the mapping units. For instance, soils mapping NKWE 1 were characterized by a reddish black hue in the epipedons (2.5 YR 2.5/2), while the endopedons varied between reddish brown to red (Table 1). However, the epipedons of soils of mapping NKWE 2 were very dark grayish brown (10 YR 3/1), while the endopedons varied between brown to very pale brown. According to Wakene (2001), soil colour is a function of pH, redox reaction and organic matter; consequently, a change in soil colour may signify differences in soil mineral type quantity and degree of weathering. Nuga *et al.* (2006) reported that the variation in soil colour matrix could be attributed to the sequence of drainage conditions and physiographic position. The grey colour observed in NKWE 2 could be attributed to the poor drainage condition of the unit (Lawal *et al*., 2013).

Table 2: Land Use Requirement for Cassava

Land Quality and characteristics	S1(100-95)	S2(94-85)	S3(84– 40)	N1(39–20)	N2(19-0)
Climate (c)					
Mean annual rainfall (mm)	1500-1100	1100 - 900	900 – 500	< 500	any
Mean annual temperature (^0C)	18 - 30	16 – 18/ 30- 35	< 12 or > 35	any	any
Topography (t) *Slope (%)*	0 -5	5 – 12	12 – 20	>20	> 30
Wetness (w) Drainage	Well drained	Imperfectly drained	Poorly drained	Very poorly drained	Very poorly drained
Soil physical characteristics (s)					
Texture and Structure	L, SC, CL	LS,SL,SCL, SiCL	S, SiC	C	any
Soil depth (cm)	> 100	100 - 75	75 – 50	< 50	< 20
Fertility (f)					
CEC (cmolkg^{-1} clay)	>16	16 - 3	< 3	any	-
Base saturation (%)	>35	35 - 20	< 20	any	-
Organic carbon (%), 0-15cm	> 2	1.2 -2.0	2.0-0.8	<0.8	-
pH	6.1 – 7.3	7.4-7.8 or 5.1-6.0	>8.4 or <3	any	-
Total Nitrogen (%)	>0.2	0.2 – 0.1	<0.1	any	-
Exch. K cmolkg^{-1})	>0.6	0.3-0.6	<0.3	-	-
Available P (mgkg^{-1})	>25	25 - 6	< 6	Any	-
Exchangeable K (cmolkg^{-1})	>0.6	0.6 – 0.3	< 0.3	any	-

Key: C-Clay, CL=Clay Loam, L=Loam, SiCL= Silty Clay Loam, SL= Sandy Loam, SCL = Sand Clay Loam, SC= Sandy Clay, LS=Loamy Sand.
Source: (Sys *et al.*, 1991; Mongkosalwat *et al*., 1997).

Table 3: Land Use Requirement for Pineapple

Land Quality and characteristics	S1(100-95)	S2(94-85)	S3(84- 40)	N1(39-20)	N2(19-0)
Climate (c)					
Mean annual rainfall (mm)	1200-1100	1100 - 800	800 – 600	6< 500	any
Mean annual temperature (^0C)	22 - 26	26 – 20	30 – 35	>35	any
Topography (t) *Slope (%)*	0-8	8- 16	16– 30	30-50	> 50
Wetness (w) Drainage	Well drained	Imperfectly drained	Poor and aeric	Poor but drainable	Poor not drainable
Soil physical characteristics (s)					
Texture and Structure	L, SL, SCL	LS, SiL, Si, SC	S, SiC	C	any
Soil depth (cm)	> 60	40 - 60	20 – 40	< 20	< 20
Fertility (f)					
CEC (cmolkg^{-1} clay)	>16	16 - 3	< 3	Any	-
Base saturation (%)	>35	35 - 20	< 20	Any	-
Organic carbon (%), 0-15cm	> 2	1.2 -2.0	0.8-1.2	<0.8	-
pH (H_2O)	5.0 – 6.5	4.5-5.0 or 6.5-7.0	7-7.8 or 4.0-4.5	<4.0/>7.8	-
Total Nitrogen (%)	>0.2	0.2 – 0.1	<0.1	Any	-
Exch. K cmolkg^{-1})	>0.6	0.3-0.6	<0.3	-	-
Available P (mgkg^{-1})	>25	25 - 6	< 6	Any	-
Exchangeable K (cmolkg^{-1})	>0.6	0.6 – 0.3	< 0.3	Any	-

Key: C-Clay, CL=Clay Loam, L=Loam, SiCL= Silty Clay Loam, SL= Sandy Loam, SCL = Sand Clay Loam, SC= Sandy Clay, LS=Loamy Sand.
Source: (Sys *et al.*, 1991; Mongkosalwat *et al*., 1997).

The structure of the soils of the project land ranged from granular in the surface horizons to weak, fine to medium angular blocky in the sub-surface horizons. Many moderate to fine plant roots were observed on the surface soils, which decreased down the profile. The soils of NKWE 1 were well-drained, while the soils of NKWE2 were imperfectly drained. Soils of NKWE 1 will not be susceptible to water logging because of the expected high infiltration rate. However, NKWE 2 was imperfectly drained, and with a low infiltration rate, water logging may occur.

The moist consistency of the surface soil remained friable, whereas the subsurface soils exhibited firm and non-sticky/non-plastic consistency under moist and wet conditions, respectively. The overall consistency showed that the soils would be workable at appropriate

moisture content. Therefore, soil conservation practices must be part of soil management practices on the farm.

Sand separate is the predominant size fraction in the soils of the project site, accounting for over eighty percent (> 80 %) in the surface soils and more than seventy percent (> 70 %) in the subsoils. The textural class ranges from sand to loamy sand in the surface soils and from loamy sand to sandy clay loam in the subsoils.

Soil texture affects the soil's physical and chemical properties, including infiltration and water retention, soil aeration, microbial activities, tillage and irrigation practices (Chude *et al*., 2011). Sandy soils have low water and nutrient-holding capacity. Soil texture is one of the inherent physical properties of soil that are less affected by management. However, Wakene (2001) has suggested that management systems may contribute indirectly to changes in particle size distribution, particularly in the surface horizons, as a result of clay removal through sheet erosion and mixing up of soils of the surface and subsurface horizons during mechanical tillage activities.

Chemical Characteristics

The soils of the farmland fall within the very strongly (4.6 – 4.9) to firmly (5.3 – 5.5) acid class (Chude *et al*., 2011), with pH (H2O) values ranging from 4.6 to 5.5 (Table 2). The acid nature of the soil can be adduced to a high rate of leaching of bases consequent upon high sand fractions in the area (Amusan *et al*., 2006). Chude *et al*. (2011) and Sasseville (2013) established a pH range of 5.5 - 7.0 (slightly acid to neutral reaction) as optimal for the overall satisfactory availability of plant nutrients. Consequently, the pH range of the farmland is not ideal for most crops to thrive well as most nutrient elements, especially phosphorus, will be fixed and, thus, will not be readily available for absorption by plant roots. Therefore, the sustainable productivity of the farmland is anchored on adequate liming to reduce the acid effects and ensure adequate availability of soil nutrients to crops.

The farmland's surface soil organic carbon content ranged from 1.38 to 2.39 % and decreased with soil depth. The surface soil organic carbon is considered moderate to high based on the soil nutrient interpretation of Chude *et al*. (2011) and Hazelton and Murphy (2016). However, the generally low organic carbon in the sub-surface horizons may be adduced to the fact that the surface horizons are where organic materials decompose and humidify. The nitrogen content of the soils of the project site was low; therefore, crop production on the project farm

Table 4: Morphological and Physical Properties of Nkwesi Farmland

Pedon	Horizon	Depth (cm)	Colour (moist)	Structure	Consistence moist	wet	Sand (%)	Silt (%)	Clay (%)	Texture
				NKWE 1						
	Ap	0 – 14	2.5 YR 2.5/1 (RB)	W, m, sbk	Friable	ns	86.80	3.00	10.20	LS
	AB	14 – 29	2.5 YR 3/2 (DR)	W, m, sbk	Friable	ns	86.80	3.00	10.20	LS
1	B1	29 – 53	2.5Y 3/4 (DRB)	W, m, sbk	Friable	ns	81.80	3.00	15.20	SL
	B2	53 – 99	2.5 YR 4/4 (RBr)	M, m, abk	Firm	ns	78.80	3.00	18.20	SL
	Bt	99 -189	2.5 YR 3/6 (DR)	M, m, abk	Firm	ss	77.80	2.00	20.20	SCL
				NKWE 1						
	Ap	0 – 18	2.5 YR 2.5/1 (RB)	M, m, abk	Friable	ns	82.80	5.00	12.20	LS
2	BA	18 – 40	2.5 YR 4/4 (RBr)	W, m, abk	Friable	ns	79.80	2.00	18.20	SL
	Bt1	40 – 82	2.5 YR 4/6 (DRB)	W, m, abk	Firm	ss	75.80	2.00	22.20	SCL
	Bt2	82 – 187	2.5 YR 4/8 (RBr)	S, f, abk	Firm	ss	73.80	2.00	24.20	SCL
				NKWE 1						
	Ap	0 – 13	2.5 YR 2.5/1 (RB)	W, m, gr	Friable	ns	89.80	3.00	7.20	S
3	AB	13 – 35	2.5 YR 4/4 (RBr)	W, c, abk	Friable	ns	83.80	2.00	14.20	LS
	BA	35 – 75	2.5 YR 5/3 (RBr)	W, c, abk	Friable	ns	79.80	4.00	16.20	SL
	B1	75 – 130	2.5 YR 4/6 (RBr)	W, c, sbk	Friable	ns	79.80	4.00	16.20	SL
	B2	130 – 200	2.5 YR 4/8 (R)	W, c, abk	Firm	ss	79.80	3.00	17.20	SL
				NKWE 2						
	Ap	0 – 18	10 YR 3/2 (DGB)	W, m, gr	Friable	ns	86.80	4.00	9.20	LS
4	BA	18 – 49	10 YR 5/3 (Br)	M, f, abk	Friable	ns	79.80	2.00	18.20	SL
	Bt1	49 – 86	10 YR 7/4 (PBr)	W, m, abk	Firm	ss	75.80	3.00	21.20	SCL
	Bt2	86-138	10 YR 7/3 (PBr)	W, M, SBK	Firm	ss	75.80	4.00	20.20	SCL

Key: Colour: RB = Reddish black, DR = Dusk red, DRB = Dark reddish brown, RBr = Reddish brown, R = Red, DGB = Dark grayish brown, Br = Brown, PBr = Pale brown,

would require the application of nitrogen in the form of inorganic fertilizer or organic manure. The soils' available phosphorous content varied from 11.5 - 41.0 mgkg-1, having irregular distribution across the depths. The available P values are considered moderate, within the range recommended for most commonly cultivated crops (Enwezor *et al.*, 1989).

Chemical Characteristics

The soils of the farmland fall within the very strongly (4.6 – 4.9) to firmly (5.3 – 5.5) acid class (Chude *et al*., 2011), with pH (H2O) values ranging from 4.6 to 5.5 (Table 2). The acid nature of the soil can be adduced to a high rate of leaching of bases consequent upon high sand fractions in the area (Amusan *et al*., 2006). Chude *et al*. (2011) and Sasseville (2013) established a pH range of 5.5 - 7.0 (slightly acid to neutral reaction) as optimal for the overall satisfactory availability of plant nutrients. Consequently, the pH range of the farmland is not ideal for most crops to thrive well as most nutrient elements, especially phosphorus, will be fixed and, thus, will not be readily available for absorption by plant roots. Therefore, the sustainable productivity of the farmland is anchored on adequate liming to reduce the acid effects and ensure adequate availability of soil nutrients to crops.

The farmland's surface soil organic carbon content ranged from 1.38 to 2.39 % and decreased with soil depth. The surface soil organic carbon is considered moderate to high based on the soil nutrient interpretation of Chude *et al*. (2011) and Hazelton and Murphy (2016). However, the generally low organic carbon in the sub-surface horizons may be adduced to the fact that the surface horizons are where organic materials decompose and humidify. The nitrogen content of the soils of the project site was low; therefore, crop production on the project farm would require the application of nitrogen in the form of inorganic fertilizer or organic manure. The soils' available phosphorous content varied from 11.5 - 41.0 mgkg-1, having irregular distribution across the depths. The available P values are considered moderate, within the range recommended for most commonly cultivated crops (Enwezor *et al.*, 1989).

Generally, there was a low accumulation of bases in the horizons of the soil. The low level of bases in these soils could suggest that leaching is a marked pedogenic process resulting from the area's high sand proportion (Amusan *et al*., 2006). The effective cations exchange capacity (ECEC) was generally low (< 7.0 cmolkg-1). The low ECEC could be attributed to the type of clay (such as 1:1 clay mineral, e.g. kaolinite). This was observed by Nnaji *et al*. (2002), who found that low CEC of soil is because of clay type content, high rainfall intensity, and previous land use. Base saturation was high and reflected the concentration of basic cations at the exchange complex site.

Table 5: Chemical Properties of the Soils of the Study site

Horizon	Depth (cm)	pH	Avail P	Total N	Org C	Ca	Mg	K	Na	EA		ECEC	BS %
			$mgkg^{-1}$			…….. $cmolkg^{-1}$ ……							
NKWE 1 (Pedon 1)													
Ap	0 – 14	5.30	32.0	0.14	1.38	4.00	1.60	0.16	0.12	0.40	0.12	6.29	94.00
AB	14 – 29	4.70	26.3	0.13	1.06	3.20	1.60	0.18	0.16	1.04	0.40	6.18	83.00
B1	29 – 53	4.80	20.1	0.08	0.40	2.80	0.80	0.18	0.12	1.12	0.32	5.03	78.00
B2	53 – 99	4.70	16.5	0.08	0.25	3.60	1.60	0.16	0.10	1.20	0.40	6.67	82.00
Bt	99 -200	4.80	18.2	0.07	0.18	3.20	1.20	0.16	0.10	0.96	0.48	5.63	83.00
NKWE 1 (Pedon 2)													
Ap	0 – 18	5.40	21.0	0.08	1.66	3.60	1.60	0.19	0.08	0.80	0.40	6.26	87.00
BA	18 – 40	4.70	12.5	0.03	0.69	2.80	1.20	0.18	0.09	0.72	0.32	4.98	86.00
Bt1	40 – 82	4.80	14.0	0.06	0.47	3.60	1.20	0.15	0.09	0.80	0.32	5.84	86.00
Bt2	82 – 187	4.80	11.5	0.04	0.36	2.40	1.60	0.16	0.07	0.88	0.40	5.11	83.00
NKWE 1 (Pedon 3)													
Ap	0 – 13	5.50	35.7	0.17	2.11	4.60	1.20	0.13	0.16	0.04	0.35	6.13	89.00
AB	13 – 35	4.90	17.1	0.08	0.73	3.20	0.80	0.14	0.12	0.40	0.16	4.66	91.00
BA	35 – 75	5.00	19.6	0.08	0.73	2.80	1.20	0.14	0.13	0.80	0.48	5.07	84.00
B1	75 – 130	4.70	15.6	0.06	0.22	4.00	1.00	0.13	0.10	0.88	0.24	6.11	88.00
B2	130 - 200	4.80	15.9	0.06	0.15	2.00	1.60	0.12	0.12	0.80	0.40	4.64	83.00
NKWE 2 (Pedon 4)													
Ap	0 – 18	5.40	41.0	0.18	2.39	4.40	1.00	0.16	0.17	0.64	0.32	6.38	91.00
BA	18 – 49	4.60	18.5	0.08	1.06	3.60	1.60	0.15	0.10	1.52	0.48	6.97	78.00
Bt1	49 – 86	4.70	15.4	0.07	0.58	3.20	0.80	0.17	0.11	1.44	0.48	5.73	75.00
Bt2	86-138	4.90	19.8	0.08	0.33	2.40	1.20	0.17	0.10	1.28	0.48	5.16	75.00

Note: LS = Loamy sand, SL = Sandy loam, S = Sand, SCL = Sandy clay loam

Classification of Soils of the study site

The soils across the study area represented by mapping units NKWE 1 (comprising pedons 1-3) and NKWE 2 (pedon 4) were classified (Soil et al., 2014) and correlated (WRB, 2014). All the pedons showed poor pedogenic horizon development, as evidenced by a slight increase in clay fraction down the profile. This classifies it into soil order inceptisols.

The prevalent ustic soil moisture regime (soils, dry for more than 90 cumulative days but less than 180) of the area has placed NKWE 1 into the sub-order Ustepts. In contrast, mapping unit NKWE 2 classified the udic soil moisture as Udepts.

Kandic horizons were established in NKWE 1 and 2 due to the following requirements observed: coarser-textured surface horizons over vertically continuous subsurface horizons; CECs within subsurface B horizons that are less than 12 cmol kg-1clay and a regular decrease in organic carbon content with increasing depth (Soil Survey Staff, 2014). Therefore, the soils were placed into the great group Kandiustepts and Kandiudepts for NKWE 1 and NKWE 2, respectively. However, high sand fraction across the site placed the soils into the great group Arenic Kandiustepts and Arenic Kandiudepts for NKWE 1 and NKWE 2, respectively (USDA) (Soil Survey Staff, 2014). They were correlated as Arenosols in the World Reference Base (WRB, 2014).

Land Suitability Evaluation

Land suitability evaluation of Nkwesi farmland for the cultivation of sweet potatoes, cassava, and pineapple using the parametric method was determined. Results of matching agronomic requirements (Tables 1 - 3) for production of the test crops with land characteristics (Tables 4 and 5) are shown in aggregate suitability class score (Table 7). The climate was not a constraint to the production of the crops in the farmland and environs because there were more than five months of steady rainfall. Consequently, these crops would do best when planting and developmental stages are programmed to fall within the rainy months of the year. Topography (slope gradient) of the entire mapping units, < 5 %, was highly suitable for optimal production of the selected crops (Sys *et al.*, 1991) and, therefore, would not pose any limitation to the optimal performance of the crops on the farmland and its environs. Similarly, soil depth in the study area was greater than 100 cm and is considered adequate for sustainable crop production (FAO, 2016).

Regarding soil wetness (drainage), NKWE 1 had good drainage, while NKWE 2 had poor drainage. Therefore, poor drainage in NKWE 2 is considered a limiting factor to the optimal unit performance for the selected crops. The entire farmland was strongly acidic and deficient in nitrogen and exchangeable potassium. These limitations limit the optimal performance of the soils for the production of the selected crops.

The aggregate assessment of the study site (Table 6) has shown that NKWE 1 is potentially highly suitable (S1) for all the test crops, but its current optimal performance is constrained by fertility (f), thus placing the unit as moderately suitable (S2f) for the cultivation of the crops. However, the productivity of NKWE 2 is constrained by fertility (f) and poor drainage (w); thus, it is currently marginally suitable (S3fw) for the cultivation of sweet potatoes, cassava and pineapple. Soil fertility status, especially pH, nitrogen, exchangeable potassium, and poor drainage conditions, have been found to limit the potential of soils for optimal crop production.

Table 6: Aggregate Suitability Scores of the Mapping Units for the Cultivation of the Test Crops

	NKWE 1			NKWE 2
Test crop	**Pedon 1**	**Pedon 2**	**Pedon 3**	**Pedon 4**
Sweet potatoes				
Potential	S1	S1	S1	S2
Actual	S2	S2	S2	S3
Limitation	*F*	*F*	*F*	*w,f*
Cassava				
Potential	S1	S1	S1	S2
Actual	S2	S2	S2	S3
Limitation	*F*	*F*	*F*	*w,f*
Pineapple				
Potential	S1	S1	S1	S2
Actual	S2	S2	S2	S3
Limitation	*F*	*F*	*F*	*Wf*

Aggregate suitability class scores: S1 =75-100; S2=50-74; S3=25-49; N1=15-24; N2=0-14

Note: f = fertility, w = wetness (drainage)

Soil Fertility Assessment the Top Soil (0-15 cm depth) of the Study Site

The pH (water) ranged from 4.80 to 5.10, indicative of very strong acid conditions and varied minimally (CV <15 %) across the site (Table 7). The acid nature of the soil could be adduced to the leaching of exchangeable bases encouraged by the high sand fraction (Nkwopara *et al.*, 2019). This high sand fraction, a characteristic of the soil in the area, contributes to the low exchangeable bases. Total nitrogen values (Fig. 5) were low (< 0.15 %), covering about 75 % of the study site, while the remaining 25 % of the site was moderate (0.15 – 0.18). The larger portion of the study site under the influence of nitrogen deficits may be attributed to volatilization, especially under high-temperature regimes, denitrification processes and massive crop removal without replenishment common in the area.

Organic carbon contents ranged from 1.20 – 2.00 %, indicating moderately low to high, and varied moderately (CV>15<35) across the site. The few portions of the site that recorded high organic carbon were attributed to higher vegetal cover on the soil surface. The generally low value of organic carbon contents in the soil could be attributed to the high rate of decomposition and mineralization of organic matter consequent upon the prevalent high temperature, low vegetal cover, and poor soil management, sometimes by burning of crop residues, intense cultivation and seasonal bush burning, which is a common practice in the area. Therefore, it is imperative for the farmers in the area to adopt cultural practices such as minimum tillage operation, mulching, organic manuring, etc., that will encourage the return and incorporation of plant/crop residues into the soil to increase the level of soil organic matter. This proactive approach can significantly improve soil fertility and crop productivity, empowering farmers to take control of their land's health.

The exchangeable bases (Ca2+, Mg2+, Na+ and K+) were generally low and significantly varied across the site (Table 7). These low values of exchangeable bases in the study area are a cause for concern as they may be connected to the poor colloidal behaviour of the soils. Sands have a lower surface area and are more physically and chemically inactive than clay (Hazelton and Murphy, 2015; Osodeke et *al.* (2005). This could significantly impact the soil's productivity and the sustainability of agricultural practices in the area.

CONCLUSION AND RECOMMENDATIONS

The study inventoried and classified selected soils of Nkwesi, Oguta LGA of Imo State and assessed the soil's potential for sustainable sweet potatoes, cassava and pineapple production.

The finding revealed high sand fraction, high acidity and low exchangeable bases. Arenic Kandiustepts and Arenic Kandiudepts (USDA) correlating to Arenosols (World Reference Base) soil types were identified. Since the soils are highly acidic, low in fertility and with high sand fractions, the judicious use of lime, the full complements of organic manure, and the split application of fertilizers are recommended. Suitability assessment revealed two classes (moderate and marginal). NKWE 1 was moderately suitable (S2) for cultivating sweet potatoes, cassava and pineapple, while NKWE 2 was marginally suitable for the crops. The optimal productivity of the soil's farmland for the test crops was constrained by the poorly drained condition of NKWE 1 and the overall low fertility status of the soils of the farmland. Adequate drainage, liming, incorporation of organic manure, and application of appropriate fertilizers are needed to enhance the optimal productivity of the land for the test crops.

Table 7: Fertility Status of the Top Soil (0-15 cm depth) of the Study Site for Crop Production

Sample	Particle size distribution (%)				pH	Avail P	Total N	Org C	Ca	Mg	K	Na	EA	ECEC	BS
point	Sand	Silt	Clay	Textural class		mg/kg	%		……. cmol/kg ……						
1	86.80	3.20	10.00	Loamy sand	4.90	28.00	0.15	1.80	2.30	1.00	0.18	0.68	1.00	5.96	70.00
2	86.00	4.00	10.00	Loamy sand	5.00	30.20	0.18	2.00	2.40	1.20	0.20	0.18	0.60	4.58	87.00
3	84.00	4.80	11.20	Loamy sand	4.90	32.00	0.18	2.00	2.00	1.06	0.16	0.16	1.20	4.58	74.00
4	82.80	5.00	12.20	Loamy sand	5.00	25.80	0.10	2.00	2.20	1.00	0.18	0.42	1.00	4.80	79.00
5	86.00	4.00	10.00	Loamy sand	5.00	26.20	0.12	1.60	1.80	1.60	0.20	0.40	0.90	4.96	82.00
6	85.80	3.00	11.20	Loamy sand	5.00	30.20	0.12	1.40	1.00	1.80	0.22	0.50	0.90	5.42	83.00
7	86.00	4.00	10.00	Loamy sand	5.00	30.80	0.12	1.42	2.00	1.60	0.22	0.20	1.00	5.00	80.00
8	86.80	4.00	9.20	Loamy sand	4.90	25.20	0.11	1.56	3.60	1.20	0.15	0.11	0.64	5.70	89.00
9	86.00	4.00	10.00	Loamy sand	5.10	28.00	0.11	1.40	2.60	0.80	0.12	0.12	0.52	4.16	88.00
10	84.00	5.00	11.00	Loamy sand	5.00	25.20	0.09	1.20	3.20	1.16	0.16	0.08	0.50	5.54	91.00
11	86.00	4.00	10.00	Loamy sand	5.00	25.20	0.09	1.25	3.00	1.40	0.10	0.11	0.50	5.11	90.00
12	85.00	4.00	11.00	Loamy sand	5.00	20.00	0.12	1.20	4.00	1.20	0.10	0.11	0.40	5.81	93.00
13	86.20	3.80	10.00	Loamy sand	5.00	20.00	0.15	1.20	4..20	1.20	0.08	0.12	0.40	5.96	93.00
14	86.80	5.00	8.20	Sand	5.00	22.50	0.10	1.83	3.60	2.00	0.14	0.16	0.08	5.97	99.00
15	84.00	6.00	10.00	Loamy sand	4.90	23.50	0.15	1.50	2.40	2.00	0.14	0.14	0.50	5.18	90.00
16	86.50	5.00	8.50	Sand	4.80	24.00	0.17	1.80	3.80	2.00	0.12	0.12	0.60	6.64	91.00
17	87.20	6.00	6.80	Sand	5.00	24.80	0.11	1.60	3.60	2.40	0.16	0.16	0.60	7.06	92.00
18	84.20	4.00	11.80	Loamy sand	5.00	25.00	0.15	1.50	3.60	2.40	0.16	0.16	0.42	6.74	94.00
19	85.00	4.00	11.00	Loamy sand	5.00	22.00	0.12	1.80	4.60	2.00	0.16	0.18	0.42	7.32	94.00
20	87.00	5.00	8.00	Sand	4.90	20.00	0.12	2.00	4.80	2.00	0.08	0.14	0.60	7.62	92.00
MEAN	**85.61**	**4.39**	**10.01**		**4.97**	**25.43**	**0.13**	**1.60**	**2.97**	**1.55**	**0.15**	**0.21**	**0.64**	**5.71**	**87.55**
STDEV	**1.24**	**0.80**	**1.34**		**0.07**	**3.60**	**0.05**	**0.29**	**1.01**	**0.49**	**0.04**	**0.16**	**0.28**	**0.97**	**7.34**
CV	**1.44**	**18.31**	**13.44**		**1.32**	**14.17**	**34.91**	**17.81**	**33.96**	**31.71**	**27.86**	**74.64**	**43.12**	**16.96**	**8.39**

Key: CV < 15= low variability (LV), CV ≥15≤35=moderate variability (MV), CV>35= high variability (HV).

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PRODUCTION AND EVALUATION OF THE FUNCTIONAL AND SENSORY PROPERTIES OF DEHYDRATED EWEDU SOUP MIX

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ABSTRACT

Ewedu soup is a mucilaginous and very slimy soup made from jute mallow leaves (Corchorus olitorius), mainly consumed by the Yoruba tribe (western region) of Nigeria. This study aimed to produce and evaluate the functional and sensory properties of instant dehydrated ewedu soup mix. The jute leaves were sorted, destemmed, washed, drained and freeze-dried in a vacuum chamber of freeze dryer at a pressure (20 Pa) for 3 hours. The dry leaves were blended with varying levels of ingredients in the ratio of 86:2:0: 10:2, 76:2:10:10:2, 96:2:0:0:2, 88:0:0:10:2 and 98:0:0:0:2 for ewedu leaf, dry paper, dry fish, iru, and potash at 100g. The samples were labelled A, B, C, D and E. The five samples were analyzed for functional and sensory analysis. The values of 7.20-9.93%, 6.61-9.71%, 0.72-0.93 g/mL, and 1.51-4.04g/mL were recorded for water absorption capacity, oil absorption capacity, bulk density, and swelling index values, respectively. The recipe formulation affected the sensory attributes of the ewedu soup. Sample B (dry pepper, dry fish and iru) was preferred due to its balanced flavor profile and pleasant aroma. Dehydrated instant ewedu soup mix should be prepared using a ratio of 76:2:10: 10:2 for ewedu, dried pepper, dried fish, iru and potash.

Keywords: *Ewedu,* Freeze Dryer, Ingredients, Instant Soup

INTRODUCTION

*Ewedu*soup is a mucilaginous and very slimy soup made from jute mallow *Corchorus Olitorius* leaves, mainly consumed by the Yoruba tribe (western region) of Nigeria. It is popularly served as a stew along with staple foods such as *amala* (made from yam, plantain or cassava flour) or *eba* (grated cassava flour), also known as *garr*i (Balogun *et al.*, 2020). These green leafy vegetable leaves are rich sources of potassium, iron, copper, manganese and zinc and high energy values essential in human and animal nutrition (Idirs *et al*., 2009).

Since preparing homemade soup is time-consuming, commercially prepared instant soup has replaced homemade soup in the modern world (Niththiya *et al.*, 2014). The challenges in marketing and preserving fresh jute leaves include quality depreciation and short shelf-life due to its elevated respiratory rate (RR) and subsequent perishability. Dehydrated soup mix has many benefits, including minimal susceptibility to pathogenic attacks, quick preparation times, quality preservation for up to one month under normal conditions, protection from enzymatic and oxidative spoilage, and favour stability at room temperature for an extended period (6–12 months) without the need for preservatives or refrigeration (Sudarsan *et al*., 2017; Mathangi *et al*., 2017; Ansari *et al.*, 2022).

However, most vegetable soups, including *ewedu* soup, rapidly deteriorated due to natural activities such as lipid oxidizing effects, protein denature and enzymatic processes (Gary and Bedford, 2010). Furthermore, frequent reheating of soups to preserve them may degrade their texture and consistency due to the limited or absence of electricity supply (Balogun *et al.*, 2020). The utilization of preservation techniques such as low-temperature techniques (freezing and refrigeration) and dry heat techniques such as oven drying at 50oC have been reported to have little or no effect on the fungal spores of *Botrytis* sp, *Alternaria* sp, *Fusarium* sp, *Diplodia* sp, *Rhizopus* sp, *Monilina* sp, *Penicillium* sp, or *Aspergillus* sp which have been implicated as the significant vegetable rot pathogens (Seema, 2015). The shortcomings of the previously stated approaches have been addressed by freeze-drying processes, which also offer a lower risk of contamination (Sagar and Suresh, 2010). According to Pandey *et al*. (2013), freeze-dried soups can be easily reconstituted by adding liquid, giving the soup a fresh taste again with little or no loss of sensory attributes. Thus, there is a need for a dehydrated *ewedu* soup mix, which can be made into soup instantly with improved sensory attributes and shelf-life.

MATERIALS AND METHODS

Source of Materials

Fresh jute leaf (*ewedu* leaf), dried pepper, locust bean (*iru*), dried fish and potash were purchased from Lapai Central Market, Niger state. The reagents used were of analytical standard.

Sample Preparation

Preparation of Dehydrated Jute Leaves (*Ewedu*)

The jute leaves (*ewedu*) leaves were sorted, and the stem was removed and washed under running tap water until it was free from all adhering soil and impurities. The clean leaves were freeze-dried in the vacuum chamber of a freeze dryer (LGJ-18, SHKY, China) at a pressure (20 Pa) for 3 h and blended into a coarse powder using a blender (PANASONIC, MX-AC300, JAPAN). The coarse powder was mixed with different ingredients (*iru*, potash, dried pepper, and dried fish) at different blend ratios, as shown in Table I. They were uniformly blended into a smooth texture and sieved (1.0 mm aperture). The powdered *ewedu* was stored in airtight containers for further analysis.

Preparation of *Ewedu* Soup

Boiling water (100 mL) was measured into five different containers, to which 5 g of *ewedu* soup mix powder was added. The mixture was mixed with a whisk for 1 minute and covered for 3 minutes to produce the *ewedu* soup samples.

Table 1: Blend Formulation for Dehydrated *Ewedu* Soup Mix

Items	Sample A(g)	Sample B(g)	Sample C(g)	Sample D(g)	Sample E (g)
Ewedu	86	76	96	88	98
Dry pepper	2	2	2	----	----
Dry fish	----	10	---	----	----
Iru	10	10	---	10	----
Potash	2	2	2	2	2

A=86% *Ewedu* + 2% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash, B=76% *Ewedu* + 2% Dry pepper + 10% Dry fish + 10% Iru + 2% Potash, C=96% *Ewedu* + 2% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash, D=88% *Ewedu* + 0% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash, E= 98% *Ewedu* + 0% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash

Determination of Functional Properties of Dehydrated*Ewedu* Soup Mix

Water Absorption Capacity

The method described by Onwuka (2005) was used. One gram of the dehydrated *ewedu* soup mix sample was weighed into a 15 mL centrifuge tube and suspended in 10 mL water. It was shaken on a platform tube rocker for 1 minute at room temperature. The sample was allowed to stand for 30 min and centrifuged (MODEL SM 800B UNISCOPE SURGIFRIENDS MEDICALS, ENGLAND) at 500 rpm for 30 min. The volume of free water was read directly from the centrifuge tube. The density of water was taken to be 1 g/mL.

$$Water\ Absorption\ Capacity = \frac{Amount\ of\ water\ added - Free\ water}{Weight\ of\ sample} \times density\ of\ water\ \times 100$$

Oil Absorption Capacity

The method, as described by Onwuka (2005), was used. One (1) gram of the dehydrated *ewedu* soup mix was mixed with 10 mL refined oil in a centrifuge tube and allowed to stand at room temperature (30 ± 2 °C) for 1 h. It was centrifuged (MODEL SM 800B UNISCOPE SURGIFRIENDS MEDICALS, ENGLAND) at 500 rpm for 30 min. The volume of free oil was recorded and decanted. Oil absorption capacity was expressed as mL of oil bound by 100 g dehydrated *ewedu* mix sample**.** The density of oil was taken to be 0.98 g/mL.

$$Oil\ Absorption\ Capacity = \frac{Amount\ of\ oil\ added - Free\ oil}{Weight\ of\ sample} \times density\ of\ oil \times 100$$

Bulk Density

The method described by Onwuka (2005) was adopted to determine bulk density. A graduated cylinder of 10 mL was weighed and gently filled with the dehydrated *ewedu* soup mix sample up to the 10 mL mark. The bottom of the cylinder was then tapped gently on a laboratory bench several times. This continued until no further diminution of the test flour sample in the cylinder after filling to mark was observed. The weight of the cylinder plus the dehydrated *ewedu* soup mix was measured and recorded. Bulk density was expressed as:

$$Bulk\ Density\ (g/\text{mL}) = \frac{weight\ of\ sample\ (g)}{volume\ of\ sample\ (cm^3)}$$

Swelling Index

This was determined using the method described by Onwuka (2005). Ten grams (10 g) of the *ewedu* soup mix sample was introduced into a graduated cylinder with the dry bulk volume noted. After that, 100 mL of boiling water was added to the sample in the cylinder and mixed thoroughly. The volume was measured after 10 minutes, and the swelling index was calculated as follows:

$$\text{Swelling index (mL/g)} = \frac{\text{Change in Volume of Sample (mL)}}{\text{Original Weight of Sample}}$$

Sensory Attributes of Ewedu Soup

Sensory evaluation of the *ewedu* soup was carried out using a 9-point hedonic scale. A panel of Twenty students from the Department of Food Science and Technology, Ibrahim Badamasi Babangida, University, Lapai, Niger State, Nigeria, was chosen based on their familiarity and experience with *ewedu* soup for sensory evaluation. Each sensory attribute (appearance, taste, sliminess, aroma, and overall acceptability) was rated on a 9-point hedonic scale (1 = dislike extremely and 9 = like extremely).

Data Analysis

The GENSTAT Statistical Software (version 17.0) was used for data analyses. Data were subjected to analysis of variance (ANOVA), and the separation of means was done using Duncan's Multiple Range Test (DMRT) at ($P \leq 0.05$).

RESULTS AND DISCUSSION

Functional Properties of Dehydrated Instant *Ewedu* Soup Mix

The results of the functional properties of the different dehydrated Instant *ewedu* soup mix samples are shown in Table 1. There were significant ($p \leq 0.05$) differences in the functional properties of the instant *ewedu* soup mix samples. The water absorption capacity ranged from 7.20-9.93%. According to Anthony *et al*. (2014), carbohydrates have been reported to greatly influence the water absorption capacity of foods. Therefore, the highest content of water absorption capacity recorded in Sample E could be attributed to the ingredients added (98:2) for ewedu and potash. This suggests That a higher proportion of these ingredients could lead to a product with better water absorption properties.

The oil absorption capacity ranged from 6.61-9.71%. According to Ohizua *et al*. (2016) oil absorption capacity measures the ability of food material to absorb oil. The mechanism of fat absorption is attributed mainly to the physical entrapment of oil and the binding of fat to a polar chain of protein (Adeleke and Odedeji, 2010; Chandra *et al*., 2015). The highest oil absorption capacity was recorded in the sample corresponding to the sample with the highest protein source (10% dry fish and 10% *iru*). This is due to the high protein content of dried fish and the added iru. Oil absorption capacities of foods increase with increased protein content since the protein in foods influences fat absorption (Omoniyi *et al*., 2016). Sample B had higher oil absorption capacity as a result of the hydrophobic character of protein in the dehydrated instant *ewedu* soup mix. The presence of protein exposes more non-polar amino acids to the fat and enhances hydrophobicity, as a result of which absorbs more oil (Oluwalana *et al*., 2012)

The bulk density ranged from 0.72-1.03 g/mL. The differences in bulk density may be due to the proportion of some ingredients added. It has been reported by Oppong *et al.* (2015) that bulk density is used to evaluate flour heaviness, handling requirements, and the type of packaging materials suitable for the storage and transportation of food materials. Dried fish and *iru*, being proteinous, do not significantly contribute to bulk density. The low bulk densities seen in sample B suggest a reduced need for packaging in greater quantity than for other samples.

The swelling index ranged from 1.51-4.04 g/mL. The swelling capacity of the samples also followed the same trend as water absorption capacity, with sample B having the lowest (E> C > D >A >B). Swelling capacity was reported as an indication of starch's water-holding capacity. The difference in swelling capacity in this study could be attributed in part to the fact that no protein source (dry fish and *iru*) was added in the formulation (98:2) for *ewedu* and potash in sample E.

Sensory Attributes of *Ewedu* soup

The results of the sensory attributes of the *ewedu* soup samples are presented in Table 2. The appearance of samples A and B was not affected significantly ($p \leq 0.05$) and was most preferred by the panellists. Sample B scored the highest (7.73) in appearance, followed by Sample A (7.60), which could be a result of the ingredients included (*ewedu,* potash, iru and dried fish), which gave it a better appearance and sample E (*ewedu* and potash) had the lowest rating because it had a dark and plain appearance.

Table 1: Functional Properties of Instant *Ewedu* Soup Mix

Samples	WAC(%)	OAC(%)	BD (g/mL)	SI (g/mL)
A	8.40^{c}±0.01	8.81^{d}±0.01	0.81^{b}±0.01	2.06^{b}±0.03
B	7.20^{d}±0.00	9.71^{c}±0.02	0.72^{d}±0.02	1.51^{d}±0.54
C	9.54^{b}±0.01	6.89^{b}±0.01	0.93^{c}±0.01	2.30^{c}±0.28
D	8.65^{c}±0.01	7.59^{a}±0.01	0.86^{b}±0.02	2.08^{b}±0.04
E	9.93^{a}±0.01	6.61^{b}±0.01	1.03^{a}±0.07	4.04^{a}±0.05

Values are means of duplicate determinations. values with same superscript along the same column are not significantly different at $p<0.05$
Key: WAC (water absorption capacity), OAC (Oil absorption capacity), BD (bulk density) SI (swelling index)
A=86% *Ewedu* + 2% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash
B=76% *Ewedu* + 2% Dry pepper + 10% Dry fish + 10% Iru + 2% Potash
C=96% *Ewedu* + 2% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash
D=88% *Ewedu* + 0% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash
E= 98% *Ewedu* + 0% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash

There was a significant ($p\leq0.05$) difference in the aroma of *ewedu* soup samples. Samples A and B were not affected significantly ($p\leq0.05$), likewise, C and E. The panellists preferred sample B, which recorded the highest score (7.67) for aroma. A similar trend was observed in the taste of *ewedu* soup samples. Sample B also had the highest sensory score for taste. This is a result of the addition of dried fish and *iru*. According to Ajani *et al*. (2012), *iru* has been known as one of the flavour (taste and aroma) enhancers that increase the attributes and palatability of a diet.

The sliminess of samples A and B was not affected significantly ($p\leq0.05$). Likewise, C and E. Sample B showed the lowest score (7.20) for sliminess. This may be attributed to the different ingredients added, which thickened the soup and made it less slimy compared to sample E, which was plain *ewedu* leaves and potash, giving a slimmer feel. All the *ewedu* soup samples were acceptable to the panellists, as indicated by their mean scores for the overall acceptability.

However, sample B was most preferred. This may be attributed to the formulation of the ingredients (dry pepper, dry fish, and iru).

Table 2: Sensory Attributes of Ewedu soup

Sample	Appearance	Aroma	Taste	Sliminess	Overall Acceptability
A	7.60^{a}±0.91	7.61^{a}±0.74	7.67^{a}±1.34	7.33^{b}±1.44	8.17^{b}±0.91
B	7.73^{a}±0.96	7.67^{a}±0.97	7.73^{a}±1.09	7.20^{b}±1.47	8.27^{a}±0.70
C	7.33^{b}±1.44	7.00^{c}±1.13	6.93^{b}±1.43	7.67^{a}±0.70	7.34^{c}±1.29
D	7.55^{c}±1.18	7.45^{d}±0.39	7.55^{c}±0.85	7.59^{c}±0.55	7.45^{c}±1.53
E	6.80^{d}±1.56	6.93^{c}±1.27	6.67^{d}±1.49	7.77^{a}±1.29	7.33^{c}±1.29

values are means ± standard deviation of triplicate determinations. Means in same column with different superscripts are significantly ($p<0.05$) different.

Key

A=86% *Ewedu* + 2% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash, B=76% *Ewedu* + 2% Dry pepper + 10% Dry fish + 10% Iru + 2% Potash, C=96% *Ewedu* + 2% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash, D=88% *Ewedu* + 0% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash, E= 98% *Ewedu* + 0% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash

CONCLUSION AND RECOMMENDATION

The freeze-drying method is a viable option for dehydrating *ewedu* leaves, with minimal impact on the sensory properties of the *ewedu* soup. This study shows that the recipe significantly ($p\leq0.05$) influenced the functional and sensory properties of the instant soup samples. The instant *ewedu* soup mix (samples C and E) demonstrated good functional properties, with sample B being the clear favourite among the panellists. This strong preference for sample B instils confidence in the recipe's potential success. However, there is a need for further study on the storage stability of dehydrated instant *ewedu* soup mix samples.

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EVALUATION OF NUTRITIONAL COMPOSITION OF DEHYDRATED EWEDU SOUP MIX

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ABSTRACT

Leafy vegetables play a significant role in the diet as they are important sources of nutrients. Ewedu leaves (Corchorus Olitorius) are abundant during the rainy season in Nigeria and many other tropical African countries but become scarce during the dry season. This aimed to dehydrate ewedu leaves and produce an instant soup mix. The jute leaves (ewedu leaves) were sorted, destemmed, washed, drained, and frozen in the dryer under a vacuum at 20 Pa for 3 hours. The dry leaves were blended with different levels of ingredients in the ratio of 86:2:0: 10:2, 76:2:10:10:2, 96:2:0:0:2, 88:0:0:10:2 and 98:0:0:0:2 for ewedu leaf, dry paper, dry fish, iru, and potash at 100g. The samples were labelled A, B, C, D and E. The samples were subjected to nutritional analysis (proximate, minerals and vitamins) to provide information on the nutrient composition of the samples. The dehydrated instant ewedu soup mix samples recorded a value of 5.02-5.89% moisture, 21.97-35.01% protein, 5.15-7.43% fat, 5.08-6.45 ash, 14.23-15.38% crude fibre, and 30.99-47.40% carbohydrate. The samples were also high in iron (11.00-15.65 mg/100 g), calcium (210.53-240.95 mg/100 g), sodium (88.99-100.48 mg/100 g), potassium (251.97-286.45 mg/100 g), phosphorus (355.09-372.61 mg/100 g), vitamin B3 (51.13-80.45 mg/100 g) and Vitamin C (52.12-63.43 mg/100 g) respectively. Dehydrated instant ewedu soup mix should be prepared by freeze-drying using sample B formulations (76:2:10: 10:2) as it was higher in nutrients due to adding 10% dried fish and "iru."

Keywords: Dehydrated, *Ewedu, Iru,* Soup

INTRODUCTION

In many Nigerian homes, green leafy vegetables play a significant role in the diet as they are excellent sources of phenolic compounds, vitamins, and minerals compared to cereal grains. They have high mineral elements like iron and calcium, the only natural folic acid sources (Natesh*et al.,* 2017). Leafy vegetables such as *Corchorus Olitorius ewedu* leaves are rarely processed in Nigeria, most likely because of inadequate dehydrating, canning, or freezing preservation facilities. However, a small quantity is sun-dried or shade-dried, producing poor-quality products with inconsistent moisture contents and microbial loads that compromise their stability during storage (Mepba *et al.,* 2007). The leafy vegetables are abundant during the rainy season in Nigeria and many other tropical African countries, but they become scarce during the dry season. Some of the traditional vegetables grown in Nigeria are *ogumo, worowo,* water leaf, *soko,* bitter leaf, *ugu,* scent leaf, *iyana ipaja, tete, utazi* leaf, *oha* leaf, *uziza* leaf *and ewedu* leaf (Sanni *et al.,* 2019).

Instant soup is a major element of instant food, and it is highly preferred in modern society for its simple, easy, and instant preparation characteristics (Islam *et al.,* 2018). Since millions worldwide suffer from malnutrition, dehydrated soup mixes are in high demand and a great way to provide these people with nutrients (Sarker *et al.,* 2019). A dehydrated *ewedu* soup mix can be a convenient solution for busy individuals, saving time and effort in traditional soup preparation, shelf life extension, food waste reduction and ensuring a readily available option. This instant soup can significantly contribute to fulfilling people's nutritional requirements, making it an ideal option for various segments of the population, including older individuals. Institutions, hotels, restaurants, medical facilities, and working families can easily reconstitute them. The extended shelf life of dehydrated soup powders, up to six months, is one of their main advantages (Rekha, 2010). Using predictive models, it was found that the shelf-life of freeze-dried *ewedu* soup was longer than 35 days at room temperature (Balogu *et al.,* 2020). There is currently limited research on producing and evaluating instant *ewedu* soup mix. Hence, this study will provide information on the best formulations and nutritional composition of the soup mix and solve the problem of seasonal availability of the leaves.

MATERIALS AND METHODS

Source of Materials

Fresh jute leaf (*ewedu* leaf), dried pepper, fermented locust bean (*iru*), dried fish and potash were purchased from Lapai Central Market, Niger state. The reagents used were of analytical standard.

Sample Preparation

Preparation of Dehydrated Jute Leaves (*Ewedu*)

The jute leaves were sorted, and the stem was removed and washed under running tap water until they were free from all adhering soil and impurities. The clean leaves were freeze-dried in the vacuum chamber of a freeze dryer (LGJ-18, SHKY, Chin) at a pressure (20 Pa) for 3 h and blended into a coarse texture using a blender (Panasonic, MX-AC300, Japan). The coarse leave powder was mixed with different ingredients (*iru*, potash, dried pepper, and dried fish) at different blend ratios, as shown in Table 1. They were uniformly blended into a smooth texture and sieved (1.0 mm aperture). The powdered *ewedu* was stored in an airtight container for further analysis.

Preparation of *Ewedu* Soup

Boiling water (100 mL) was measured into five different containers, to which 4 g of *ewedu* powder was added, mixed with a whisk for 1 minute, and covered for 3 minutes to produce the *ewedu* soup samples.

Table 1: Blend Formulation for Dehydrated *Ewedu* Soup Mix

Items	Sample A(g)	Sample B(g)	Sample C(g)	Sample D(g)	Sample E (g)
Ewedu	86	76	96	88	98
Dry pepper	2	2	2	----	----
Dry fish	----	10	---	----	----
Iru	10	10	---	10	----
Potash	2	2	2	2	2

A=86% *Ewedu* + 2% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash, B=76% *Ewedu* + 2% Dry pepper + 10% Dry fish + 10% Iru + 2% Potash, C=96% *Ewedu* + 2% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash, D=88% *Ewedu* + 0% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash, E= 98% *Ewedu* + 0% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash

Determination of the Proximate Composition of Dehydrated Ewedu Soup Mix

The proximate composition of dehydrated *ewedu* soup mix was determined according to AOAC (2015) methods, and carbohydrate content was determined by difference according to Ihekoronye and Ngoddy (1985).

Moisture Content Determination

Moisture content was determined using the air oven dry method. A clean dish with a lid was dried in an oven (Uniscope Surgifriend Medicals, England) at 100 ^{o}C for 30 min. It was cooled in desiccators and weighed. Two grams of sample was then weighed into the dish. The dish with its content was then put in the oven at 105^{o}C and dried to a fairly constant weight. The loss in weight from the original sample (before heating) was reported as a percentage of moisture.

$$\%\ Moisture = \frac{Weight\ Loss\ (W_2 - W_3)}{Weight\ of\ Sample\ (W_2 - W_1)}\ x\ 100$$

$where$:

$W_1 = Weight\ of\ dish,$

$W_2 = Weight\ of\ dish + sample\ before\ drying,$

$W_3 = Weight\ of\ dish + sample\ before\ drying.$

Ash Content Determination

Two grams of sample was weighed into an ashing dish, which had been pre-heated, cooled in a desiccator and weighed soon after reaching room temperature. The crucible and content were then heated in a muffle furnace at 55 ^{o}C for 6 h. The dish was cooled in a desiccator and weighed soon after reaching room temperature. The total ash was calculated as a percentage of the original sample weight

$$\%\ Ash = \frac{(W_3 - W_1)}{(W_2 - W_1)}\ x\ 100$$

$$where: W_1 = weight\ of\ empty\ crucible, W_2 = weight\ of\ crucible + sample\ before\ ashing,$$

$W_3 = weight\ of\ crucible + content\ after\ ashing$

Crude Fibre Determination

Two grams of the sample was extracted using diethyl ether. This was digested and filtered through the California Buchner System. The resulting residue was dried at 130 ^{o}C for 2 h, cooled in a desiccator and weighed. The residue was then transferred into a muffle furnace (Uniscope Surgifriend Medicals, England), ignited at 550 ^{o}C for 30 minutes, and cooled and weighed. The percentage of crude fibre content was calculated as

:

$$\%\ Crude\ Fibre\ = \frac{Loss\ in\ weight\ after\ incineration}{Weight\ of\ original\ food} \times 100$$

Crude Fat Determination

Fat was determined using the Soxhlet method. Samples were weighed into a thimble, and loose plug fat-free cotton wool was fitted into the top of the thimble with its content inserted into the bottom extractor of the Soxhlet apparatus. A flat bottom flask (250 mL) of known weight containing 200 mL of hexane was fitted to the extractor. The apparatus was heated, and fat was extracted for 8 hours. The solvent was recovered, and the flask (containing oil and solvent mixture) was transferred into a hot air oven (UNISCOPE SURGIFRIEND MEDICALS, ENGLAND) at 105 ^{o} C for 1 h to remove the residual moisture and to evaporate the solvent. It was later transferred into a desiccator to cool for 15 min before weighing. Percentage fat content was calculated as:

$$\%\ Crude\ Fat = \frac{weight\ of\ extracted\ fat}{Weight\ of\ Sample}\ x\ 100$$

Crude Protein Determination

The Kjeldahl method was used to determine the percentage of crude protein. Two grams of sample was weighed into a Kjeldahl digestion flask using a digital weighing balance (Uniscope Surgifriend Medicals, England: Max. 180 g). A catalyst mixture weighing 0.88 g (96% anhydrous sodium sulphate, 3.5% copper sulphate and 0.5% selenium dioxide) was added. Concentrated sulphuric acid (7 mL) was added and swirled to mix content. The Kjeldahl flask was heated gently in an inclined position in the fume chamber until no particles of the sample were adhered to the side of the flask. The solution was heated more strongly to make the liquid boil with intermittent shaking of the flask until a clear solution was obtained. The solution was

allowed to cool and diluted to 25 mL with distilled water in a volumetric flask. Ten mL of diluted digest was transferred into a steam distillation apparatus. The digest was made alkaline with 8 mL of 40 % NaOH. To the receiving flask, 5 mL of 2 % boric acid solution was added, and 3 drops of the mixed indicator were dropped. The distillation apparatus was connected to the receiving flask with the delivery tube dipped into the 100 mL conical flask and titrated with 0.01 M HCl. A blank titration was done. The percentage of nitrogen was calculated from the formula

:

$$\% \, Nitrogen = \frac{(S-B)\times 0.0014\times 100\times D}{Sample\ Weight}$$

$where$

$S = sample\ titre, B = blank\ titre, S - B = corrected\ titre, D = diluted\ factor$

$\% \, Crude\ Protein = \% \, Nitrogen \times 6.25\ (correction\ factor)$

Carbohydrate Determination

Carbohydrate content was determined by difference according to Ihekoronye and Ngoddy (1985) as follows:

$\% \, Carbohydrate\ = 100 - (\% \, Moisture + \% \, Ash + \ \% \, Fibre + \% \, Fat + \ \% \, Protein)$

Determination of the Mineral Content (Mg/100g) of *Ewedu* Soup Mix

Determination of Iron

The determination of iron was carried out using the AOAC (2015) method. A standard solution, containing 100 mg/mL of Fe3+ ions, was prepared from 1 g pure iron wire. The wire was dissolved in 20 mL of concentrated HNO3, boiled in a water bath, and diluted to 1000 mL with distilled water. A standard solution containing 0, 0.5, 1.0, 2.0, and 4.0 ppm was prepared. Two millilitres of sample aliquot were diluted to 100 mL and used to determine the absorbance of the sample using an atomic absorption spectrophotometer (Uniscope Surgifriends Medicals, England) at 510 nm. The standard and sample absorbance were noted, and the concentration of iron in the sample was determined from the standard curve.

Determination of Potassium

Potassium was determined by Flame Photometry (AOAC, 2015). One gram of sample was dissolved in 20 mL of acid mixture (650 mL of concentrated HNO3; 80 mL PCA; 20 mL conc. H2SO4), and aliquots of the diluted clear digest were taken for photometry using a Flame analyzer.

Determination of Calcium

The standard AOAC (2015) method was used for calcium determination using the atomic absorption spectrophotometer. Calcium carbonate (2.495 g) was dissolved and diluted to 100 mL with de-ionized water. This solution contains 1000 mg Ca2+ ions, and from this stock solution, calcium standards of the following concentration levels: 0.0, 3.0, 6.0, and 9.0 were prepared. The absorbance of both the sample and the standard working aliquot was determined in the atomic absorption spectrophotometer (Uniscope Surgifriends, England) at 239.9 nm. The concentration of the test mineral in the sample was calculated with reference to the graph (standard curve) and obtained as follows:

$$Calcium(mg/kg) = \frac{100 \times Y \times Vf \times D}{W \times 100 \times Va}$$

Where

$W =$ weight of the sample analyzed,

$Y =$ Concentration of Calcium obtained from the standard curve,

$Vf =$ Total volume of extract

$Va =$ volume of extract used

$D =$ Dilution factor

Determination of Phosphorus

The standard method of AOAC (2015) was phosphorus determination using a spectrophotometer. Phosphorus in the sample was determined by the molybdate method using hydroquinone as a reducing agent. Sodium sulphate (1.0 mL), 1.0 mL of ammonium molybdate and 1 mL of hydroquinone were added to 1 mL of the sample digest. The mixture was agitated and allowed to stand for 30 minutes for the blue colour to develop. The absorbance of the

sample was determined using the spectrophotometer at 600 nm. The phosphorus standard was prepared by dissolving 1.1 g of monobasic potassium phosphorus (KH_2PO_4) into a 500 mL volumetric flask containing 500 mL of distilled water. Five drops of toluene were added to diminish microbial activity. Twenty millilitres of the standard stock was collected and made up to 100 mL. This contained 100 ppm. Standard stock (0.1 mL) = 0.2 ppm. Zero to one millilitre of the 100 ppm phosphorus stock solution was poured into a 100 mL volumetric flask separately and treated the same way as the sample. The reading of the standard was taken at 600 nm in UV/VIS spectrophotometer (Uniscope Surgifriend Medicals, England) and a standard curve was plot

$$P(mg/kg) = \frac{100 \times Au \times C \times Vf}{W \times As \times Va}$$

Where

W = Weight of sample analyzed

Au = Absorbance of test sample

As =Absorbance of standard phosphorus solution

C =Concentration (in mg/ml) of sample

Vf = Total vomule of extract

Va =Volume of extract analyzed

Determination of Sodium

The determination of sodium concentration was achieved using the standard method of AOAC (2015). A weight of 0.2542 g of NaCl was dissolved in 1 litre of distilled water to give a 100 ppm Na solution. This working standard solution was then diluted to produce a range of 0-10 ppm sodium. A 2 mL sample aliquot (sample stock solution) was read using a flame photometer. The concentration of sodium in the sample was then calculated with reference to the standard curve, as follows:

$$Sodium(mg/kg) = \frac{100 \times Y \times Vf \times D}{W \times 100 \times Va}$$

Where:

W =Weight of the sample analyzed

Y =Concentration of Na obtained from the standard curve

Vf =Total volume of digest/extract (100 ml)

Va = Volume of extractused

D = Dilution factor

Determination of Vitamins Content of the *Ewedu* Soup Mix

Determination of Vitamin B (B1 and B2)

The standard fluorimetric method of the AOAC (2015) was followed, and the procedure for pyridoxine is as follows. A portion (30 mL) of hydrochloric acid (0.1) solution was added to about 5 g of sample, and the content was mixed thoroughly; 1 mL of the solution was transferred to a cleaned test tube and 4 mL of distilled water. In the second test tube, 5 mL of standard solution was put (standard), and in the third test tube, distilled water was used as the mobile phase. For the blank determination, sodium hydrosulphite (Na_2SO_4) was dissolved in 0.4% sodium acetate as specified in the AOAC semi-automated method. The sample was aspirated into the sample loop, and fluorescence was recorded.

Determination of Vitamin B3

These were determined using the method described by AOAC (2015). Five grams of the homogenized sample was weighed into a 100 mL volumetric flask. 0.1 N hydrogen chloride was added and mixed, then autoclaved for 30 minutes at 121 ^{o}C. The samples were allowed to cool. Interfering substances were precipitated by adjusting the pH to 6.0, followed immediately by readjusting the pH to 4.5. This was then diluted to volume with water and filtered. Five mL of 6 % enzyme (mylase 100) was added and incubated for 3 hours at 45-50 ^{o}C. This was then cooled, with pH adjusted to 3.5, diluted with water to volume, mixed, and filtered. Ten mL of diluted extract was oxidized by passing through a sepak C18 cartridge followed by 5 mL 0.01 M phosphate buffer at pH 7.0. The vitamins were separated by high-performance liquid chromatography (HPLC) (Model: BLC-10/11, Buck scientific, USA) using a 4.6 mm × 25 cm

ultra-sphere ODS (operational data store), 5 column or equivalent and detected by florescence at 360 nm/415 nmex/em. The pyridoxine, riboflavin and thiamin contents were measured by the calculation below

:

$$\mu g/g = C \times V(Df \times Wt)$$

$Where$:

$$C = Conc.ofvitamin\ in\ \mu\frac{g}{ml}obtained\ from\ height\ or\ area\ of\ sample\ and\ standard$$

$\mathrm{V} = \text{Sample volume (ml)}$

$\mathrm{Df} = \text{Dilutionfactor}$

$\mathrm{Wt} = \text{Weight of sample (g)}$

Determination of Vitamin C (Ascorbic Acid)

Vitamin C was determined by the titration method as described by (AOAC, 2015). A standard solution of ascorbic acid (5 mL) was pipetted into a 100 mL conical flask, 10 mL of oxalic acid was added, and the solution was titrated against the dye (V1) until a pink colour persisted for 15 seconds. The dye consumed is equivalent to the amount of ascorbic acid. Also, 0.5 g of the sample was extracted in 4% oxalic acid and made up to 100 mL. The solution was titrated against the dye solution (2,6 dichlorophenol indophenols). The volume of the dye was recorded as V2. The calculation below was used to calculate vitamin C:

Data Analysis

The GENSTAT Statistical Software (version 17.0) was used for data analyses. Data were subjected to analysis of variance (ANOVA), and the separation of means was done using Duncan's Multiple Range Test (DMRT) at ($P \leq 0.05$).

RESULTS AND DISCUSSION

Proximate Composition of Dehydrated Instant *Ewedu* Soup Mix

The results of the proximate compositions of the different dehydrated instant *ewedu* soup mix samples are presented in Table 2. There was a significant ($p<0.05$) difference in the proximate composition of the samples. The moisture content of the samples ranged from 5.02 -

5.89%. This value is close to 5.21%, as reported by Ncube (2022) in *Corchorus Olitorius.* However, the result of this study is lower compared to 7.44-13.5% for *Corchorus Olitorius* (*ewedu* leaf) by Adesina*et al.* (2022) and 8% by Balogu *et al*. (2020) for *ewedu* leaves. The variation in moisture content may be due to climatic conditions and the maturity stage of harvest (Ncube, 2022). Abdel-Haleem and Omran (2014) reported that food powders with less than 10% moisture content have better keeping qualities as soup ingredients. Thus, longer shelf life. The protein content of the samples ranged between 21.97 - 35.01%. These values are higher than the 17.5% reported for *the Sooro* variety of *Corchorus Olitorius* (Adesina *et al.,* 2022) and 14% reported for *ewedu* leaf (Balogu*et al*., 2020). Dried locust beans (*iru*) have a crude protein content of 32.51% - 33.52% (Famuwagun and Taiwo, 2023). The higher crude protein content of samples B and A can be attributed to including animal protein (fish) and *iru*. Thus, they are good sources of protein needed in the body for growth and tissue replacement. Deepa *et al*. (2021) reported that plant foods when rightly combined with other foods, can be of high biological value and satisfactorily meet the protein needs of children and adults.

The crude fat content of the samples ranged between 5.15 and 7.43%. The level of fat content in this study is higher than 1.98-2.22% by Adesina *et al.* (2022) for *ewedu* varieties and lower than 34% and 19.76 % by (Balogu *et al*., 2020) and (Ncube, 2022) for *ewedu* leaf. Sample B had the highest percentage of fat (7.43 %). This might be due to the inclusion of dried fish, a fat source. Dried fish contain fatty tissues with varying amounts of fat (Fitri *et al.,* 2022). This explains the significantly higher fat content of sample B. This indicates sample B is a good source of fat and energy. The ash content of the samples ranged between 5.08-6.45%. The values were lower than 9.36-11.7% for *ewedu* varieties by Adesina *et al.* (2022). The ash contents of the soups are suggestive that they can be good sources of minerals, especially macro minerals. The moderately high ash values for the samples may be attributed to the ingredients (pepper, *iru,* potash, and dried fish) used in preparing the soups. This indicates that sample B contained some inorganic substances (minerals) necessary for body utilization.

The crude fibre content of the samples ranged from 14.23-15.38%. These values were higher than 11.2-12.9%, as Adesina *et al.* (2022) reported for a similar sample. According to Ishida *et al*. (2000), vegetables are often abundant in dietary fibre, significantly benefiting consumers by lowering their risk of colon cancer, diabetes, hypertension, constipation, and heart disease. It has also helped in faecal elimination. The carbohydrate content of the samples ranged from 30.99-47.40%. The values in this study were lower than 31.8-48.5% reported for *ewedu*

varieties by Adesina *et al.* (2022). The available carbohydrates constituted almost one-third of the soups. The carbohydrate content of the soups is relatively low when compared with that of roots, tubers, grains and legumes, indicating that soups are generally not a major source of energy for body use but rather a supplementary source of carbohydrates and energy. Omah *et al.* (2015) reported that the carbohydrate contents of soups were lower probably because of the products' high protein, fat, ash, and fibre content. Since soups that are low in carbohydrate content are usually consumed with carbohydrate-based meals, taking these soups and accompanying dishes will promote good health among consumers.

Table 2: Proximate Composition *Ewedu* Soup Mix

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Crude fibre (%)	Carbohydrate (%)
A	$5.33^{a}\pm0.11$	$31.12^{a}\pm0.36$	$6.60^{a}\pm0.13$	$6.25^{a}\pm0.11$	$15.01^{a}\pm0.11$	$35.69^{a}\pm0.71$
B	$5.89^{b}\pm0.15$	$35.01^{b}\pm0.22$	$7.43^{b}\pm0.10$	$6.45^{b}\pm0.09$	$14.23^{b}\pm0.19$	$30.99^{b}\pm0.50$
C	$5.10^{c}\pm0.02$	$24.51^{c}\pm0.54$	$5.79^{c}\pm0.25$	$5.29^{c}\pm0.07$	$15.25^{c}\pm0.21$	$44.29^{c}\pm0.87$
D	$5.19^{c}\pm0.10$	$27.01^{d}\pm0.37$	$6.52^{a}\pm0.43$	$6.01^{d}\pm0.04$	$14.95^{d}\pm0.28$	$40.32^{d}\pm0.43$
E	$5.02^{c}\pm0.17$	$21.97^{e}\pm0.36$	$5.15^{d}\pm0.49$	$5.08^{e}\pm0.08$	$15.38^{e}\pm0.30$	$47.40^{e}\pm0.55$

values are means of duplicate determinations. values with same superscript along the same column are not significantly different at $p<0.05$

Key:

A=86% *Ewedu* + 2% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash

B=76% *Ewedu* + 2% Dry pepper + 10% Dry fish + 10% Iru + 2% Potash

C=96% *Ewedu* + 2% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash

D=88% *Ewedu* + 0% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash

E= 98% *Ewedu* + 0% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash

Mineral composition of Instant *Ewedu* Soup Mix

The results of the mineral composition of the different dehydrated instant *ewedu* soup mix samples are indicated in Table 3. There was a significant ($p<0.05$) difference in the mineral composition of dehydrated instant *ewedu* soup mix samples. The iron content of the samples ranged from 11.00-15.65 mg/100 g. The values are lower than (25.98 mg/kg) by Musa and Ogbadoyi (2012) for sun-dried *ewedu* leaves. Sample B had moderate iron content, which is believed to be bioavailable, as the soups contained ingredients from animal sources, which

contributed significantly to the iron values of the soups. The sodium content of the samples ranged between 88.99 and 100.48 mg/100 g. The sodium contents are very high. The value is low compared to 180 mg/100 g reported by Famuwagun and Taiwo (2023) for *miyan kuka* and higher than 28.5 mg/kg for *Oniyaya* leaf of *Corchorus Olitorius* (*ewedu*). The high value of this study may be attributed to the potash added to all samples, which aided the sliminess of *the ewedu* soup samples. Sodium has been implicated in cardiovascular disease risk, particularly hypertension (Ross *et al.,* 2016). However, sodium is essential for absorbing glucose in the kidney and intestine and transporting other nutrients across membranes (Vishwanath, 2012).

The potassium content of the samples, ranging from 251.97-286.45 mg/100 g, was notably high. This can be attributed to the potash added, which enhances the sliminess of *ewedu* soups. This value was higher than the 167-424 mg/100 g reported for ewedu varieties by Adesina *et al.* (2022) and *the* 25.08- 38.61 mg/100 g for *ewedu* leaves by Adejumo *et al*. (2022). However, it was lower than the 840 mg/100g in *miyan kuka*, *Onugbu* soups reported by Kayode *et al*. (2010). The high potassium content is advantageous, as it plays a crucial role in balancing intracellular fluid and is associated with lower blood pressure values. Sample B had a significantly higher potassium Value compared to other samples.

The calcium content of the samples, ranging from 210.53-268.39 mg/100 g, is significantly high. This value is higher than the 35.6- 46.5 mg/100 g reported by Adesina *et al.* (2022). The high calcium content can contribute meaningfully to the daily calcium requirements of both adults and children. This high calcium value could be attributed to the contribution from the ingredients, especially *iru*, which has been reported to contain high amounts of calcium (711.56 - 745.16 mg/100 g) (Famuwagun and Taiwo, 2023). The phosphorus content ranged from 255.09-272.51 mg/100 g, indicating high levels. This may be attributed to the presence of dried fish and *iru*, which have good levels of phosphorus. Hence, the observed high value of phosphorus in sample B.

Vitamin Content of Instant *Ewedu* Soup Mix

The results of the vitamin content of the dehydrated instant *ewedu* soup mix samples are shown in Table 4. There was a significant ($p \leq 0.05$) difference in the vitamin content of the samples. Vitamin B1, B2, B3, and vitamin C ranged from 1.41-1.72 mg/100 g, 0.43-0.77 mg/100 g, 60.67-80.45 mg/100 g and 53.25-63.43 mg/100 g, respectively. These values were higher than 0.04 mg/100 g (vitamin B1), 0.06 mg/100 g (vitamin B2) and 0.61 mg/100 g (vitamin B3)

reported by Adeniyi *et al*. (2012) in *Corchorus Olitorius* (*ewedu* leaves). However, vitamin C content in this study was lower than 316.80 mg/100 g reported by Adeniyi *et al*. (2012 The soup mixes contained appreciable amounts of vitamins B1, B2, B3 and C. The appreciable amounts of water-soluble vitamins observed in this study might have been due to their retention during freeze-drying and the ingredients used. This may explain the higher value of these vitamins in the soup mixes with dried fish in this study.

Table 3: Mineral Composition *Ewedu* Soup Mix

Samples	Iron (mg/100g)	Calcium (mg/100g)	Sodium (mg/100g)	Potassium (mg/100g)	Phosphorus (mg/100g)
A	13.00^{a}±0.91	240.95^{a}±2.75	96.55^{a}±1.85	274.65^{a}±0.35	360.79^{a}±0.15
B	15.65^{b}±0.41	268.39^{b}±2.01	100.48^{b}±1.19	286.45^{c}±0.25	372.61^{b}±0.50
C	11.20^{c}±1.20	231.12^{c}±1.25	91.11^{c}±1.35	258.33^{b}±1.30	364.01^{a}±0.10
D	13.40^{d}±0.02	245.80^{a}±1.05	96.93^{a}±1.05	275.78^{a}±1.25	365.34^{a}±0.10
E	11.00^{c}±1.35	210.53^{d}±1.09	88.99^{d}±1.40	251.97^{b}±1.80	355.09^{c}±0.21

values are means of duplicate determinations. values with same superscript along the same column are not significantly different at $p<0.05$

Key:

A=86% *Ewedu* + 2% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash, B=76% *Ewedu* + 2% Dry pepper + 10% Dry fish + 10% Iru + 2% Potash , C=96% *Ewedu* + 2% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash, D=88% *Ewedu* + 0% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash, E= 98% *Ewedu* + 0% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash

Table 4: Vitamin Content of Instant *Ewedu* Soup Mix

Samples	Vitamin B1 (Thiamine) (mg/100 g)	Vitamin B2 (Riboflavin) (mg/ 100 g)	Vitamin B3 (Niacin) (mg/ 100 g)	Vitamin C (Ascorbic acid) (mg/100 g)
A	1.69^{a}±0.05	0.53^{b}±0.06	60.67^{a}±0.09	58.600^{a}±0.11
B	1.72^{a}±0.06	0.43^{c}±0.08	60.94^{a}±0.11	53.25^{b}±0.06
C	1.43^{c}±0.08	0.77^{a}±0.06	80.45^{b}±0.13	63.43^{b}±0.03
D	1.61^{b}±0.03	0.45^{c}±0.02	51.13^{c}±0.10	52.12^{c}±0.13
E	1.41^{c}±0.08	0.56^{b}±0.03	71.26^{d}±0.07	60.70^{d}±0.09

Values are means of Duplicate determinations. Values with same superscript along the same column are not significantly different at $p<0.05$.

Key:

A=86% *Ewedu* + 2% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash, B=76% *Ewedu* + 2% Dry pepper + 10% Dry fish + 10% Iru + 2% Potash, C=96% *Ewedu* + 2% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash, D=88% *Ewedu* + 0% Dry pepper + 0% Dry fish + 10% Iru + 2% Potash, E= 98% *Ewedu* + 0% Dry pepper + 0% Dry fish + 0% Iru + 2% Potash

CONCLUSION AND RECOMMENDATION

Dehydrated instant *ewedu* soup mixes are rich in nutrients such as protein, vitamins (B3 and C), and minerals (calcium, phosphorus, and potassium). This study indicated that dehydrated instant *ewedu* soup mixes prepared using dried fish and "*iru"* (sample B) were highly nutritional. This blend's good value indicates that the recipe should be adopted and utilized.

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CHARACTERIZATION AND FERTILITY MAPPING OF AN ACRISOL FOR SITE-SPECIFIC SOIL MANAGEMENT AT OKPORUZOR COMMUNITY, SOUTHEAST NIGERIA

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ABSTRACT

The study characterized and assessed the fertility status of an Acrisol for site-specific soil management at Okporouzor community, Southeastern Nigeria. Following the line transect survey method (east-west), soil samples were investigated. Consequently, changes in physiographic features along the segment formed the basis for delineating the landscape into three mapping units (IJN I–III). Representative profile pits were after that established in the mapping units and described in situ for morphological attributes. Soil samples from profile pits and top soil across the site were analyzed for physical and chemical properties. The geo-spatial technique estimated the spatial distribution of the fertility of the soils. Results revealed well-moderately drained and deep (>100cm) soils. Sandy clay loam overlaid clay in IJN I and sandy loam underlain by sandy clay loam in IJN II and III. Sand fractions varied significantly (CV>35) with depth in IJN I but not (CV<15) in JN II and III. Clay varied (CV>35) with depth across the units. The pH (water) was moderately acidic (4.66-5.91). Organic carbon was high (1.81%) in IJN I and moderate (1.47–1.48%) in IJN II and IJN III, with significant variation (CV>20<42). Available P was moderate (9.81-18.25mgkg-1). Exchangeable bases were generally low except Mg, which was moderate. Cation exchange capacity was low

(<16.00cmolkg-1) following this order: IJN II<IJN III<IJN I. Base saturation was dystric (<50%) across the units. The soils were classified as Haplic Kandiudults (USDA) and Haplic Acrisols (WRB). Soil fertility mapping showed strong acidity (60% area), moderate organic carbon (80%) and low total N (80%). The site was also low in exchangeable Ca (100%) and K (100%) but medium in Mg (100%) and available Phosphorous (100%). The findings of this research are significant, providing a comprehensive understanding of soil fertility and its implications for site-specific soil management.

Keywords: Characterization, Fertility mapping, Management, Site-specific, Soil information

INTRODUCTION

The persistent and widespread hunger and malnutrition across the country may not be reduced to an appreciable level by 2030, as proposed by the Second Development Goal of the United Nations (UN, 2017), which aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture. This goal underscores the urgency of making more lands available for inclusive and sustainable food production. However, inadequacies evident in present-day farm planning procedures require that attention be given to soil survey and land evaluation - the starting point for land-use planning (Esu, 2004). The ability to maximally harness the potential of any soil begins with a detailed survey and correct interpretation of the survey report (evaluation) of that soil (Akinbola *et al*., 2009).

Therefore, soil survey and land evaluation are fundamental to land potential for agricultural purposes and management decisions, planning, and utilization, providing a link between resource assessment and decision-making (Osinuga *et al*., 2020). Soil management and conservation may only be effective if the soil is reliably characterized, classified, and interpreted according to specific crop growth requirements (Akinbola *et al*., 2009). This is very expedient, particularly in this era of constant threats of misuse of soil resources that result in serious degradation, soil erosion and other environmental hazards (Akamigbo, 2010).

Ojanuga *et al*. (2003) reported that the variability of soils over a landscape is consequent upon soil forming factors and, thus, needs an adequate inventory of their characteristics for classification and optimal utilization. The study of soil resources through characterization, classification and evaluation for various land utilization has been reported as one of the strategies to achieve food security and a sustainable environment (Esu, 2004; Ande *et al*., 2008). This aligns with the work of Ogbodo and Chukwu (2012), who state that soil evaluation is a veritable tool used to assess soil health and is a guide to improve soil productivity. Therefore,

understanding the fertility status of soils in an area is crucial for the productive and sustainable management of such soils without diminishing the potential for their future use (Ojeniyi, 2002; Chude *et al*., 2011).

Acrisols, which are known to be low-activity clay soils, are the most cultivated and dominant soils in southeastern Nigeria (Lekwa, 2002; Ojanuga *et al.*, 2003; Oguike *et al*., 2006). Low-activity clay soils are characterized by their low cation exchange capacity and poor nutrient retention. The organic matter content of some of these soils tends to decline rapidly under continuous cultivation (Oguike and Mbagwu, 2009). Soil nutrients such as nitrogen and phosphorus have been reported to decline with decreased soil organic matter (Chukwu *et al*., 2007).

Geographic information system (GIS) is a robust set of tools for collecting, storing, transforming and displaying spatial data from the real world and can be of great use for the assessment and management of soil fertility in precision agriculture (site-specific farming) (Basavaraj *et al*., 2020). This will help the farmers to identify the correct input at the right time and in the right amount, which will not only avoid wastage of inputs but also reduce pollution due to excessive use of inputs. Geospatial techniques, such as GIS, can be used to produce a soil fertility map of an area. This will help formulate balanced fertilizer recommendations and understand the status of soil fertility spatially. Thus, through digital mapping, GIS can be employed in various spheres of agriculture.

In line with the task of feeding the world population, which is estimated to reach 9.5 billion by 2050, there is a need to improve agricultural productivity. A major strategy to achieve this is soil characterization and geospatial fertility mapping. This research has the potential to provide adequate soil information as regards land uses in Okporuzor, an agrarian community that lies in the Umuahia area where important crops like Maize, cassava, yam, potato, plantain, oil palm *etc*., are largely grown. The findings could lead to a significant reduction in environmental degradation and contribute to food security.

In view of this, an attempt was made to characterize and delineate the soil fertility status and prepare the thematic maps of varied soil macronutrients using Geospatial techniques. The findings of this research will ensure site-specific application of soil nutrients and amendments based on spatial variability tailored to the soil requirements. The study will also guarantee

appropriate land use by farmers and land use planners using procedures that guarantee a sustainable environment.

MATERIALS AND METHODS

Study Area

The study was conducted in Okporuzor, Afaraukwu, in Umuahia North Local Government Area of Abia State, Southeast Nigeria. The area is located in the rainforest zone of Nigeria. It lies between latitudes 5o29' –5o 42' N and longitudes 7o 29' –7o 33' E (Fig. 1). The area has an average annual rainfall of 2,238 mm distributed over seven months in the rainy season (NRCRI, 2020). Annual air temperatures range between 23o C and 32o, with a relative humidity of 60-80 % (NRCRI, 2020). The study area's vegetation is typical of Nigeria's forest belt. It contains wild oil palm trees of various densities, rubber, and woody shrubs. Land use comprised of arable crops with varying fallow periods that are used as a means of fertility orientation techniques.

The study area is underlain by one main geological formation: the coastal plain sands, which consist largely of unconsolidated sands (Lekwa, 2002). These sands are dominated by low-activity clays with low organic matter content and are susceptible to accelerated erosion and soil degradation (Ogban and Ibia, 2006).

Field Work and Sampling Technique

The study site was reconnoitred for relevant information by observing different physiographic features. Subsequently, a perimeter survey of the land area was carried out, and the project site was geo-referenced using a Global Positioning System (GPS) receiver. Following the line transects survey method, the site was traversed, and five transects at intervals of 100 m apart were cut along the east-west of the study site. Soil samples were investigated consequent upon changes in physiographic features like slope, elevation and drainage along the transects. The observed features formed the basis for delineating the landscape into three mapping units (IJN I – III)

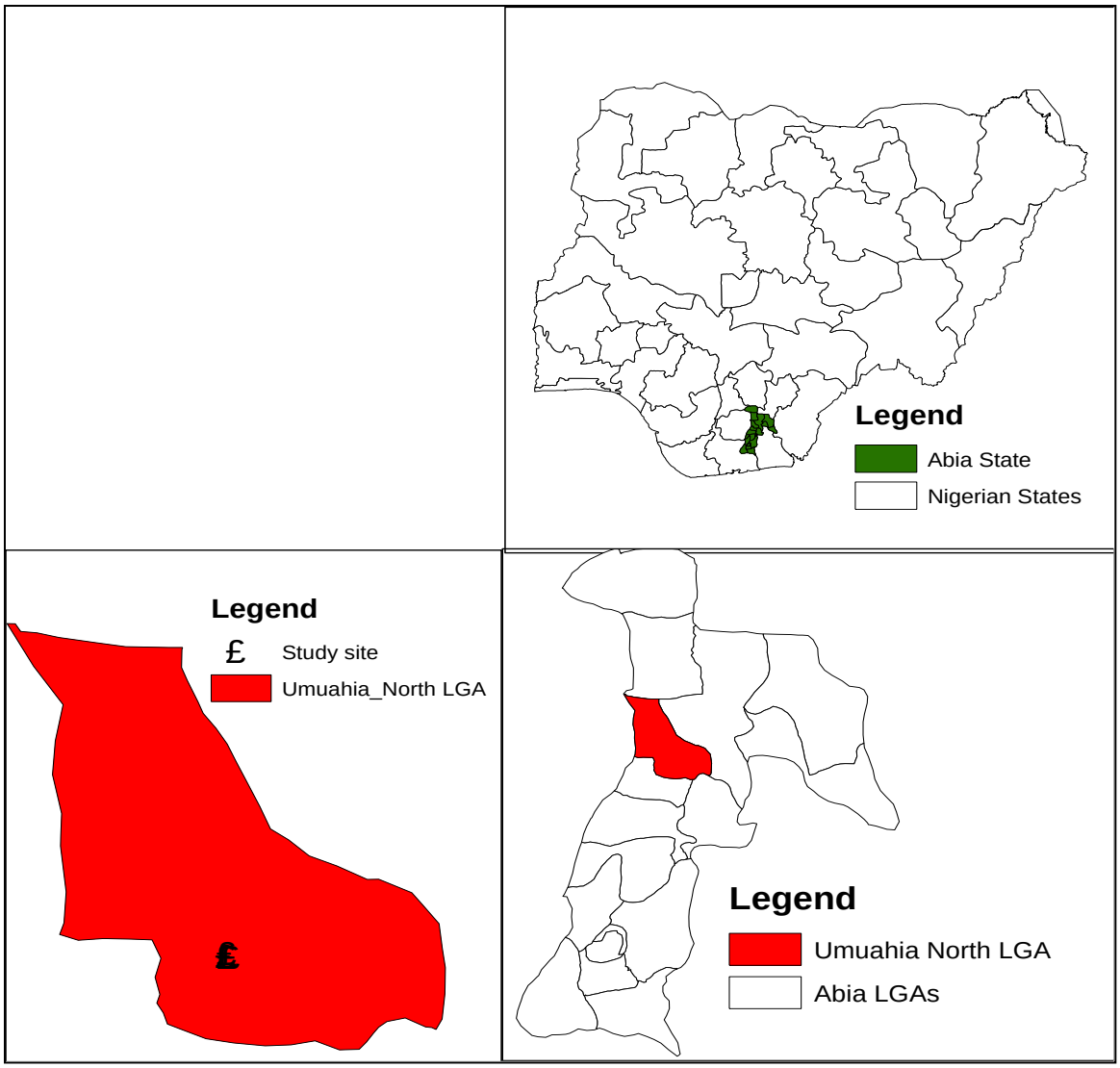

Figure 1: Location map of the study area

Representative profile pits were established in the mapping units delineated. Each profile pit was demarcated into horizons and described *in-situ for* morphological attributes, which was in line with the procedure recommended by FAO (2006). Disturbed and undisturbed (core) soil samples from identified horizons of the profile pits were collected and analyzed for their physical and chemical properties. In addition, top (0 - 20 cm) composite soil samples (each composite sample was taken from six auger samples) were collected in a random pattern across the study site and analyzed for fertility evaluation. All profile pits and top soil sample locations were geo-referenced using a hand-held Global Positioning System (GPS) receiver for geospatial analysis.

Soil Analysis and Data Interpretation

The soil samples were air-dried and ground to pass through a 2 mm sieve. For the determination of total N and organic carbon (OC), a 0.5 mm sieve was used. Analyses of the physicochemical properties were carried out following standard laboratory procedures. Particle-size distribution and bulk density were determined by Bouyocous hydrometer methods (Gee and Or, 2002). Undisturbed soil core samples were oven-dried at 105oC to a constant weight, and bulk density was calculated using the formulae

:

$$Bulk\ density\ (mg/m^3) = \frac{mass\ of\ oven\ dried\ soil\ sample\ (g)}{Volume\ of\ soil\ sample\ (m^3)} \quad \ldots\ldots\ldots\ldots \text{ equation 1}$$

Where: v = volume of core sampler {v = π r ^{2} h} {where r is radius (m^2) and h, height (m) of the core sampler}.

Total porosity (Tp) was computed as:

$$Tp = 1 - \{Bd \div Pd\} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ equation 2}$$

Where: Bd = bulk density and Pd = particle density

Soil pH was measured using a 1:2.5 soil-to-water ratio (Thomas, 1996), whereas soil organic carbon was determined by the wet oxidation method of Nelson and Sommers (1982). Total N was determined by the Kjeldahl wet digestion and distillation method (Bremner, 1996). Available P was determined using Bray-2 extract (Olsen and Sommers, 1984). Total exchangeable bases were determined by extracting with neutral normal ammonium acetate (NH4OAc) at pH 7.0. Exchangeable K+ and Na+ in the extract were determined using a flame photometer, while exchangeable Ca2+ and Mg2+ were determined by the ethylene diamine tetraacetic acid (EDTA) titration method (Jackson, 1962). The exchangeable acidity {hydrogen (H+) and aluminium (Al3+)} was determined by titration method. Cation exchange capacity (CEC) was determined by ammonium acetate (NH4OAc) of 1.0M leaching at pH 7 (Jackson, 1962), and finally, the base saturation (BS-%) was determined using the relationship:

$$BS\ (\%) = \frac{\sum Exchageable\ Bases}{\sum Exchageable\ Bases + \sum Exchangeable\ Acidity} \times 100 \quad \ldots\ldots\ldots \text{ equation 3}$$

Data were interpreted based on Chude *et al*. (2011) ratings for soil data interpretation and fertilizer recommendation from a program organized for crop facilitators from the Agricultural

Development Projects (ADPs) by the Soil Fertility Initiative (SFI) of the National Programme for Food Security (NPFS), Abuja-Nigeria.

Soil Classification

The soils were classified using the USDA soil taxonomy system (Soil Survey Staff, 2014) and World Reference Base (WRB, 2014) soil classification systems based on the morphological, physical, and chemical properties obtained.

Table 1: Nutrient Rating for Soil Data Interpretation

	Very Low	**Low**	**Moderate**	**High**	**Very High**
Organic Carbon (%)	< 0.4	0.4 – 1.0	1.0 - 1.5	1.5 – 2.0	> 2.0
Total N (%)	< 0.05	0.05 – 0.15	0.15 – 0.25	0.25 – 0.30	> 0.30
Available P (mg/kg)	< 3.0	3.0 – 7.0	7.0 – 20.0	> 20.0	-
Exch. K (cmol/kg)	< 0.2	0.2 – 0.3	0.3 – 0.6	0.6 – 1.2	> 1.2
Exch. Na (cmol/kg)	< 0.1	0.1 – 0.3	0.3 – 0.7	0.7 – 2.0	> 2.0
Exch. Ca (cmol/kg)	< 2.0	2.0 – 5.0	5.0 – 10.0	10.0 – 20.0	> 20.0
Exch.Mg (cmol/kg)	< 0.3	0.3 – 1.0	1.0 – 3.0	3.0 – 8. 0	> 8.0
CEC (cmol/kg)	<6.0	6.0 – 12.0	12.0 – 25.0	25.0 - 40	> 40
Base Saturation (%)	0 – 20	20 - 40	40 - 60	60 - 80	90 - 100
Soil Depth (cm)		**Soil Reaction (H_2O)**			
		(*Acid*)		**(*Alkaline*)**	
Very shallow: < 30		Extremely acidic: < 4.5		Neutral (6.6 – 7.2)	
Shallow: 30-50		Very strongly acidic: 4.5 - 5.0		Slightly alkaline (7.3 - 7.8)	
Moderate: 50 - 100		Strongly acidic: 5.1 - 5.5		Moderately alkaline (7.9 – 8.4)	
Deep: > 100		Moderately acidic: 5.6 - 6.0		Strongly alkaline (8.5 – 9.0)	
		Slightly acidic: 6.1 - 6.5		Very strongly alkaline (> 9.0)	

Source: Chude *et al. (*2011)

Generation of Fertility Maps

Following the Framework for land evaluation, a multi-criteria evaluation technique in GIS was used to model fertility indices of the study area (FAO, 1976). Based on the extent to which the soil properties meet the nutrient rating index (Table 1) and the coordinates of the sample locations, the thematic layer was prepared according to the rating scale as very low, low, medium, and high. All the scaled thematic layers were assigned weighted values and integrated into map algebra using Inverse Distance Weighted (IDW) interpolation provided in Arc GIS 10.3 software to produce soil fertility maps of the area.

RESULTS AND DISCUSSION

Delineation of Mapping Units

The spatial (geo-referenced) data generated from the perimeter, profile pits and the surface soil samples of the farmland were input into the ArcGIS 10.3 software of Geographic Information System (GIS) application to produce the map of the project site (Fig.2). Following the transect survey method; the site was traversed at 100 m interval and soil samples investigated consequent upon changes in physiographic features (slope, elevation and drainage) observed along the traverses. These observable features formed the basis for delineating the landscape into three mapping units (IJN I – III), and representative profile pits were established in the mapping unit delineated (Figure. 2).

The community farmland, covering a total land area of 20.06 ha, was located between altitudes 100 and 115 m above sea level. Mapping unit IJN I covered 2.8 ha (14% area) of the farmland and was situated on an elevation between 111 and 115 m above sea level with gently sloping terrain (3 %). Mapping unit IJN II was also located on gently sloping terrain (4 %) but with lower elevations (105 - 109 m above sea level) and larger area-7.02 ha (35% area) than mapping unit IJN I. Contrarily, mapping unit IJN III occurred on nearly flat slope gradient (2 %) and altitudes between 99 and 103 m above sea level); and covered the largest land area-10. 24 ha (51% area).

Morphological Properties of Soils of the Study Site

The soils across the mapping units were generally deep (> 100 cm), moderately drained and non-concretionary (Table 2). Matrix colour notation ranged from brown (10YR 3/3) surface overlying shades of brownish colour endopedons such as yellowish brown (10YR 5/4), strong brown and brownish yellow (10 YR 6/6). Due to organic matter darkening, A- and B-horizon

boundaries were visible. All the profiles displayed weak to moderate crumb structure over moderate, strong sub-angular structured subsurface horizons. The weak and crumb-structured absence of cracks on the surfaces of the units probably inferred that the soils have non-expanding clay minerals, e.g. kaolinite, in them (Alhassan *et al*., 2012). The moist consistency of the surface soil remained friable, whereas the sub-surface soils exhibited firm and slightly sticky/slightly plastic consistency under moist and wet conditions, respectively. However, in mapping unit IJN, I had a sticky and plastic consistency (wet). This may result from higher clay fractions in this unit than other mapping units. The friable surface consistency (moisture) observed across all land use types, as reported by Ogban and Ibia (2006), will enhance tillage operation and the easy penetration of plant roots. The mottle-free condition of mapping units IJN II and III, contrary to mapping unit IJN I, may be attributed to sesquioxides (Adesemuyi *et al*., 2021). By distinctness-topography, all the profiles had clear-smooth, clear-wavy and gradual-wavy horizon borders.

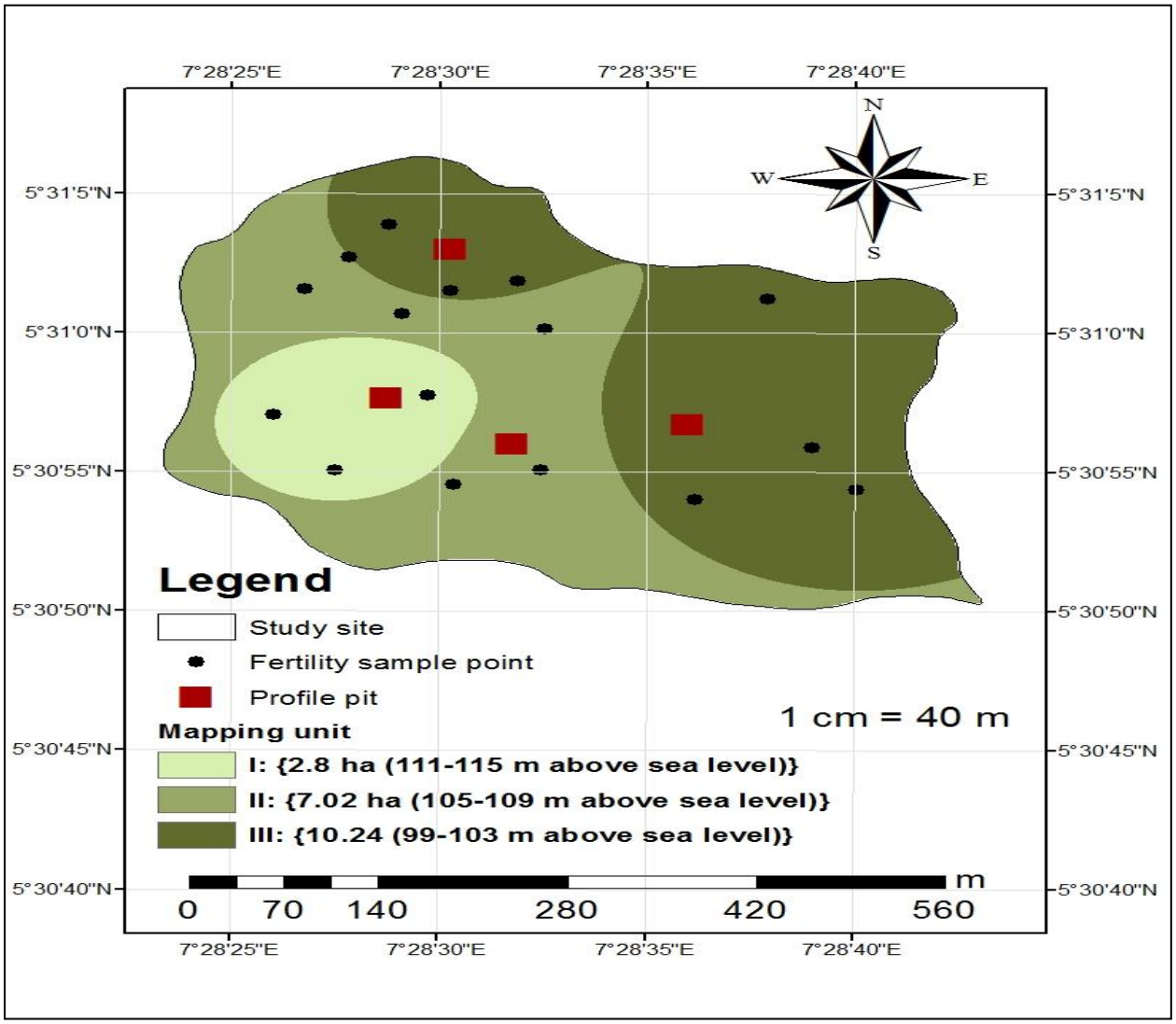

Figure 2: Map of the Study Site Showing Delineated Mapping Units

Physical Properties of Soil of the Study Site

Sand, silt, and clay particle sizes varied from 17 to 77 %, 7.5 to 18 %, and 12 to 66 % across the mapping units. As a result, soil texture ranged from sandy clay loam overlying clay in IJN I, while sandy loam was underlain by sandy clay loam in IJN II and III (Table 3).

Sand fractions varied significantly (CV>35) with depth in mapping unit UIN I, whereas units II and III did not show significant variation (CV<15) with depth. However, clay fractions varied significantly (CV>35) with depth across the mapping units. The clay enrichment in the endopedon is a characteristic of an argillic horizon. This marked eluviation-illuviation process selectively removes clay from the surface layer because sand is less transportable than .finer soil fractions (clay). The average silt/clay ratio was 0.36, 0.48 and 0.55, respectively, for UIN-1, UIN-2 and UIN-3. The silt/clay ratio is above 0.25, indicating that the soils are relatively young, probably indicating that these soils still have weatherable minerals (Lawal *et al*., 2013). The Ap-horizons of mapping units UIN-1, II and III have surface bulk densities of 1.40, 1.29 and 1.48 g·cm - 3respectively (Table 2). These are acceptable values (1.0 - 1.6 mgm-3) for agronomic activities in most mineral soils (Chude *et al.*, 2011; Chaudhari *et al*., 2013). Lower bulk density was generally recorded in the topsoil. This may be adduced to the influence of organic matter on soil bulk density, causing less soil compaction, and its increase down the pedal depth could be attributed to a decrease in organic matter (Oguike and Mbagwu, 2009; Sakin *et al.*, 2011). The total porosity ranged from 40.75 - 51.32 % and decreased with profile depth. Pravin *et al.* (2013) reported that over 50 % of total porosity is ideal for soils; between 45 – 50 % is satisfactory, 40 - 45 unsatisfactory, and 40 % and below are poor.

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Chemical Properties of Soils of the Study Site

The pH (water) ranged from 5.61-5.91 (surface) to 4.66-5.41 (subsurface), indicative of very moderately to strongly acid conditions (Table 4). The pH varied minimally (CV <15 %) across the mapping units. The acidic nature of the sub-surface soils of the site may be attributed to the nature of the parent material (Nnaji *et al*., 2002). Surface organic carbon was relatively high (1.52 – 1.81 %) across the mapping units, with significant variation down the depth. The higher organic carbon observed on the surface compared to the subsurface horizons may be attributed to higher litter falls on the surface horizons, which are the points where the decomposition of organic materials takes place (Akinrinde and Obigbesan, 2000).

Table 2: Morphological properties of soil of the study site

Horizon	Depth (cm)	Colour (moist)	Mottles	Drainage	Slope (%)	Structure	Consistence		Concretion	Pores	Roots	Boundary
							Moist	Wet				
Mapping unit I (Pedon 2): 5.51601˚N; 7.47466˚E; 115 m above sea level												
Ap	0-10	7.5YR4/2(db)	Absent	Moderate	3	m/crumb	friable	ss/np	Absent	m/fw	c/fw	cs
Bt	10-35	7.5YR 5/4(b)	Absent			m/sbk	firm	s/sp	Absent	f/cm	f/cm	cw
Btc	35-95	7.5YR5/8 (sb)	10YR7/8(ry)			s/sbk	v/firm	s/p	Absent	f/m	f/fw	cs
BtC	95-125	5YR 6/8 (ry)	10R5/4(wr)			s/sbk	v/firm	s/p	Few	f/m	vf/fw	-
Mapping unit II (Pedon 3): 5.51555˚N; 7.4755˚E; 111 m above sea level												
Ap	0–25	10YR 3/3(db)	Absent	Good	4	w/crumb	Friable	ns/np	Absent	m/fw	c/fw	cs
Bt1	25–66	10YR5/3 (b)	Absent			m/crumb	Friable	ns/np	Absent	f/cm	f/cm	cs
Bt2	66–108	10YR4/4 (dyb)	Absent			m/sbk	Firm	ss/sp	Absent	f/m	f/fw	cs
BtC	108–195	10YR5/8 (yb)	Absent			m/sbk	Firm	Ss/sp	Absent	f/m	vf/fw	-
Mapping unit III (Pedon 1): 5.5175˚N; 7.47508˚E; 103 m above sea level												
Ap	0–20	10YR3/3 (db)	Absent	Moderate	2	m/crumb	friable	ns/np	Absent	m/cm	f/cm	cs
Bt1	20–48	10YR 4/4 (dyb)	Absent			w/sbk	firm	ns/np	Absent	f/cm	f/fw	cs
Bt2	48–76	10YR5/3 (b)	Absent			m/sbk	firm	ss/np	Absent	f/m	f/vfw	cs
Bt3	76–129	10YR 5/4 (yb)	Absent			m/sbk	firm	ss/sp	Absent	f/m	-	-
BtC	129-177	10YR 5/6 (yb)	Absent			s/sbk	firm					
Pedon 4: 5.51575˚N; 7.47667˚E; 100 m above sea level												
Ap	0-18	10YR3/3 (db)	Absent	Moderate	2	m/crumb	friable	ns/np	Absent	c/m	m/cm	cs
Bt1	18-45	10YR 5/4 (yb)	Absent			w/sbk	firm	ns/np	Absent	c/m	f/cm	cs
Bt2	45-110	10YR 6/6 (by)	Absent			m/sbk	firm	ss/np	Absent	f/cm	f/fw	cs
BtC	110-173	10YR 5/8 (yb)	Absent			m/sbk	firm	ss/np	Absent	f/fw	f/fw	-

Key: Colour: vdb=very dark brown, b= brown, pb=pale brown, reddish yellow, db=dark brown, rb=reddish brown, sb=strong brown

Structure: s=strong, w=weak, m=moderate, sbk=sub-angular blocky; **Consistence (wet):** ns/np-non sticky/non plastic, ss/np=slightly sticky/non plastic, s/sp=sticky/slightly plastic; **Pores/Roots:** /fw=coarse/few, f/cm=fine/common, f/m=fine/many, m/cm=moderate/common, f/cm=fine/common, f/m=fine/many, c/m=coarse/many, f/fw=fine/few, vf/fw=very fine/few, f/vfw=fine/very few;

Boundary: cs=clear and smooth, gw-gradual and wavy

Table 3: Physical Properties of the Soils in the Study Site

Mapping Unit	Pedon	Horizon designation	Depth (cm)	Sand	Silt %	Clay	Textural Class	Bulk Density mg/m^3	Total Porosity %	K-Sat cm^3/hr	Silt/clay
IJN I	**2**	Ap	0-10	53.20	18.40	28.40	Sandy	1.40	47.20	6.81	0.65
		Bt	10 - 35	49.30	12.50	38.20	Sandy	1.53	42.26	2.54	0.33
		Btc	35-95	37.60	10.20	52.20	Clay	1.57	40.75	1.22	0.20
		BtC	95-125	17.30	16.40	66.30	Clay	1.51	43.02	1.23	0.25
MEAN				**39.35**	**14.38**	**46.28**		**1.50**	**43.31**	**2.95**	**0.36**
STDEV				**16.13**	**3.71**	**16.54**		**0.07**	**2.76**	**2.65**	**0.20**
CV				**40.98**	**25.79**	**35.75**		**4.84**	**6.38**	**89.73**	**56.56**
IJN II	**3**	Ap	0–25	77.50	10.20	12.30	Sandy	1.29	51.32	12.60	0.83
		Bt1	25–66	72.30	9.60	18.10	Sandy	1.50	43.40	6.72	0.53
		Bt2	66–108	65.20	7.50	27.30	Sandy	1.74	34.33	2.33	0.27
		BtC	108–195	55.70	10.10	34.20	Sandy	1.76	33.58	2.27	0.30
MEAN				**67.68**	**9.35**	**22.98**		**1.57**	**40.66**	**5.98**	**0.48**
STDEV				**9.44**	**1.26**	**9.70**		**0.22**	**8.39**	**4.88**	**0.26**
CV				**13.95**	**13.49**	**42.23**		**14.14**	**20.64**	**81.61**	**53.71**
IJN III	**1**	Ap	0–20	69.30	12.10	18.60	Sandy	1.39	47.60	9.26	0.65
		Bt1	22–48	61.20	15.30	23.50	Sandy	1.48	44.20	5.34	0.65
		Bt2	48–76	57.60	14.20	28.20	Sandy	1.48	44.20	3.43	0.50
		Bt3	76–129	55.20	10.70	34.10	Sandy	1.50	43.40	2.14	0.31
		BtC	129-177	53.30	8.30	38.40	Sandy	1.75	33.96	2.12	0.22
MEAN				**60.83**	**13.08**	**26.10**		**1.46**	**44.85**	**5.04**	**0.53**
STDEV				**6.31**	**2.79**	**7.94**		**0.14**	**5.13**	**2.99**	**0.20**
CV				**10.38**	**21.31**	**30.44**		**9.26**	**11.44**	**59.27**	**37.16**
	4	Ap	0-18	68.20	14.30	17.50	Sandy	1.57	40.75	13.33	0.82
		Bt1	18-45	60.60	13.40	26.00	Sandy	1.72	35.09	4.52	0.52
		Bt2	45-110	56.00	12.50	31.50	Sandy	1.81	31.69	1.85	0.40
		BtC	110-173	55.20	10.50	34.30	Sandy	1.63	38.49	1.81	0.31
MEAN				**60.00**	**12.68**	**27.33**		**1.68**	**36.51**	**5.38**	**0.51**
STDEV				**5.96**	**1.63**	**7.40**		**0.11**	**3.96**	**5.45**	**0.22**
CV				**9.94**	**12.83**	**27.09**		**6.24**	**10.86**	**101.37**	**43.38**

CV = Coefficient of variation, CV < 15= low variability, CV ≥15≤35=moderate variability, CV>35= high variability

Significant variation (CV>35 %) in total nitrogen was also observed, from low (0.13-0.14 %) in mapping units II and III but relatively high (0.18) in unit I. Available P was moderate (>7.00 mg kg-1) and varied moderately with depth across the mapping units. Exchangeable bases (Ca2+ Na+ and K+) were generally low except for exchangeable Mg, which was moderate in all the mapping units. Base saturation provides an indication of how closely nutrient status approaches potential fertility in the soil. Clays have higher base saturation and higher surface area and are more physically and chemically active than sands (Hazelton and Murphy, 2015). Therefore, the generally low base saturation may result from the type and low clay particle size fraction in the area (Table 4).

The general decline in fertility status of the study site might be consequent upon continual cultivation of the soils, resulting in a reduction in soil organic carbon, low exchangeable bases, low base saturation and the acidic nature of the soils. Oguike and Mbagwu (2009) posited that through continuous cultivation, the physical properties and productivity of many soils commonly decline.

Classification of Soils of the Study Site

The soils across the mapping units were classified (Soil Survey Staff, 2014) and correlated (WRB, 2014). The enrichment of clay in the subsurface horizons signifies the presence of argillic or kandic horizons established in all the mapping units because they meet the following requirements: coarser-textured surface horizons over vertically (morphologically) continuous subsurface horizons; CEC within subsurface B horizons that are less than 12 cmol(+)kg-1 clay; a regular decrease in organic carbon content with increasing depth; and all these in addition to the requirement of clay content which progressively increased with depth (Table 4.2) (Soil Survey Staff, 2014). The evidence of argillic horizons coupled with low base saturation (< 50% by NH4OAc at pH 7.0) classifies the pedons into the order Ultisols. The pedons' prevalent udic moisture regime (soil solum is not dry in any part for as long as 90 cumulative days in the normal year) classified them as Udult. The soils had low CEC, indicating low-activity clay and are therefore classified as Kandiudults in the great group with reference to Soil Survey Staff (2014). The progression in accumulation of clay in the B-horizons within 150 cm of the mineral soil surface coupled with soil colour (moist) value of 4 or more in the argillic horizons classified all the units as Haplic Kandiudults in the sub-group of the USDA soil Taxonomy (Soil Survey Staff, 2014) and as Haplic Acrisols in the World Reference Base (WRB 2014).

Table 4: Selected Chemical Properties of Soils in the Study Site

Mappin	Pedon	Horizo	Depth (cm)	pH H_2O	pH KCl	Av. P mg/kg	N %	OC %	Ca^{++}	Mg^{++} cmo/kg	K^+	Na^+	EA	CEC	BS %	Al^{3+}
IJN I	**2**	Ap	0-10	5.91	5.17	18.25	0.18	1.81	4.20	2.40	0.23	0.17	1.22	14.62	47.88	0.42
		Bt	10 35	5.24	4.65	15.83	0.10	1.09	3.42	2.10	0.15	0.13	1.36	12.98	44.68	0.46
		Btc	35-95	5.06	4.24	11.66	0.08	1.00	3.12	1.31	0.11	0.09	1.48	11.55	40.03	0.50
		BtC	95-125	5.15	4.36	11.27	0.08	0.89	2.80	1.00	0.11	0.08	1.52	12.23	32.62	0.52
MEAN				**5.34**	**4.61**	**14.25**	**0.11**	**1.20**	**3.39**	**1.70**	**0.15**	**0.12**	**1.40**	**12.85**	**41.30**	**0.48**
STDEV				**0.39**	**0.41**	**3.37**	**0.05**	**0.42**	**0.60**	**0.66**	**0.06**	**0.04**	**0.14**	**1.32**	**6.63**	**0.04**
CV				**7.25**	**8.99**	**23.65**	**43.28**	**34.78**	**17.71**	**38.55**	**37.71**	**35.00**	**9.68**	**10.27**	**16.04**	**9.34**
IJN II	**3**	Ap	0–25	5.64	4.96	16.62	0.13	1.47	3.14	1.81	0.15	0.15	1.42	9.65	54.40	0.48
		Bt1	25–66	5.48	4.76	13.84	0.07	0.79	2.86	1.62	0.13	0.13	1.54	9.88	47.98	0.52
		Bt2	66–108	5.37	4.61	10.23	0.07	0.77	2.05	0.82	0.10	0.08	1.54	8.45	36.09	0.54
		BtC	108–195	4.96	4.21	10.04	0.07	0.63	1.19	0.75	0.10	0.08	1.52	7.94	26.70	0.54
MEAN				**5.36**	**4.64**	**12.68**	**0.09**	**0.92**	**2.31**	**1.25**	**0.12**	**0.11**	**1.51**	**8.98**	**41.29**	**0.52**
STDEV				**0.29**	**0.32**	**3.15**	**0.03**	**0.38**	**0.88**	**0.54**	**0.02**	**0.04**	**0.06**	**0.93**	**12.34**	**0.03**
CV				**5.41**	**6.85**	**24.87**	**35.29**	**41.18**	**38.01**	**43.46**	**20.41**	**32.35**	**3.82**	**10.41**	**29.87**	**5.44**
IJN III	**1**	Ap	0–20	5.61	4.88	17.24	0.13	1.40	3.29	2.21	0.16	0.14	1.28	12.51	46.36	0.44
		Bt1	22–48	5.18	4.52	15.51	0.11	1.17	2.67	2.05	0.15	0.13	1.38	11.77	42.48	0.46
		Bt2	48–76	5.06	4.22	12.81	0.10	1.17	2.61	1.22	0.14	0.12	1.42	11.98	34.14	0.48
		Bt3	76–129	4.87	4.12	12.24	0.08	0.92	1.50	0.81	0.11	0.09	1.58	9.33	26.90	0.54
		BtC	129-177	4.81	4.10	12.32	0.08	0.84	1.48	0.65	0.10	0.09	1.56	9.81	23.65	0.42
MEAN				**5.11**	**4.37**	**14.02**	**0.10**	**1.10**	**2.31**	**1.39**	**0.13**	**0.11**	**1.44**	**11.08**	**34.71**	**0.47**
STDEV				**0.32**	**0.33**	**2.24**	**0.02**	**0.22**	**0.79**	**0.71**	**0.03**	**0.02**	**0.13**	**1.41**	**9.74**	**0.05**
CV				**6.23**	**7.60**	**15.99**	**21.21**	**20.32**	**34.39**	**51.21**	**19.61**	**20.19**	**8.73**	**12.77**	**28.07**	**9.84**
	4	Ap	0-18	5.58	4.82	15.08	0.15	1.55	3.08	2.03	0.18	0.15	1.36	11.17	48.70	0.46
		Bt1	18-45	5.30	4.60	14.11	0.10	1.02	2.67	1.42	0.14	0.13	1.46	10.26	42.50	0.48
		Bt2	45-110	5.06	4.25	10.43	0.07	0.81	2.11	1.09	0.11	0.10	1.54	10.67	31.96	0.52
		BtC	110-173	4.66	4.02	9.81	0.06	0.80	2.05	1.01	0.12	0.10	1.56	9.34	35.12	0.52
MEAN				**5.15**	**4.42**	**12.36**	**0.10**	**1.05**	**2.48**	**1.39**	**0.14**	**0.12**	**1.48**	**10.36**	**39.57**	**0.50**
STDEV				**0.39**	**0.36**	**2.63**	**0.04**	**0.35**	**0.49**	**0.46**	**0.03**	**0.02**	**0.09**	**0.78**	**7.52**	**0.03**
CV				**7.57**	**8.06**	**21.25**	**42.54**	**33.65**	**19.74**	**33.42**	**22.51**	**20.41**	**6.14**	**7.48**	**19.00**	**6.06**

CV = Coefficient of variation, CV < 15= low variability, CV ≥15≤35=moderate variability, CV>35= high variability.

Soil Fertility Status of the Site for Crop Production

The soil acidity of the study site ranged between strong (5.26-5.47) and moderate (5.53-5.93) (Table 5). The pH varied minimally (CV <15 %) across the mapping units. The acidic nature of the sub-surface soils of the site is consequent upon the nature of the parent material (Nnaji *et al*., 2002). About 40 %, covering 8.02 ha of the site, was under strongly acidic conditions, while the remaining 60 % (12.04) was moderately acidic (Figure 3). The slight increase in pH values in some portions of the site may be consequent upon higher vegetal cover, resulting in the release of exchangeable bases from decomposed litters and roots (Alemayeha and Sheleme, 2013).

Total nitrogen values (Figure 4) were low (< 0.15 %), covering about 16.06 ha (80 %) of the study site, while 4.0 ha (20 %) was moderate (0.15 – 0.25). The larger portion of the study site (16.06 ha) under the influence of nitrogen deficits may be attributed to volatilization, especially under high-temperature regimes and denitrification processes. Organic carbon contents (Figure 5) were moderate (1.0-1.5 %) in about 16.00 ha (80 %) across the study site, whereas the remaining 4.06 ha (20 %) was relatively high (1.5 – 1.81 %). The few portions of the site that recorded organic carbon slightly above the critical values were attributed to the fact that the study site was still under fallow. However, there is a high rate of decomposition and mineralization of organic matter, which is consequent upon the prevalent high temperature and poor soil management, sometimes by burning crop residues, intense cultivation, and seasonal bush burning, a common practice in the area. Therefore, there is a need for the farmers in the area to adopt cultural practices such as minimum tillage operation, mulching, organic manuring, etc, that will encourage the return and incorporation of plant/crop residues into the soil to increase the level of soil organic matter.

The exchangeable bases (Ca2+, Na+, and K+) were generally low across the site except for exchangeable Mg2+(Table 5). The low values of exchangeable bases in the study area may be connected to the soils' low CEC values; available P in the soils was moderate (15.10 – 18.40 mg/kg). Base saturation, which provides an indication of how closely nutrient status approaches potential fertility in the soil, was generally low across the site. This may be a result of the area's type and low clay particle size fraction, indicating potential challenges in soil fertility.

CONCLUSION AND RECOMMENDATIONS

The study inventoried the soils of Okporuzor community farmland in Umuahia North LGA of Abia State and assessed the fertility mapping of the soil for site-specific soil management. The findings, which revealed variations in soil properties studied, such as soil texture, organic carbon and exchangeable bases across the study site, are crucial for understanding and improving the soil conditions. The soil was classified as Haplic Kandiudults (USDA) and Haplic Acrisols (WRB). Topsoil fertility mapping showed strong acidity covering about 60% of the land area, moderate organic carbon (80% of the area) and low total N (80% of the area). The site was also low in exchangeable Ca (100% area) and K (100% area) but medium in Mg (100% area) and available Phosphorous (100% area).

Despite the challenges posed by the highly acidic soils, their low nutrient content, and high sand fractions, there is hope for improvement. By implementing specific soil management practices such as liming, the incorporation of organic residues, and the efficient use of fertilizers, the soil conditions can be significantly enhanced. The findings highlight the potential benefits of having local-scale-specific soil information, which can assist in the site-specific application of soil nutrients and amendments based on spatial variability tailored to the soil requiremen

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Table 5: Fertility Status of the Soils of the Study Site

Sample	Sand	Silt	Clay	T/C	pH	Av. P	TN	OC	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	EA	CEC	BS	Al^{3+}
			%		H_2O	mg/kg	%	%		cmol/kg					%	
1	71.20	13.40	15.40	SL	5.32	15.60	0.15	1.62	4.20	1.82	0.15	0.15	1.34	13.41	46.98	0.46
2	73.20	12.40	14.40	SL	5.69	15.10	0.14	1.40	3.62	1.84	0.15	0.15	1.36	12.31	46.79	0.46
3	72.20	11.40	14.40	SL	5.41	15.40	0.13	1.58	3.71	1.91	0.16	0.16	1.38	9.97	59.58	0.47
4	71.20	11.40	17.40	SL	5.46	15.10	0.16	1.55	4.02	1.85	0.15	0.15	1.42	11.37	54.27	0.44
5	55.20	20.40	24.40	SCL	5.82	18.00	0.14	1.40	2.95	2.13	0.22	0.17	1.26	13.01	42.04	0.42
6	66.20	17.40	16.40	SL	5.56	18.30	0.14	1.51	3.73	2.04	0.21	0.17	1.26	13.54	45.42	0.42
7	62.20	16.40	21.40	SCL	5.67	17.80	0.16	1.58	4.15	1.73	0.16	0.14	1.40	11.72	52.73	0.44
8	59.20	17.40	23.40	SCL	5.55	17.20	0.14	1.38	3.48	1.65	0.15	0.15	1.34	10.51	51.67	0.42
9	75.20	13.40	11.40	SL	5.65	17.50	0.13	1.36	4.00	1.72	0.17	0.15	1.32	12.05	50.12	0.44
10	72.20	14.40	13.40	SL	5.93	18.40	0.17	1.81	3.81	1.63	0.16	0.15	1.26	12.33	46.63	0.42
11	73.20	12.30	14.40	SL	5.62	16.70	0.16	1.51	4.23	1.71	0.15	0.16	1.42	10.87	57.50	0.43
12	74.20	13.40	12.40	SL	5.53	17.10	0.13	1.46	3.19	1.85	0.15	0.15	1.34	12.32	43.34	0.45
13	53.20	12.40	34.40	SCL	5.26	16.70	0.11	1.13	3.62	1.76	0.18	0.16	1.40	13.31	42.98	0.48
14	61.20	16.40	22.40	SCL	5.47	17.60	0.14	1.47	3.70	2.04	0.17	0.16	1.38	13.76	44.11	0.46
15	55.20	12.40	32.40	SCL	5.44	17.10	0.13	1.38	3.54	1.81	0.15	0.15	0.36	12.22	46.24	0.46
16	58.20	15.40	26.40	SCL	5.37	16.20	0.14	1.40	3.72	2.15	0.22	0.17	1.26	11.65	53.73	0.43
MEAN	**65.83**	**14.39**	**19.65**		**5.55**	**16.86**	**0.14**	**1.47**	**3.73**	**1.85**	**0.17**	**0.16**	**1.28**	**12.15**	**49.01**	**0.44**
STDEV	**7.86**	**2.59**	**7.07**		**0.18**	**1.10**	**0.02**	**0.15**	**0.35**	**0.16**	**0.03**	**0.01**	**0.25**	**1.11**	**5.37**	**0.02**
CV	**11.95**	**17.97**	**35.96**		**3.23**	**6.54**	**11.94**	**10.09**	**9.38**	**8.75**	**15.13**	**5.73**	**19.69**	**9.12**	**10.95**	**4.42**

Key: T/C = Textural class; OC = Organic carbon; TN = Total nitrogen; Av. P = Available phosphorus; EA = Exchangeable acidity; CEC = cation exchange capacity; BS = Base saturation.

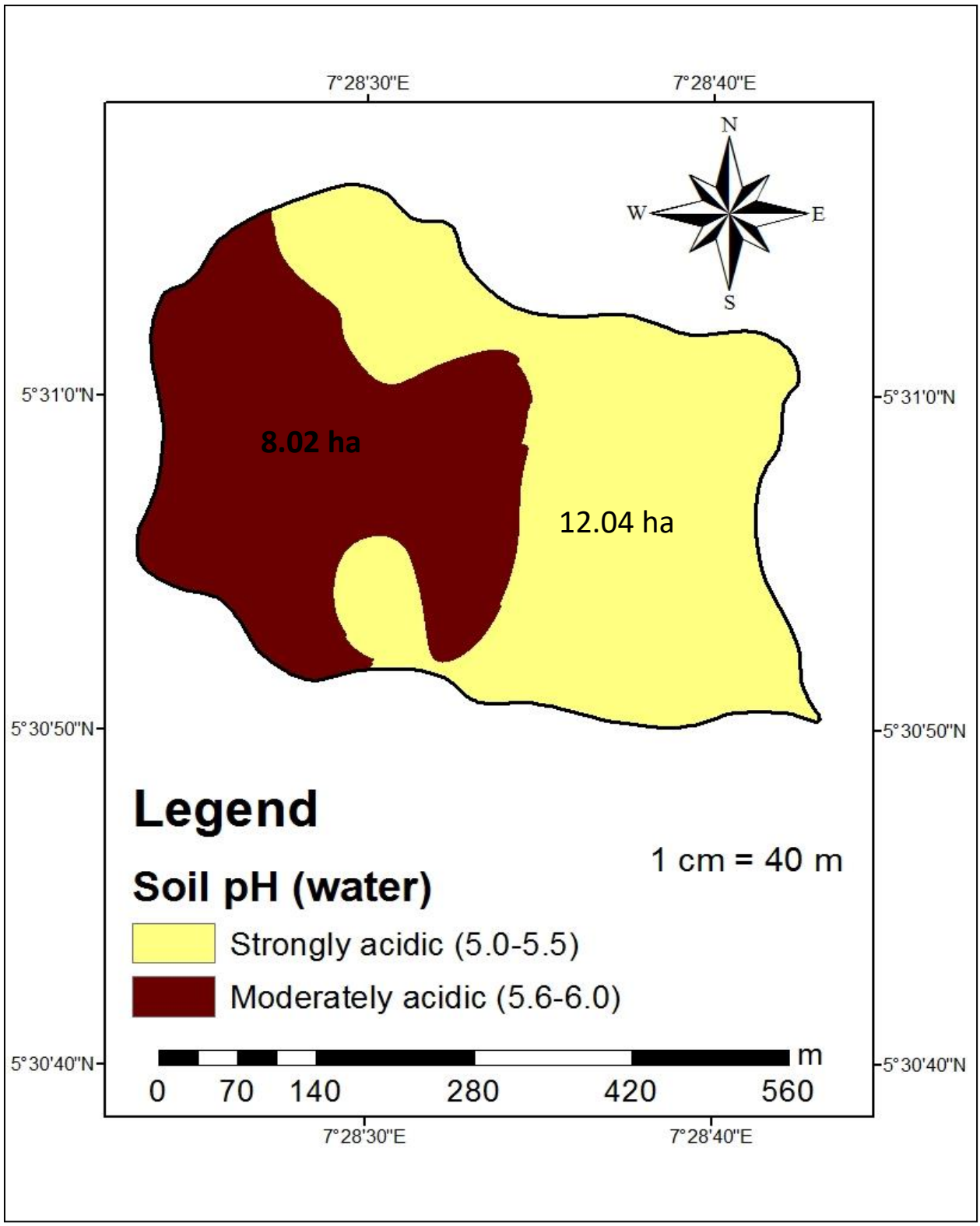

Figure 3: Spatial distribution of pH in the soils of the study site

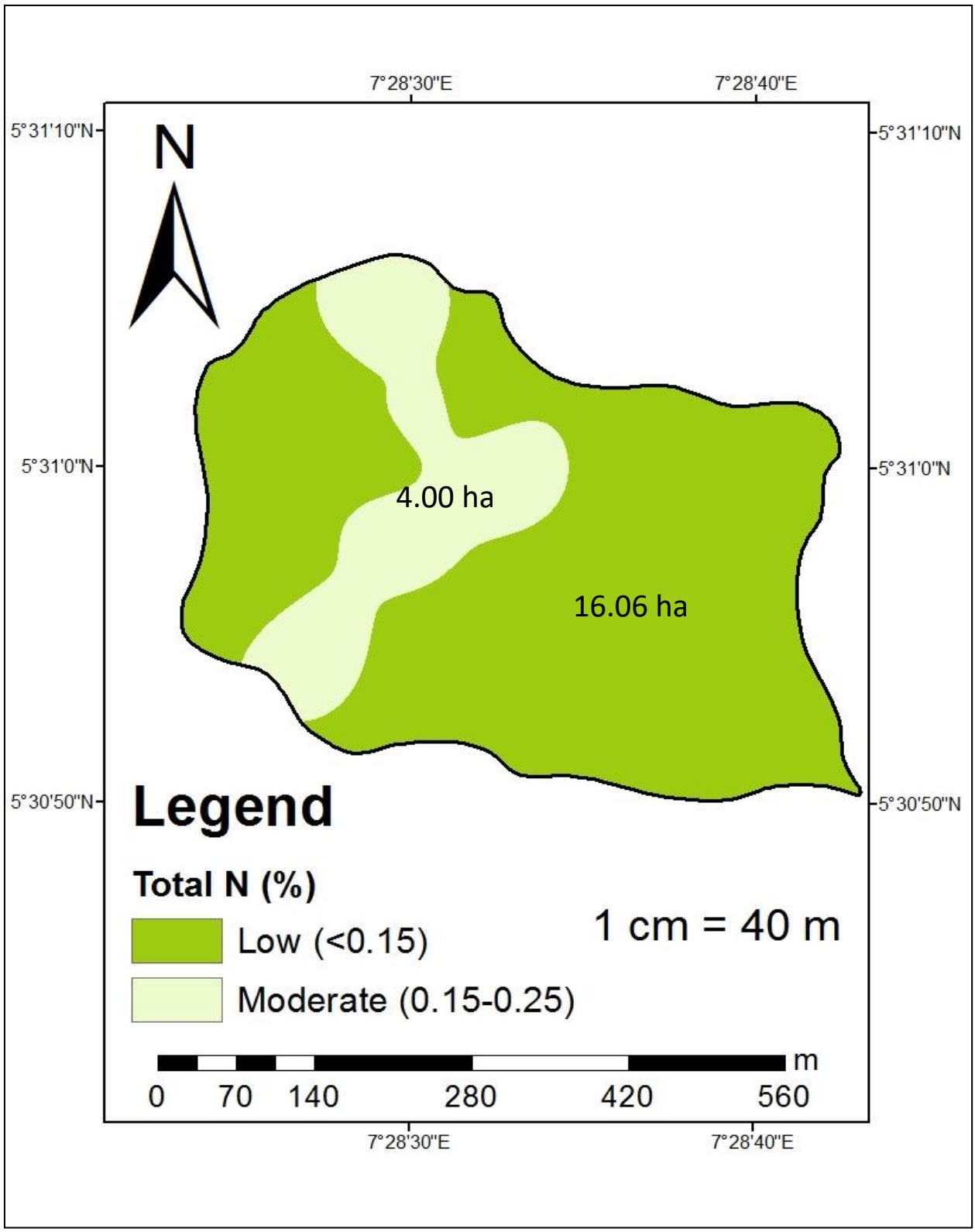

Figure 4: Spatial distribution of total nitrogen in the soils of the study site

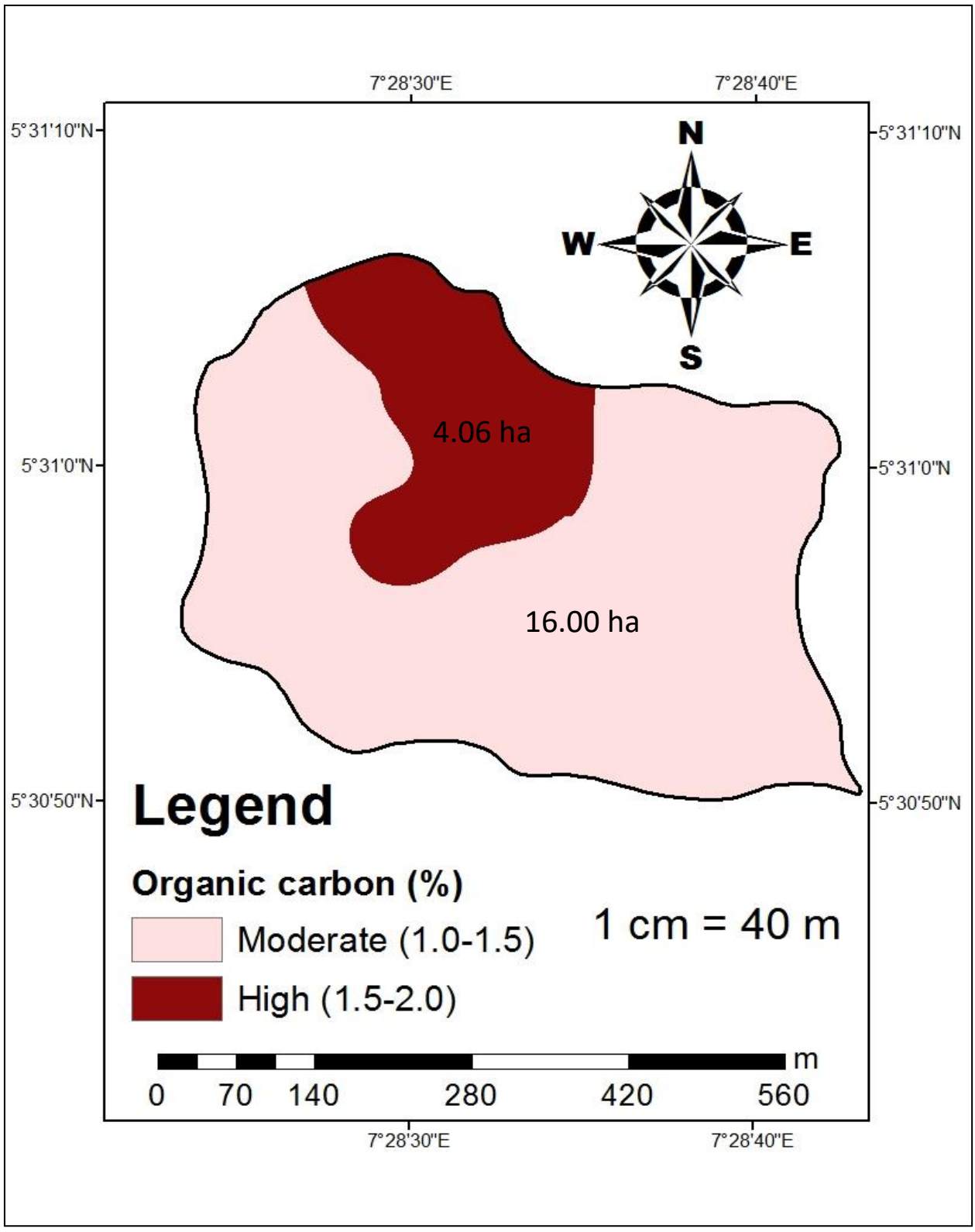

Figure 5: Organic carbon distribution in the soils of the study site

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ISOLATION, SCREENING AND CHARACTERIZATION OF BIOSURFACTANTS-PRODUCING BACTERIA FROM PETROLEUM PRODUCTS-IMPACTED SOIL

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ABSTRACT

Microbial surfactants are a diverse and heterogeneous microbial metabolites synthesized by bacteria, yeasts, and fungi. They are equally biodegradable and resilient to pH, temperature, and ionic quality. This study was carried out to isolate, characterize and screen bacterial isolates for abilities to produce biosurfactants. Soil samples were collected in 2018 from refined petroleum products contaminated soil in Ladipo Market, Lagos, Nigeria and transported to the Biotechnology Laboratory, Federal Institute of Industrial Research, Oshodi, Lagos state –Nigeria. The total petroleum hydrocarbon utilizing bacteria was determined, and pure cultures were subjected to biosurfactant screening assays like haemolytic indices assay, blue plate assay, lipase assay, and emulsification index (E24) assay. The hyper-producers of biosurfactants were further identified using biochemical tests. The heterotrophic bacterial counts and total hydrocarbon utilizing bacteria in the crude oil-contaminated soil were between the ranges of 1.46×105-1.0×108 and 1.8×104-5.2×106cfu/g of the soil. The emulsification index of the hydrocarbon utilizing isolates. Emulsification activity carried out showed that while the supernatants obtained from isolates B(Bacillus spp), C(Bacillus spp) D(Proteus spp), E(Corynebacterium spp), J (Bacillus spp), K(Micrococcus spp), L(Serratia spp), S315(Staphylococcus spp) showed no emulsification

activity, supernatants obtained from isolates E301(Bacillus spp), SS206(Klebsiella spp), I(Acinetobacter spp), G(Acinetobacter spp) and H(Pseudomonas spp) were able to emulsify crude oil to some extent with the values of 60.6%, 60.8%, 58.5%, 44.65% and 58.5% respectively. Out of the total 22 bacterial isolates, 13(59%) showed the presence of anionic surfactants, while 9(44%) showed the presence of cationic surfactants. Isolates H (Pseudomonas spp), SS327 (Burkholderia ambifera), G (Acinetobacter spp), I(Acinetobacter spp)SS206(Klebsiella spp) which are hyper-producers of biosurfactants were biochemically identified as Pseudomonas species, Burkholderia species, Acinetobacter species, Acinetobacter species, and Klebsiella species. There is a need to intensify research attention on the area of biosurfactants to sustain local industries and save foreign reserves through local production.

Key words: Biosurfactants, bacteria, emulsification, sustainable Development

INTRODUCTION

Surface-active compounds of biological origin, mostly microorganisms, have attracted much attention, and their popularity has steadily increased recently. This may be due to new or innovative processes in industrialization and the quest for continuous improvement in sustainability (Ibukun and Thring, 2018). The wide range of benefits of biosurfactants compared to their synthetic counterparts (chemical surfactants) are reasons for increasing research in this area. These include the ability to thrive and function within a wide range of temperatures, pH, and environmental degradability. They are environmentally friendly with confirmed abilities for removing petroleum hydrocarbon contaminants from drill cuttings and hydrocarbon-contaminated waste streams (Souza *et al*., 2014). In addition, they are highly favourable because of their high biodegradability, high specificity, high stability and activity at extremely low environmental impact, low toxicity, a wide range of industrial applications, and structural diversity (Luna *et al.,* 2015). This reassures us about their potential to be a sustainable and environmentally friendly alternative to chemical surfactants. Microbial surfactants, a diverse and heterogeneous group of microbial metabolites, are synthesized by a variety of microorganisms, including bacteria, yeasts, and fungi. They share a chemical relationship with compounds such as rhamnolipids and surfactin (Brumano *et al.,* 2016; Varjani *et al.,* 2017), contributing to their diverse nature.

They are classified into various groups based on chemical structure: lipoproteins, glycolipids, phospholipids, lipopeptides, fatty acids, neutral acids, etc (Mulligan, 2005). Microbial surfactants have been applied on both a laboratory scale and pilot scale for numerous biotechnological and industrial applications (Satpute, 2010). Surfactants are broadly utilized for mechanical, farming, nourishment, beauty care products and pharmaceutical applications. However, the vast majority of these mixes are orchestrated artificially and possibly cause ecological and toxicology issues due to these substances' refractory and determined nature (Ron and Rosenbery, 2002; Ibukun and Thring, 2018). The properties of biosurfactants viz-a-viz their chemically synthesized counterparts and broad substrate availability made them suitable for commercial applications. Microbial surfactants exhibit surface movement, resilience to pH, temperature and ionic quality, and biodegradability (Desai and Banat, 1997). This investigation aims to isolate, screen and characterize biosurfactants-producing bacteria from petroleum hydrocarbon-contaminated soil

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MATERIALS AND METHODS

Collection of Samples

Oil-contaminated soil samples from mechanic workshops were collected at Mechanic Workshops in Ladipo market, near Oshodi, and transported to the laboratory for analysis.

The Enumeration of Hydrocarbon Utilizing Bacteria (HUB)

This was done by using the mineral salt Agar/ vapour phase method, as described by Amanchukwu *et al.* (1989). The Mineral salt agar contained (g/l) 15 g $NaNO_3$, 1.1 g KCl, 1.1 g NaCl, 0.00028 g $FeSO_4.7H_2O$, 3.4g KH_2PO_4, 4.4 g K_2HPO_4, 0.5g $MgSO_4.7H_2O$, 15g Agat Technical. The Petri dish lid was loaded with filter paper (Whatman no 1) impregnated with bonny light crude oil. The incubation was done at 37°C for 5 days. Subculture was done using nutrient agar to obtain discrete colonies.

Screening for Biosurfactant Producing Bacteria

The isolated colonies were tested for their biosurfactant production using four methods.

Blood Haemolysis Test

Each isolate was streaked on blood agar medium and incubated at 37°C for 24 - 48 hours to assay for haemolytic activity. The plates were visually inspected for zones of clearing around the colonies, indicative of biosurfactant production (Mulligan, 2005)

Emulsification Stability Test

This was done by homogenizing an equal volume of kerosine and cell-free supernatant by vortexing at 1000rpm for 2 minutes, after which the mixture was allowed to stand for 24 hours before calculating the emulsification index using the formula stated in Equation 1 (Cooper *et al*., 2002). The emulsification index at 24 hours was calculated by

;

$$\%E24 = \frac{\text{Height of emulsified layer}}{\text{Height of liquid layer}} x100 \ldots\ldots \text{Equation 1.}$$

Blue Plate Assay Method

The Cetyltrimethylammonium bromide (CTAB) agar plate method is a semi-quantitative assay for detecting extracellular glycolipids or other anionic surfactants. Siegmund and Wagner developed it. Blue agar plates containing cetyltrimethylammonium bromide (CTAB) (0.2 mg ml-1) and methylene blue (5 mg ml-1) were used to detect extracellular glycolipid production. Biosurfactants were observed by the formation of dark blue halos around the colonies (Satpute *et al.,* 2010).

Lipase Screening Method

The hydrolytic activity of each of the bacterial isolates was done on a lipase screening medium (Trybutyrin agar) with the following composition: 20 (g/L): peptone, 10; NaCl, 5; CaCl2.2H2O, 0.1; Trybutyrin, 10 mL (v/v). The agar was freshly prepared, and pure cultures were spot-inoculated in the central position of the Petri dish. After incubation, the clearance zones were carefully examined and measured with a ruler in millimetres (mm). (Okoli *et al.*,2019).

Biochemical Characterization of the Isolates

Biochemical tests were carried out on isolates capable of producing biosurfactants. These included a catalase test, a urease test, nitrate reduction, hydrogen sulphide production, casein, and gelatin liquefaction.

RESULTS AND DISCUSSION

The heterotrophic bacterial counts and total hydrocarbon utilizing bacteria in the hydrocarbon-contaminated soil ranged between 1.46×105-1.0×108and 1.8×104-5.2x×106cfu/g respectively. Statistics showed a significant difference in the population size of hydrocarbon-utilizing bacteria

compared to the heterotrophic bacterial population. The high heterotrophic bacterial population reflects an environment with relatively abundant nutrients/carbon sources besides petroleum hydrocarbon. In addition, the relatively high population of hydrocarbon-utilizing bacteria reflects an environment in which the bacterial communities are adapted to survive through the metabolism of crude oil.

In a similar report in Niger Delta soil polluted by crude oil, Ibiene *et al* (2011) reported that soils of Mogho and Aluu (Port Harcourt, Nigeria) had total heterotrophic bacteria counts between 6.56×x103 and 1.94×107cfu/g, while the hydrocarbon utilizing bacteria counts in Mogho and Aluu soils were in the range of 3.11×103-2.56×104cFu/g. Chikere and Ekuuabu (2014), in a culture-dependent approach, reported similarly that crude oil-polluted sites in the Bodo community in Gokana LGA of Rivers State-Nigeria, had a very low population of hydrocarbon utilizing bacteria [0.1-8.0×106] and heterotrophic bacterial counts (0.1x107-0.2×108cfu/g) Uba *et al.* (2019) observed in a diesel oil contaminated soil that the total heterotrophic bacterial counts were within the range of 8.3-8.9×105cgu/g while the hydrocarbon utilizing bacterial counts still at the range of 8.65-9.2(Log10).

The identities of the hydrocarbon-utilizing bacteria and the biosurfactant producers are reported in Table 2. These include *Pseudomonas, Bacillus, proteus, Corynebacterium, Acinetobacter, Micrococcus, Klebsiella, Staphylococcus,* and *Burkholderia* spp (Table 2). Edlund and Jansson (2006) found that members of the class Gammaproteobacteria *(Pseudomonas* spp. inclusive) and *Flavobacterium* spp. were the most dominant bacteria in a highly PAH-- and polychlorinated biphenyl-polluted sediment before and after dredging. Said *et al.* (2008) isolated *Bacillus, Staphylococcus, Pseudomonas and Acinetobacter spp.* capable of degrading PAHs from a polluted sediment. The works of Margesin *et al.* (2003) and Quatrini *et al.* (2008) demonstrated that Actinobacteria play an important role during petroleum hydrocarbon degradation. Adebusoye *et al.* (2008) had previously repeated the biosurfactant potential of some wild strains of C*orynebacterium* spp DDVI, *Flavobacterium*sp, *Micrococcus roseus* DDV3, *Pseudomonas aeruginosa* DDV4.

Table 1: Counts of Total Heterotrophic Bacteria (THB) and Total Hydrocarbon Utilizing Bacteria (THUB) in Hydrocarbon Contaminated Soil

BACTERIA	Cfu/g
THB	$1.46\pm1.53\times10^{5}$
THB	$1.01\pm0.06\times10^{8}$
THB	$7.4\pm0.72\times10^{8}$
THUB	$1.8\pm0.25\times10^{4}$
THUB	$8.5\pm0.47\times10^{5}$
THUB	$5.2\pm0.66\times10^{6}$

Values are Mean ±SEM of duplicate determinations. Values with different alphabets along a row are significantly different at $p<0.05$

Table 2: The Morphology and Selected Biochemical Characteristics of Bacterial Isolates

ISOLATE CODE	COLONIAL APPEARANCE	GRAM STAIN AND MORPHOLOGY	CATALASE TEST	OXIDASE TEST	UREASE TEST	H_2S PRODUCTION	CASEIN HYDROLYSES	GELATIN HYDROLYSIS	PRESUMPTIVE IDENTITY
A	Yellow, dry, raised with serated edges. 9-10mm in diameter	Gram negative rods in cluster and in chains	Positive	+	+	+	+	+	*Pseudomonas spp*
B	Creamy yellow, wet, raised with entire edge. 3-5mm in diameter	Gram positive rods	Positive	-	+	+	+	-	*Bacillus spp*
C	Cream, wet, raised with entire edge. 3-5mm in diameter	Gram positive cocci in twos and multiples of twos	Positive	_	+	+	+	+	*Bacillus spp*
D	Swimming organism, cream with brownish pigments, entire, 3-5mm in diameter	Gram negative rods in irregular clusters	Positive	+	+	-	-	-	*Proteus species*

E	Cream, wet, raised with entire edge. 3-5mm in diameter	Gram positive rods in irregular clusters with club like ends	Positive	+	_	+	+	+	*Corynebacterium spp*
F	Swimming organism, cream with light green pigments, entire, 3-5mm in diameter	Gram NEGATIVE rods in clusters	NEGATIVE	-	+	-	-	-	*Pseudomonas spp*
G	Colonies were creamish, entire, 3-5mm in diameter	Gram negative rods in irregular clusters	-	-	+	-	+	+	*Acinetobacter spp*
H	cream with brownish pigments, entire, 3-5mm in diameter	Gram negative rods in irregular clusters	Negative	-	+	-	-	-	*Pseudomonas spp*
I	Cream, wet, raised with entire edge. 3-5mm in diameter	Gram negative rods in irregular clusters	Negative	_	+	-	+	+	*Acinetobacter spp*
J	Cream, wet, raised with entire edge. 2-3mm in diameter	Gram positive rods in irregular clusters	Positive	+	+	-	+	-	*Bacillus spp*
K	Cream, wet, raised with entire edge. 3-5mm in diameter	Gram positive rods in irregular clusters	Positive	+	+	-	-	-	*Micrococcus spp*
L	Cream, wet, raised with entire edge. 3-5mm in diameter with reddish pigmentation	Gram Negative rods in clusters	NEGATIVE	-	+	-	-	-	*Serratia species*
SS206	Cream, wet, raised with entire edge. 3-5mm in diameter and appearing	Gram negative rods in singles and in pairs	Negative	-	-	-	-	-	*Klebsiella* sp.

	sticky on the wire loop								
SS314	Cream, wet, raised with entire edge. 3-5mm in diameter	Gram positive rods in irregular clusters	Positive	-	+	+	+	-	*Bacillus species*
SS315	Cream, wet, raised with entire edge. 2-3mm in diameter	Gram positive cocci in pairs	Positive	-	-	-	+	-	*Staphylococcus species*
SS325	Moderate heart like organism, entire, colourless and raised. 10-12mm in diameter	Gram positive rods in irregular clusters	Positive	-	+	+	+	+	*Bacillus spp*
SS327	Cream, wet, raised with entire edge. 3-5mm in diameter	Gram negative rods in irregular clusters	NEGATIVE	-	+	-	+	+	*Burkholderia ambifera*
SG140	Yellow, dry, raised with serated edges. 9-10mm in diameter	Gram positive rods in irregular clusters	Positive	-	+	+	+	+	*Bacillus spp*
SG146	Swimming organism, cream with crystal violet pigments, entire, 3-5mm in diameter	Gram negative rods in irregular clusters	Positive	+	+	-	-	+	*Chromobacterium spp*
F047	Swimming organism, cream with brownish pigments, entire, 3-5mm in diameter	Gram positive rods in clusters	Positive	-	+	+	+	+	*Bacillus species*
E301		Gram positive rods in clusters	Positive	-	+	-	-	+	*Bacillus species*

The reports documented that *Corynebacterium* sp DDVI and *Pseudomonas aeruginosa* had emulsification indices of 63 % and 78 %, respectively. This is within the range of emulsification indices observed in bacterial isolates in this study. In a related study, Ndibe *et al.* (2018) observed that similar groups of bacteria (*Bacillus*/*Corynebacterium, staphylococcus auerus*) from River Rido, Kaduna State, Nigeria exhibited an emulsification index between 42 and 64 %. The emulsification index of the hydrocarbon utilizing isolates. Emulsification activity carried out revealed that while the supernatants obtained from isolates B (*Bacillus* spp), C(*Bacillus* spp), D (*Proteus*spp), E (*Corynebacterium*spp), J(*Bacillus*spp), K(*Micrococcus* spp), L(*Serratia* spp), SS315(*Staphylococcus* spp), SS325 (*Bacillus*spp), SG140 (*Bacillus* spp) and F047(*Bacillus* spp) showed no emulsification activity, supernatants obtained from isolates E301(*Bacillus* spp), SS206(*Klebsiella* spp), I(*Acinetobacter* spp), G(*Acinetobacter* spp) and H(*Pseudomonas*spp) were able to emulsify crude oil to some extent with the values of 60.6 %, 60.8 %, 58.5 %, 44.65 % and 58.5 % respectively. Emulsification assay is an indirect method used to screen biosurfactant production. This assumption is that if the cell-free culture broth used in this assay contains biosurfactant, it will emulsify the hydrocarbons in the test solution. Emulsification assay is an indirect method used to screen biosurfactant production. This assumption is that if the cell-free culture broth used in this assay contains biosurfactant, it will emulsify the hydrocarbons in the test solution. Bonilla *et al*. (2005) showed that emulsifying activities (E24) determine the productivity of biosurfactants, and those are given as a percentage of the height of the emulsified layer divided by the total height.

Feniboet *al.* (2019) opined *that Pseudomonas aeruginosa*, *Bacillus subtilis, Acinetobacter calcoceticus* and *Candida albicans* represent major genera of microorganisms with high ability to produce emulsions, rhamnolipids, surfactin, sophorolipids, mannosylerithritol lipids. *Klebsiella pneumonia* (strain IVN51) isolated from hydrocarbon–polluted soil in Ogoniland (Niger Delta) soil showed an emulsification index of 60 % as compared with the emulsification index of sodium dodecyl sulphate (SDS) (Anna and Marinella, 2022).

The blue-plate assay was introduced into the screening to ascertain the types of charges released by microbial surfactants (Table 4). The plates with deep bluish colouration after the growth of the bacteria tentatively showed that the surfactant produced by the bacteria is negatively charged. However, the Non--bluish growth pattern tentatively indicates that the surfactant produced by the bacteria is positively charged. In this current study, out of a total of 22 bacterial isolates, 13(59%) showed the presence of anionic surfactants, while 9(44 %) showed the

presence of cationic surfactants. Hussain and Khan (2018) had previously reported the presence of anionic surfactant-producing *Pseudomonas aeruginosa* strain from soils of automobile workshops in Aligash, India.

.**Table 3: The Emulsification Index of the Hydrocarbon-utilizing Bacterial Isolates Screened for Biosurfactants Production**

Isolate code/Bacteria	Emulsification Index (%)
A(*Pseudomonas* spp)	5.80±2.5
B(*Bacillus* spp)	0.00±0.00^{a}
C(*Bacillus* spp)	0.00±0.00^{a}
D(*Proteus* species)	0.00±0.00^{a}
E(*Corynebacterium* spp)	0.00±0.00^{a}
F(*Pseudomonas* spp)	3.00±0.30^{a}
G(*Acinetobacter* spp)	44.65±10.15^{bc}
H(*Acinetobacter* spp)	41.00±6.40^{bc}
I(*Acinetobacter* spp)	58.45±0.35^{c}
J(*Bacillus* spp)	0.00±0.00^{a}
K(*Micrococcus* spp)	0.00±0.00^{a}
L(*Serratia* species)	0.00±0.00^{a}
SS206(*Klebsiella* sp)	60.80±0.10^{c}
SS314(*Bacillus* species)	3.75±1.25^{a}
SS315(*Staphylococcus* species)	0.00±0.00^{a}
SS325(*Bacillus* spp)	28.84±28.84^{a}
SS327(*Burkholderia ambifera*)	56.50±0.30^{c}
SG140(*Bacillus* spp)	0.00±0.00^{a}
SG146(*Chromobacterium* spp)	10.1±1.80^{b}
F047(*Bacillus* species)	0.00±0.00^{a}
E301(*Bacillus* species)	60.55±4.45^{c}

Values are Mean ±SEM of duplicate determinations. Values with different alphabets along a row are significantly different at $p<0.05$

Table 4: Blue Plate Assay on Hydrocarbon-Utilising Bacterial Isolates

Isolate Code/Bacteria	Observation	Remarks
A(*Pseudomonas* spp)	Bluish coloration and moderate growth	Anionic surfactant
B(*Bacillus* spp)	Bluish coloration and moderate growth	Anionic surfactant
C(*Bacillus* spp)	Non bluish coloration and moderate growth	Cationic surfactant
D(*Proteus* species)	Bluish coloration and moderate growth	Anionic surfactant
E(*Corynebacterium* spp)	Non bluish coloration and moderate growth	Cationic surfactant
F(*Pseudomonas* spp)	Bluish coloration and moderate growth	Anionic surfactant
G(*Acinetobacter* spp)	Bluish coloration and moderate growth	Anionic surfactant
H(*Acinetobacter* spp)	Bluish coloration and moderate growth	Anionic surfactant
I(*Acinetobacter* spp)	Bluish coloration and moderate growth	Anionic surfactant
J(*Bacillus* spp)	Bluish coloration and moderate growth	Anionic surfactant
K(*Micrococcus* spp)	Non bluish coloration and moderate growth	Cationic surfactant
L(*Serratia* species)	Bluish coloration and moderate growth	Anionic surfactant
SS206(*Klebsiella* sp)	Bluish coloration and moderate growth	Anionic surfactant
SS314(*Bacillus* species)	Bluish coloration and moderate growth	Anionic surfactant
SS315(*Staphylococcus* species)	Non bluish coloration and moderate growth	Cationic surfactant
SS325(*Bacillus* spp)	Bluish coloration and moderate growth	Anionic surfactant
SS327(*Burkholderia ambifera*)	Bluish coloration and moderate growth	Anionic surfactant
SG140(*Bacillus* spp)	Non bluish coloration and moderate growth	Cationic surfactant
SG146(*Chromobacterium* spp)	Non bluish coloration and moderate growth	Cationic surfactant
F047(*Bacillus* species)	Non bluish coloration and moderate growth	Cationic surfactant
E301(*Bacillus* species)	Non bluish coloration and moderate growth	Cationic surfactant

In this study, the ability to express lipase enzymes was one of the integral screening procedures, as reported in Table 5. The zone of clearance by the bacteria on trybutyrin agar showed that isolates C (*Bacillus* spp), H (*Pseudomonas* spp), SS206 (*Klebsiella* sp), SS314 (*Bacillus* spp),

SS315(*Staphylococcus species*), SS327(*Burkholderia ambifera*), SG146 (*Chromobacterium spp*), F047 (*Bacillus* spp), and E301 (*Bacillus spp*) had the highest zone of 15.50 cm, 16.50 cm, 25.0 cm, 18.50 cm, 24.00cm, 18.50 cm, 16.00cm, and 13.00 cm respectively (Table 5).

The microorganisms that degrade or utilize petroleum hydrocarbons mostly possess genes for breaking down complex lipid molecules through lipase (Enzyme). These same groups of hydrocarbon utilizers are also biosurfactant producers. Pendse and Aruna (2018) also reported that hydrocarbon-utilizing bacterial isolates with the ability to produce biosurfactants also showed strong abilities to produce lipase. Zarinviarsagh *et al.* (2017) showed *Ochrobactrum intermedium strain* MZV101 with potentials for lipase and biosurfactants producing potentials. The ability of isolates to produce haemolysis on a blood agar plate indicates their ability to produce biosurfactants. Three types of haemolysis are known to occur: α, β, and γ. Alpha (α) haemolysis is said to occur when a greenish colouration is produced around the colony. Beta (β) haemolysis occurs when a clear zone is produced around the colony, while Gamma (γ) haemolysis (γ) occurs when no change occurs around the colony. The blood hemolysis pattern of the hydrocarbon-utilizing bacteria was studied as part of the screening program to identify the hyperproducers of biosurfactants. Isolates A (*Pseudomonas* spp), D (*Proteus species*), E (*Corynebacterium* spp), F (*Pseudomonas* spp), G (*Acinetobacter*spp), H (*Pseudomonas* spp), I (*Acinetobacter* spp), SS315 (*Staphylococcus* spp), SS 325 (*Bacillus* spp), SS 327 (*Burkholderia ambifera*), SG 140(*Bacillus* spp), SG 146(*Chromobacterium* spp), F047(*Bacillus* species), and E301(*Bacillus* species), had haemolytic zones of 33.00 mm, 25 mm, 32.00 mm, 59.50 mm, 14.50 mm, 35.00 mm, 41.00 mm, 35.50 mm, 35.00 m, 77 m, respectively (Table 6). Bacterial isolates coded A (*Pseudomonas* spp), D (*Proteus* species), F (*Pseudomonas* spp), G (*Acinetobacter* spp), SS314 (*Bacillus* species), SS315 (*Staphylococcus* species), SS327(*Burkholderia ambifera*) had complete β-haemolysis and are identified as best or hyper-producers of biosurfactants. Haemolytic activity appears to be a good screening criterion in the generic search for biosurfactants in microorganisms, as Saravanakumari *et al.* (2010) mentioned. In another related study, Astuti *et al.* (2019) also documented high haemolytic indices of *Pseudoxanthomonas* sp strain G3, which had a high emulsification index of 72% and reduced interfacial tension between 12.6-9.7 dynes/cm. Isolates H (*Pseudomonas* spp), SS327 (*Burkholderia ambifera*), G (*Acinetobacter* spp), I (*Acinetobacter* spp), SS206 (*Klebsiella* sp) had proved to be the best of the biosurfactants producing bacteria based on the screening results as discussed in this study

Table 5: Effect of Lipase Producing Potential

Isolate Code/Bacteria	Mean (Zone Of Clearance)
A(*Pseudomonas* spp)	0.00±0.00[a]
B(*Bacillus* spp)	0.00±0.00[a]
C(*Bacillus* spp)	15.50±2.50[cd]
D(*Proteus* species)	7.50±2.50[b]
E(*Corynebacterium* spp)	0.00±0.00[a]
F(*Pseudomonas* spp)	0.00±0.00[a]
G(*Acinetobacter* spp)	5.00±0.00[b]
H(*Acinetobacter* spp)	16.50±1.50[cd]
I(*Acinetobacter* spp)	5.00±0.00[b]
J(*Bacillus* spp)	5.00±0.00[b]
K(*Micrococcus* spp)	0.00±0.00[a]
L(*Serratia* species)	0.00±0.00[a]
SS206(*Klebsiella* sp)	25.00±3.00[f]
SS314(*Bacillus* species)	18.50±0.50[de]
SS315(*Staphylococcus* species)	24.00±2.00[f]
SS325(*Bacillus* spp)	0.00±0.00[a]
SS327(*Burkholderia ambifera*)	22.00±2.00[ef]
SG140(*Bacillus* spp)	6.00±1.00[b]
SG146(*Chromobacterium* spp)	18.50±1.50[de]
F047(*Bacillus* species)	16.00±2.00[cd]
E301(*Bacillus* species)	13.00±1.00[c]
A(*Pseudomonas* spp)	

Values are Mean± SEM of duplicate determinations. Values with different alphabets along a row are significantly different at $p<0.05$

Table 6: Effect of Blood Haemolytic Indices

Isolate Code	Mean (Zone Of Clearance In Mm)	Type Of Haemolysis
A(*Pseudomonas* spp)	33.00±2.00^{de}	β(complete zone)
B(*Bacillus* spp)	0.00±0.00^{a}	-
C(*Bacillus* spp)	25.00±2.00^{c}	β(complete zone)
D(*Proteus* species)	32.00±2.00^{cd}	α(incomplete zone)
E(*Corynebacterium* spp)	59.50±1.50	β(complete zone)
F(*Pseudomonas* spp)	14.50±2.50^{b}	β(complete zone)
G(*Acinetobacter* spp)	35.00±4.00^{de}	α(incomplete zone)
H(*Acinetobacter* spp)	41.00±2.00^{e}	α(incomplete zone)
I(*Acinetobacter* spp)	0.00±0.00^{a}	-
J(*Bacillus* spp)	0.00±0.00^{a}	-
K(*Micrococcus* spp)	0.00±0.00^{a}	-
L(*Serratia* species)	0.00±0.00^{a}	-
SS206(*Klebsiella* sp)	0.00±0.00^{a}	β(complete zone)
SS314(*Bacillus* species)	35.50±4.50^{de}	β(complete zone)
SS315(*Staphylococcus* species)	35.00±4.50^{de}	α(incomplete zone)
SS325(*Bacillus* spp)	77.00±8.00^{g}	β(complete zone)
SS327(*Burkholderia ambifera*)	0.00±0.00^{a}	-
SG140(*Bacillus* spp)	0.00±0.00^{a}	-
SG146(*Chromobacterium* spp)	0.00±0.00^{a}	α(incomplete zone)
F047(*Bacillus* species)	62.50±2.50^{f}	-

Values are Mean± SEM of duplicate determinations. Values with different alphabets along a row are significantly different at $p<0.05$

CONCLUSION AND RECOMMENDATIONS

In summary, this study successfully isolated and characterized 22 strains of soil-dwelling bacteria, of which 13(59%) showed the presence of anionic surfactants, while 9(44%) showed the presence of cationic surfactants. Hyper-producers of biosurfactants were biochemically

identified as *Pseudomonas* species, *Burkholderia*species, *Acinetobacter* species, and *Klebsiella* species. It is highly recommended that these organisms be subjected to molecular characterization as the biochemical characterization method used in this study is inadequate to ascertain the identity of the organisms. Also, there is a need to intensify research attention on biosurfactant production, which is a better alternative to synthetic surfactants in diverse industries.

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COMPARATIVE EXPRESSION PATTERNS OF LIPOPROTEIN LIPASE AND ASSOCIATED LIPID REGULATING GENES IN DIFFERENT BREEDS OF CHICKENS IN SOUTHERN GUINEA SAVANA OF NIGERIA

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ABSTRACT

Comparative Expression patterns of Lipoprotein Lipase and associated Lipids regulating genes in different breeds of Chickens in Southern Guinea Savana of Nigeria were investigated. A total of 300 day-old birds of mixed sexes were used in this study. One hundred each of the Fulani ecotype, Noiler and Broiler chicken birds were randomly allotted into three experimental treatments, with each treatment replicated into five containing twenty birds per replicate in a completely randomized design (CRD) arrangement, with Fulani ecotype as treatment 1 (T_1), Noilers as treatment 2 (T_2) and Broiler as treatment 3 (T_3 control). The birds were fed an experimental diet containing 21 % crude protein and 2900 Kcal ME/kg in a single-phase feeding regime for 22 weeks for T_1 and T_2 and 8 weeks for T_3. Nine fresh liver samples were collected from each of the three treatments. Lipoprotein lipase (LPL), Apolipoprotein AI (APOA1), Apolipoprotein B (APOB) and Peroxisome proliferator-activated receptor alpha (PPARA) genes were extracted and expressed. Lipoprotein lipase was highly upward regulated in Fulani ecotype chickens with a cycle threshold value of 2.61, while there was a downward regulation of the gene in the Noilers and Broilers with cycle threshold values of -0.97 and -1.64, respectively. Apolipoprotein lipase A-1 (APOA-1) was upwardly regulated in the Broilers

with a cycle threshold value of 0.65. In contrast, this gene was downwardly regulated in the Fulani ecotype and the Noilers, with cycle threshold values of -0.39 and -0.25, respectively. Apolipoprotein B precursor (APOB) showed a highly upward regulation in the Fulani ecotype with a cycle threshold value of 2.19, while there was a downward regulation of the gene in a similar pattern in both the Noilers and Broilers with cycle threshold values -0.1.03 and -1.16, respectively. A slightly upward regulation of Peroxisome proliferator-activated receptor gamma (PPARG) was observed in the Fulani ecotype with a cycle threshold value of 0.23. At the same time, there was a slight downward regulation of the gene in the Noilers and a lesser downward regulation of the gene in the Arbor acre, with cycle threshold values of -0.002 and -2.23, respectively. Understanding the dynamics of this genetic determinant in domestic chicken species in this study will facilitate the development of molecular markers for a prospective marker-assisted selection for improvement of growth and sensory attributes of Indigenous chicken breeds as lipid regulation is known to influence growth and meat sensory attributes.

Keywords: Associated Lipids Regulating Genes, Comparative Gene Expression, Different Breeds of Chickens, Lipoprotein Lipase.

INTRODUCTION

Presently, poultry meat's market structure is changing from producer- to consumer-driven. Poultry producers are encouraged to increase productivity when there is a sustained demand that will guarantee profit maximization. Commercial chicken breeds are characteristically fast growers, high-feed consumers, poor disease resistors, and high-fat accumulators, and they are poor in organoleptic perception by consumers (Debora *et al*., 2017). These properties have always constituted a threat factor and a risk too big for some farmers and investors to undertake. On the other hand, local chicken ecotypes have been reported to have a better organoleptic perception by consumers, a condition thought to be a result of their minimal fat accumulation (Debora *et al*., 2017). Lipoprotein lipase (LPL) has been known to playplay a critical role in regulating the breaking down of fat in triglycerides (Mead *et al.,* 2002a; b). Other genes that exert a regulatory influence on the breaking down of fat in the form of triglycerides are Apolipoprotein AI (APOA1), Apolipoprotein B (APOB), and Peroxisome proliferator-activated receptor alpha (PPARA). Knowledge about these genes has greatly increased over the past decade (Andrade, 2018). Lipoprotein Lipase (LPL) and the associated genes have been reported to control triacylglycerol partitioning between adipose tissue and muscle that increases fat storage or provides energy in fatty acids for muscular growth (Hidayati *et al*., 2015). The

expression pattern of this Lipoprotein lipase and the associated genes in fatty tissues is therefore thought to greatly influence the growth and sensory attributes of different poultry species. So, studying and properly understanding the mechanism of expression of these genes in different poultry species will form a solid foundation for developing molecular markers required to design a probable marker-assisted selection programme to improve growth performance and desired sensory attributes of poultry species in Nigeria. This study was, therefore, conducted to evaluate the expression of lipoprotein lipase (LPL) and associated genes in Fulani ecotype, Noiler and Broiler birds at the lipoprotein lipase and the associated genes loci levels. It is hoped that information from this study will form a foundation for developing genetic markers for a prospective marker-assisted selection to improve indigenous chicken breeds in Nigeria.

MATERIALS AND METHODS

Experimental Location

The research was conducted in the Teaching and Research farm of the Federal University of Technology, Minna, Bosso and Gidan Kwano Campuses, respectively. Laboratory work was conducted in the Department of Animal Production and Biochemistry Laboratories, Federal University of Technology Minna and The African Bioscience Laboratory Ibadan. Bosso Campus is situated between latitude 9o 28′ and 9o 37′ N, longitude 6o 23′ and 6o 33′ E. The Gidan-Kwano campus is situated at latitude 9o 51 ‘N and longitude 6o44 ‘E. The mean annual rainfall of the study area varies from 1102.6mm to 1361.7 mm. The vegetation is Southern Guinea Savannah agro-climatic vegetation. It has an altitude of 147 m above sea level (Njoku *et al*., 2021).

Experimental Materials

The birds used in this study include the Fulani ecotype, Noiler, and Broiler birds. Maize, maize offal, and broiler concentrates were used for diet formulation. Other materials used were feeding and drinking troughs, wood shavings, and wire mesh to construct the pens. Heat sources for brooding birds (electric bulb and charcoal heat source) were also used during the study.

Source of Experimental Materials

Parent stock of the Fulani ecotype fowl was sourced from the open market within Bosso Local Government Area of Niger State, Nigeria, to generate the birds used in this study, while the Noiler and Broiler chicken birds were procured from Amo hatchery, Ibadan. The feed ingredients used in the study (Maize, maize offal, and broiler concentrates) were sourced from

the open markets and an agro mill shop within the Bosso local government area of Niger State. Drugs and vaccines were sourced from an accredited agro-veterinary store within the Minna metropolis.

Experimental Diet and Design

A total of 300 day-old birds of mixed sexes were used in this study. One hundred each of the Fulani ecotype, Noiler and Broiler chicken birds were randomly allotted into three experimental treatments. Each treatment was replicated five times with twenty birds (20) per replicate in a completely randomized design (CRD). The birds were grouped into three treatments with Fulani ecotype as treatment 1 (T_1), Noiler birds as treatment 2 (T_2) and Broiler birds as treatment 3 (T_3 as the control). The birds were fed an experimental diet formulated to contain 21 % crude protein and 2900 Kcal ME/kg (Table 1) in a single-phase feeding regime. Feed and water were served *ad libitum* throughout the experimental duration of 22 weeks for T_1 and T_2, while T_3 was fed for 8 weeks.

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Table 1: Ingredient and Proximate composition of experimental diet

Ingredients	Percentage (%)
Maize	55.32
Maize offal	5.00
Concentrate	39.68
Total weight (kg)	**100.00**
Proximate analysis	
Crude Protein	21.00
Metabolisable Energy (Kcal/kg)	2,900
Moisture content	4.20
Crude fiber	5.50
Crude fat	7.24
Ash	9.00
Nitrogen free extract	53.05

Management of the Experimental Birds

The birds were managed using a deep litter system. Before the arrival of the chicks, the pens were cleaned, disinfected/fumigated, and littered with wood shavings up to 5 cm deep. A charcoal fire maintained the temperature in the brooding house. Daily cleaning, Drug administration, and vaccination were carried out until the birds attained maturity.

Sample Collection and Handling

A total of 9 fresh liver tissue samples were collected from three birds, each of which is a Fulani ecotype, Noiler and Broiler chicken. Five grams of the fresh liver samples were collected using a surgical knife and gently placed into a sterile Eppendorf tube and completely submerged with RNAlater (an aqueous, non-toxic tissue and cell storage reagent that stabilizes and protects cellular RNA intact) solution. The samples were properly labelled and transported in an icepack to African Biosciences Laboratory, JaaGee House, Ibadan-Ife expressway, Ibadan, Oyo state, Nigeria, within 24 hours of collection, where they were kept under -20 ^{o}C in a deep freezer for RNA extraction and Lipoprotein lipase and associated genes Expression studies.

Table 2: Lipoprotein Lipase and the Associated Genes Primer Designs and Description

Gene name	Accession number	Primer sequence	Primer length	Product length	Exon-exon junction
Lipoprotein lipase (LPL), Mrna	NM_205282.2	Forward – GCGACTCAGTTCTACTTCGTG Reverse – TTCATCTCAGCTTCGGGATCG	21 21	250	Yes
Apolipoprotein AI (APOA1), mRNA	NM_205525.5	Forward – TGGGCAAACAGCTTGACCTGA Reverse – CCGTCCACTTGGCAGAGAAC	21 20	216	Yes
Apolipoprotein B (APOB), mRNA	NM_001044633.2	Forward – CTTTAGAGGCCTCCGCCAG Reverse – TGCCTCTCCAGAACCTTTCA	19 20	170	Yes
Peroxisome proliferator activated receptor alpha (PPARA), mRNA	NM_001001464.1	Forward – TAGTAAGCTCTCAGAAACTTTGTTG Reverse – GAAACAGAAGCCGCTTTCCA	25 20	157	Yes

Extraction and Purification of Lipoprotein Lipase Gene/cDNA

The guanidinium thiocyanate-phenol-chloroform method was used to extract genomic mRNA from the liver samples, as Chomczynski and Sacchi (1987) described using the following forward and reverse primers, as shown in Table 2.

Lipoprotein Lipase and Associated Genes Expression/Ct values determination

The extracted Lipoprotein lipase and associated genes mRNA's were converted to their cDNA's using the FIREScript RT cDNA Synthesis KIT according to the procedure explained by Egena *et al.* (2023) and Okolo *et al.* (2023). The process involved using 1ul of Reverse Transcriptase, 2ul of 10x reaction buffer, 0.5ul RNase Inhibitor (Ribogrip), 0.5ul of primers with a 5-uM concentration and 10ul of the RNA sample (at 50ng/µl). Nuclease-free water was used to balance the reaction volume to 20ul. The thermocycling conditions were as follows: Annealing at 25°C for 10 minutes, Reverse Transcription at 45°C for 30 minutes and Enzyme inactivation at 85°C for 5 minutes. The synthesized cDNAs were amplified using the My IQ single-color real-time cycler. TheqPCRmix used was Solis Biodyne 5x HOT FirePol qPCR supermix plus. The reaction was done in 25µl reactions consisting of 4 µl of the 5x HOTFirepolqPCR Mix, 0.4 µl each of the forward and reverse primers and a specific probe, which had a concentration of 250nM, 18.2 µl of Nuclease-free water and 2 µl cDNA template(100ng). The cycling conditions were as follows: Initial Activation at 95°C for 12 minutes, Denaturation at 95°C for 15 seconds, Annealing at 55 and 53°C for 20 seconds (for Lipoprotein lipase and associated genes and GAPDH, respectively and Elongation at 72°C for 20 seconds.

RESULTS AND DISCUSSION

The results of the gene Expression/Cycle threshold value determination Lipoprotein lipase (LPL), Apolipoprotein AI (APOA1), Apolipoprotein B (APOB) and Peroxisome proliferator-activated receptor alpha (PPARA) genes in Different Breeds of Chickens are shown in Figures 1, 2, 3 and 4, respectively. These results are significant as they provide insights into the potential impact of gene expression on fat content in meat. The results in Figure 1 showed a highly upward regulation of the Lipoprotein lipase gene in Fulani ecotype chickens with a cycle threshold value of 2.61, while there was a downward regulation of the gene in both the Noilers and Broiler chickens with cycle threshold values of -0.97 and -1.64, respectively. The high upward regulation of the gene in the Fulani ecotype is indicative of the presence of low-fat content in the meat from this species of chicken. More so, the downward regulation of the gene in Noiler and Broiler birds is suggestive of the presence of high-fat content in these breeds of chicken. However, as seen from the result of the gene expression, the fat content regulates fat concentration and, as such, more fatty meat.

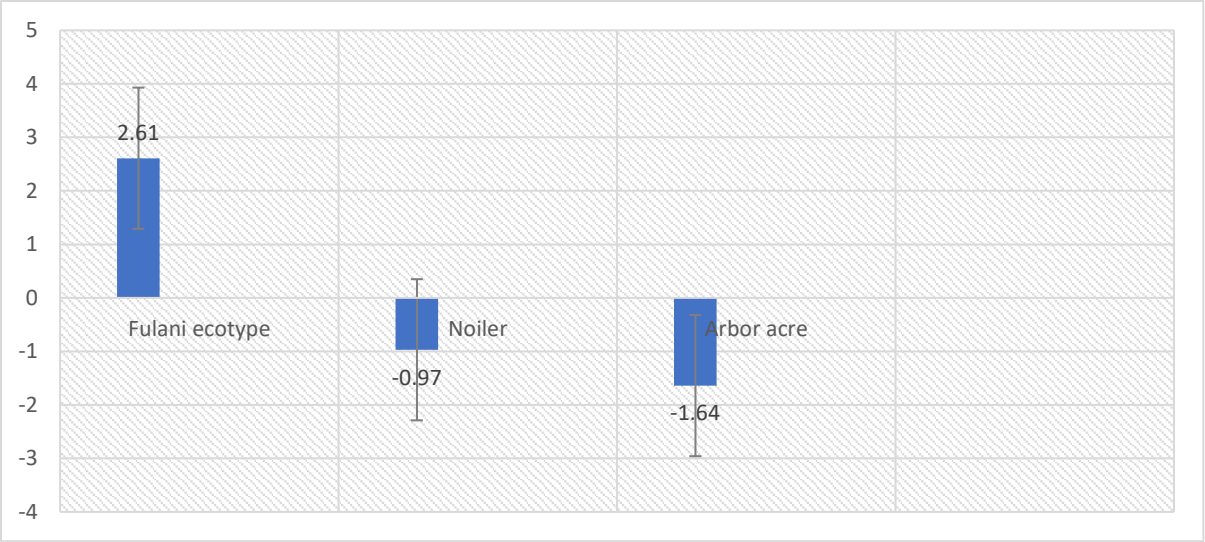

Figure 1: Expression Pattern of Lipoprotein Lipase (LPL) Gene of Three Breeds of Chicken

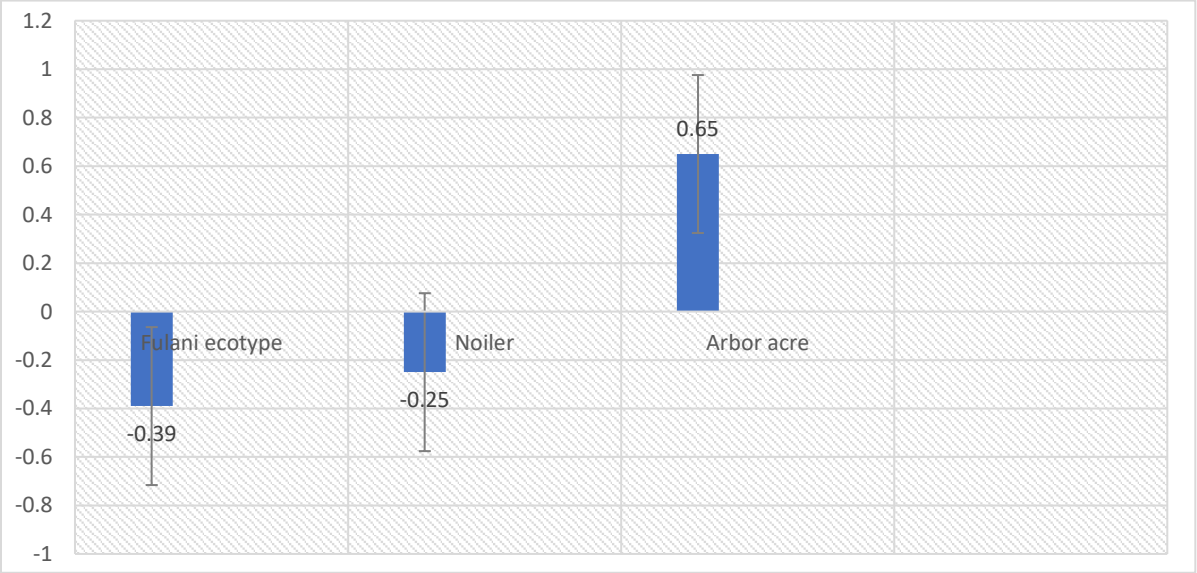

Figure 2: Expression Pattern of Apolipoprotein Lipase A-1 (APOA-1) Gene of Three Breeds of Chicken

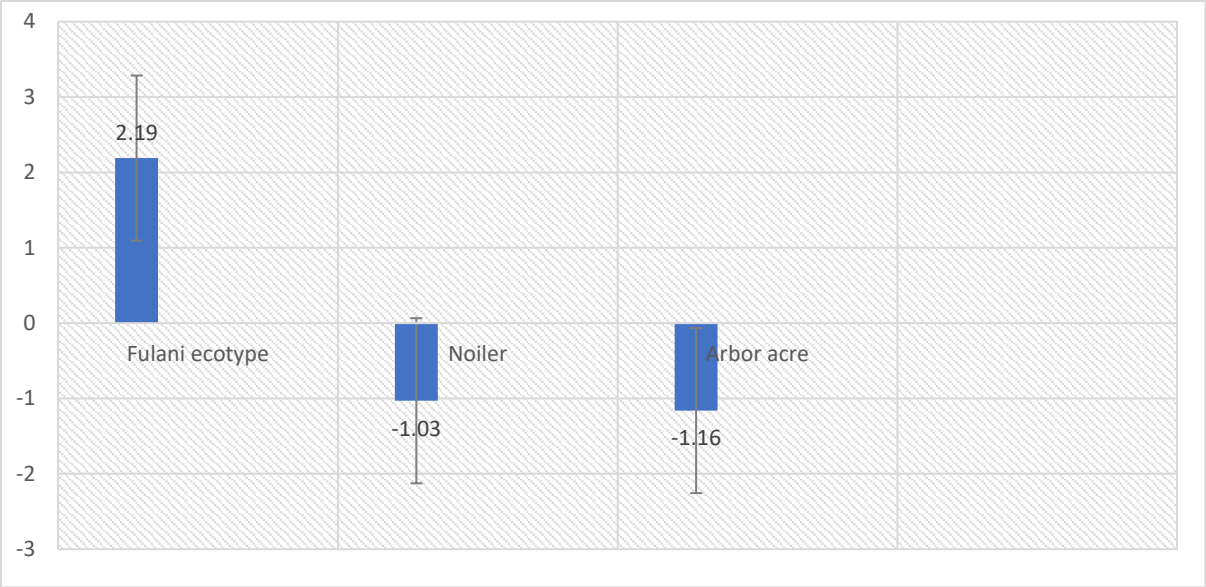

Figure 3: Expression Pattern of Apolipoprotein B Precursor (Apob) Gene of Three Breeds of Chicken

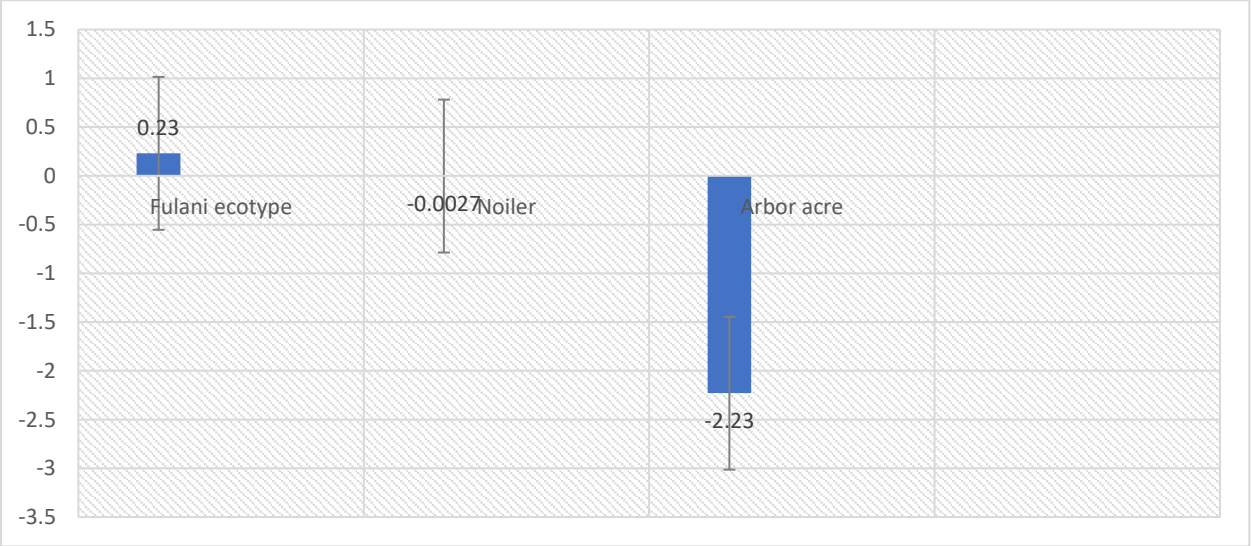

Figure 4: Expression Pattern of Peroxisome Proliferator Activated Receptor Gamma (PPARG) Gene of Three Breeds of Chicken

These results align with the report of Mead *et al.* (2002a; b), who reported that this gene has been known to play a critical role in regulating the breaking down of fat in the form of triglycerides, which could be more in the Arbor acre Broiler chickens than in the Noiler birds as results showed a lower downward regulation of the gene in Broiler chickens than in the

Noiler chickens. The higher the upward regulation, the more the activity of the gene in regulating fat concentration and, as such, more, leaner meat, while the lower the downward regulation, the lesser the activity of The results in Figure 2 showed an upward regulation of Apolipoprotein lipase A-1 (APOA-1) gene in Arbor acre Broiler chickens with a cycle threshold value of 0.65. In contrast, the gene was downwardly regulated in the Fulani ecotype and the Noiler chickens, with cycle threshold values of -0.39 and -0.25, respectively. The high upward regulation of this gene in Arbor acre chicken could be suggestive of high-fat content in the meat from this species of chicken. This result is in line with the description of Jialal and Barton (2016) that the gene is a major protein component of high-density lipids known for regulating cholesterol trafficking and protecting against cardiovascular complications. More so, the downward regulation of the gene in Noiler and Broiler birds suggests the presence of low-fat content in these breeds of chicken. However, as seen from the gene expression results, the fat content could be lower in the Fulani ecotype chickens than in the Noiler birds, as results showed a lower downward regulation of the gene in the Fulani ecotype than in the Noiler chickens. The lower the downward regulation, the more the activity of the gene in regulating fat concentration and, as such, leaner meat, while the lower downward regulation, the lesser the activity of the gene in regulating fat concentration and, as such, more fatty meat.

The results in Figure 3, on the other hand, showed a highly upward regulation of apolipoprotein B precursor (APOB) in Fulani ecotype chickens with a cycle threshold value of 2.19. At the same time, there was a downward regulation of the gene in a similar pattern in the Noilers and Broiler chickens with cycle threshold values -0.1.03 and -1.16, respectively. The high upward regulation of the gene in the Fulani ecotype, as was the case with the Lipoprotein lipase, may also signify the presence of low-fat content in the meat from this species of chicken. More so, the downward gene regulation in Noiler and Broiler birds could measure high-fat content in these chicken breeds. These results agree with Contois *et al.* (2009), who stated that APOB provides a direct measure of the number of atherogenic lipoprotein particles that act as ligands for low-density lipoprotein (LDL) receptor-mediated clearance, resulting in a similar expression pattern as that of the LPL gene. However, as seen from the result of the gene expression, the fat content could be higher in the Arbor Acre Broiler chickens and the Noiler birds, as results showed a lower downward regulation of the gene in Broiler chickens than in the Noiler chickens.

Figure 4 shows a slightly upward regulation of the peroxisome proliferator-activated receptor gamma (PPARG) gene in Fulani ecotype chickens with a cycle threshold value of 0.23. At the same time, there was a slight downward regulation of the gene in the Noilers chickens and a lesser downward regulation of the gene in Arbor acre broiler chickens, with cycle threshhold values of -0.002 and -2.23, respectively. As was the case with the expression of LPL, the results of the PPRAG expression agree with the report of Schoonjans *et al*. (1996) that states that increased activity of LPL may be responsible for the hypotriglyceridemic effects of known activators of various peroxisome proliferators-activated receptors such as PPARG. The up-regulation of the PPARG in the Fulani ecotype indicates low-fat content in this breed's meat. This agrees with the report of Kubota *et al*. (2006) that PPPARG has been known for some time to regulate adipocyte differentiation, fat storage and glucose metabolism. In their separate studies, Sandeep *et al.* (2011) and Kubota *et al*. (2006) also confirmed that activation of PPARG causes insulin sensitization and enhances the expression of several genes encoding proteins involved in glucose and lipid metabolism.

Conclusion

The Expression pattern/Cycle threshold values of Lipoprotein lipase (LPL), Apolipoprotein AI (APOA1), Apolipoprotein B (APOB) and Peroxisome proliferator-activated receptor alpha (PPARA) genes have provided details on the inter-muscular and subcutaneous lipid regulatory capabilities of the different Breeds of Chickens. It is hoped that a better understanding of the dynamics of this genetic determinant in domestic chicken species in this study will facilitate the development of molecular markers for a prospective marker-assisted selection for the improvement of growth and sensory attributes of indigenous chicken breeds in Nigeria.

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INCIDENCE AND SEVERITY OF MAIZE STEM BORERS IN NASARAWA STATE, NIGERIA

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ABSTRACT

Maize is one of the major cereal crops and ranks third in production worldwide, following wheat and rice. In sub-Saharan Africa, maize is one of the most important staple foods, providing food and income to over 300 million resource-poor smallholders. Stem borers are the most damaging insect pests in maize cultivation worldwide. Feeding by borer larvae on maize plants usually results in crop losses due to death of the growing point (dead heart), early leaf senescence, reduced translocation, lodging and direct damage to the ears. A farm survey was conducted in some selected Local Government Areas (LGAs) of Nasarawa State (Keanna, Keffi, Wamba and Lafia) from July to September 2019. In each LGA, five maize farms were surveyed. In each field, maize stem borer incidence was assessed as a percentage of the plants exhibiting maize stem borer symptoms. The severity of the infestation was determined by counting holes in the plants' leaves using a scale. The stem borer larvae on each farm were collected and caged differently and reared to adults. These were then taken to the Insect Museum at the Department of Crop Protection, Ahmadu Bello University, Zaria, Kaduna State, for identification. The results showed that the species of Sesamia calamistis was the only stem borer found in maize fields of the four LGAs of Nasarawa State. Keffi LGA had the highest incidence (28.00), followed by Lafia (26.50) and Wamba (23.00), while Kaena had the most

minor incidence of stem borers (20.00) Also, highest stem borers' severity (3.0) was found in Agundu in Kaena, Uko in Keffi LGAs, Dangi and Arikia in Wamba and Maraba in Lafia LGAs.

Key words: Larvae, Maize, *Sesamia calamistis,* Stem borers

INTRODUCTION

Maize (*Zea mays* L.) is not just a crop, but a vital staple food in sub-Saharan Africa (SSA), grown in diverse agroecological zones and consumed by people with varying food preferences and socio-economic backgrounds (Olaniyan, 2015). Sixteen out of 22 countries in the world where maize forms the highest percentage of calorie intake in the national diet are in Africa (Nuss and Tanumihardjo, 2011). Over 650 million people consume an average of 43 kg of maize per year (a 35% increase since 1960), reaching 85–140 kg in Kenya, Lesotho, Malawi, South Africa, Zambia and Zimbabwe (Kamara *et al*., 2003). Its cultivation spans the entire continent and is the dominant cereal food crop in many countries, accounting for 56 % of the total harvested area of annual food crops and 30-70 % of total caloric consumption.

The potential yield for sub-Saharan Africa is significant, with 5 tonnes /ha in tropical highlands, 7.0 in subtropical and mid-altitude zones and 4.5 in tropical lowlands, compared to the current yields of 0.6, 2.5 and 0.7 tones/ha, respectively (Pingali, 2001). This large yield gap is attributable to both abiotic and biotic constraints (Wambugu and Wafula, 2000). The major abiotic constraint is drought, which causes an annual yield loss of about 15% (Kamara *et al*., 2003), while the second most important constraint is nitrogen (Kamara *et al*., 2003). Maize is susceptible to common species of Pythium and moderately susceptible to *Sclerotium rolfsii* and *Rhizoctonia* spp. Maize is also susceptible to stalk and cob rots caused by several *Fusarium* species, but these do not normally affect vegetable crops.

A generally accepted estimate of annual losses during the early 20th century was 10 % of the South African crop (Kfir *et al.*, 2002). South African maize production increased from less than one million Tonnes (mt) in 1910 to 2.6 mt in 1950 and 8.2 mt in 1972. This increase in production and the concomitant increase in area under maize production (4.7 million ha in 1972) significantly raised the economic status of stem borers until the mid-1970s. *Busseola fusca* received surprisingly little research attention over half a century, and control strategies relied heavily on principles derived from earlier research.

Busseola fusca, a pest that has plagued maize production since the early 20th century, continues to be a major threat. It was first mentioned as *Sesamia fusca* in a report by Fuller in 1901 and described under the same name by Hampson in 1902. In 1953, African species of *Sesamia* and related genera were morpho-taxonomically revised, and finally, *S. fusca* was placed in the *Busseola* Thurau genus (Tams and Bowden, 1953). The first description of the oviposition site, eggs, larval behaviour and damage symptoms caused by *B. fusca* stemmed from South Africa. Since 1920, *B. fusca* has become an important pest of maize and sorghum in sub-Saharan Africa, and the first recommendations on how to control this pest were given in 1905. Since then, a plethora of information on its distribution, pest status and injuriousness has been produced (Kfir *et al.*, 2002). *B. fusca* is considered to be the most destructive lepidopteran pests of maize (Kfir *et al*., 2002) and sorghum (Van den Berg *et al.,* 1991) in Africa. Estimates of crop losses vary greatly in different regions and agroecological zones. In Kenya alone, losses due to *B. fusca* damage on maize fluctuate around 14 % on average (De Groote, 2002), while in the humid forest zone of Cameroon, losses of around 40 % are common in monocropped maize fields (Chabi-Olaye *et al*., 2005). Currently, this pest still presents a major constraint to the production of maize in areas where they are abundant.

Stem borers have been the most damaging insect pests in maize cultivation worldwide (Tefera *et al*., 2011). Feeding by borer larvae on maize plants usually results in crop losses due to the death of the growing point (dead heart), early leaf senescence, reduced translocation, lodging and direct damage to the ears. Yield loss due to stem borers in Africa varies from 0 - 100 % among ecological zones, regions and seasons. In sub-Saharan Africa, particularly Nigeria, they can cause 20 - 40 % losses during cultivation and 30 – 90% losses postharvest (Malusi and Okuku, 2013). However, estimated yield losses higher than 40 % are expected to occur at the smallholder level, where suppression of the pest by chemicals is generally not practised. Yield losses of 12 % for every 10 % of plants infested have been reported in Tanzania and Kenya (Malusi and Okuku, 2013). The Economic Injury Level (EIL) of *B. fusca* in maize is 4 and 5 larvae per plant 20 and 40 days after plant emergence, respectively. Therefore, the study's objective was to obtain information on the presence, incidence, severity, and distribution of maize stem borers in Nassarawa, Nigeria.

MATERIALS AND METHODS

Determination of Incidence and Severity of Maize Stem Borers

Sample Collection

Maize farms were surveyed during the 2019 cropping season from May to August to determine the incidence and severity of maize stem borer in the study area. Four Local Government Areas (LGAs) were selected: Keana, Keffi, Wamba and Lafia. In each LGA, five maize farms were surveyed. The Local Government Areas where the survey was carried out are presented in the maps below (Figure 1). Passport data of each site was captured using a structured questionnaire. Information on each farm's longitude, latitude and elevation was obtained using Global Positioning System (GPS) equipment. In each field, maize stem borer incidence was assessed as a percentage of the plants exhibiting maize stem borer symptoms. The severity of infestation was also determined by counting holes on the plants' leaves using a scale as shown in Table 1.

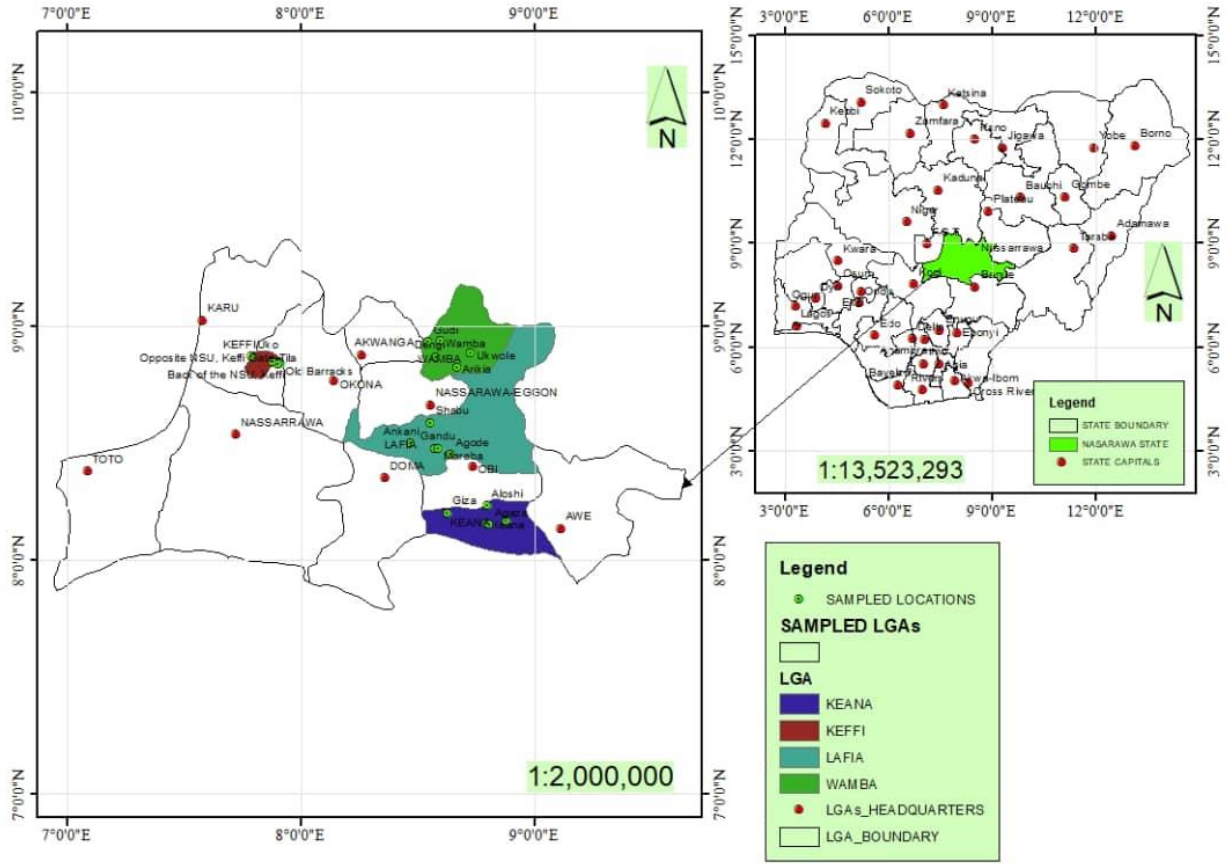

Figure 1: Map Showing Sample Points and Stem Borers in Nassarawa State, Nigeria

Table 1: Scale Used for Scoring Stem Borer Leaf Damage From Seedling to Whorl Stage in Maize

Numerical Score	Visual ratings of plant damage	Reaction to resistance
0	No damage	Probable escape
1	Few pin holes	Highly resistant
2	Few pin holes on older leaves.	Resistant
3	Several shot holes on leaves (<50%).	Resistant
4	Several shot holes on leaves (>50%) or small lesions (<2 cm long)	Moderately resistant
5	Elongated lesions (> 2 cm long) on a few leaves.	Moderately resistant
6	Elongated lesions on several leaves.	Susceptible
7	Several leaves with elongated lesions or tattering.	Susceptible
8	Several leaves with long lesions with severe leaf tattering	Highly susceptible
9	Plant dying due to death of growing points (dead-hearts)	Extensively sensitive to damage

Source: CIMMYT, (2011)

Identification of Maize Stem Borer Species/Biotypes

Borers from each LGA were caged separately on healthy maize seedlings using wooden cages measuring 50 cm ×50 cm in diameter and 150 cm in height, which were kept in a screen house till maize maturity. Ten seeds Pool -16 maize varieties were sown in plastic pots (25 cm diameter and 30 cm deep). F1 progeny of the insects were reared into adults, and sex was determined using the insect genital differentiation technique (Kruger *et al*., 2014). The males were used for species identification. Firstly, the insect specimens were treated with 10 % potassium hydroxide solution for about 24 hours, then transferred to 70 % ethanol. The male genitalia were dissected under a dissecting microscope (Ken-A- Vision, Kansas City, Missouri 64133 USA), and the aedeagus and pygofer processes were examined under the high power of a stereoscopic microscope (Acrifab model Atico Medical Pvt. Ltd., Grain Market, Ambala).

Data Analysis

The average number of infested plants in each farm from various LGAs was converted into percentage infestation. The data were subjected to Analysis of variance (ANOVA) using the Minitab package. Significant levels of the ANOVA were tested at the 5% probability level, and means were separated using the least significant difference (LSD).

RESULTS AND DISCUSSION

Passport Data of the Surveyed Areas

Maize in the surveyed areas was grown on at least one hectare of land for sale and family consumption. Farmers cultivated maize once a year (wet season only). Maize was grown with other principal food and vegetable crops such as cassava, cowpea, millet, rice, okra, garden egg, sorrel and groundnut. The farmers interviewed said they usually buy seeds from the market or previous harvests. Only a few seeds were obtained from reliable sources, such as the Research Institutes and Ministries of Agriculture and Agricultural Development Projects (ADPs). Most of the farmers interviewed controlled weeds manually, while few applied herbicides for weed control, and pesticides were used to control insect pests and diseases. Inorganic fertilizers such as NPK and urea were the primary sources of soil improvement, while few used organic and inorganic manure. These imply that most farmers are not planting certified and hybrid seeds. The cropping system practised by most farmers in the areas encourages a favourite breeding environment for the survival and infestation of stem borers because most farmers intercropped maize with sorghum, millet and pearl millet, which serve as alternative hosts for stem borer species. This agrees with the findings of Fajinmi and Odebode (2010), who stated that preventing pest incidence with intercropping of non-host plants should be carefully adopted. Cultivar planting, seed source, and fertilization methods adopted by farmers all significantly spread the infection of stem borers in the study area.

Incidence of Stem Borer Infestation in Selected Local Government Area of Nasarawa State

There were significant ($p \leq 0.05$) differences among the four local government areas surveyed in terms of the incidence of stem borer infestation, underscoring the urgency of the issue (Figure 1). Keffi LGA had the highest incidence (28.00), followed by Lafia (26.50) and Wamba (23.00), while Kaena had the lowest incidence of stem borers (20.00) (Figure 2).

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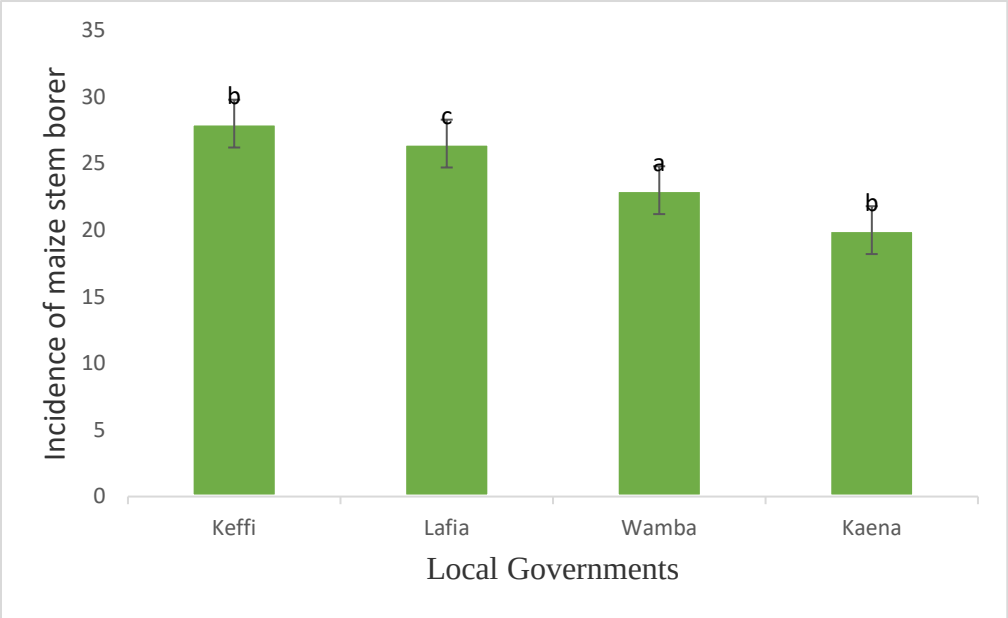

Figure 2: Incidence of Maize Stem Borer in Selected Local Government of Nasarawa State

Severity Rating of Infestation by Stem Borers in the Farms Surveyed

The lowest severity (1.0) of stem borers infestation was recorded in Agaza and Giza, both in Kaena LGA and Gandu in Lafia LGA. In contrast, the highest (3.0) stem borers' severity was found in Agundu in Kaena, Uko in Keffi LGAs, Dangi and Arikia in Wamba and Maraba in Lafia LGA (Figure 3).

Identification of Maize Stem Borer Species/Biotypes

The study revealed that *Sesemia calamistis* was the only borer species in the studied location (Nassarawa), Nigeria. This is significant for farmers as it indicates *the potential impact on their maize crops. The* absence of the A. ignefusalis population in the Local Government Areas surveyed is also noteworthy, as it suggests a lower risk of infestation by this species. This finding aligns with the research of Obhiokhenan *et al.* (2002), who reported a higher percentage of *S. calamistis* in the mangrove and rainforest zones. Similar observations have been made in studies carried out in Southwestern Nigeria (Balogun and Tanimola, 2001). In time, *B. fusca* became eliminated to the advantage of *S. calamistis.* This was due to the fact that *B. fusca* was more susceptible to high mortality at higher temperatures than *S. calamistis*. Ekoja *et al.* (2015) reported that the difference in population between the two borer species was due to the feeding habit of the borer.

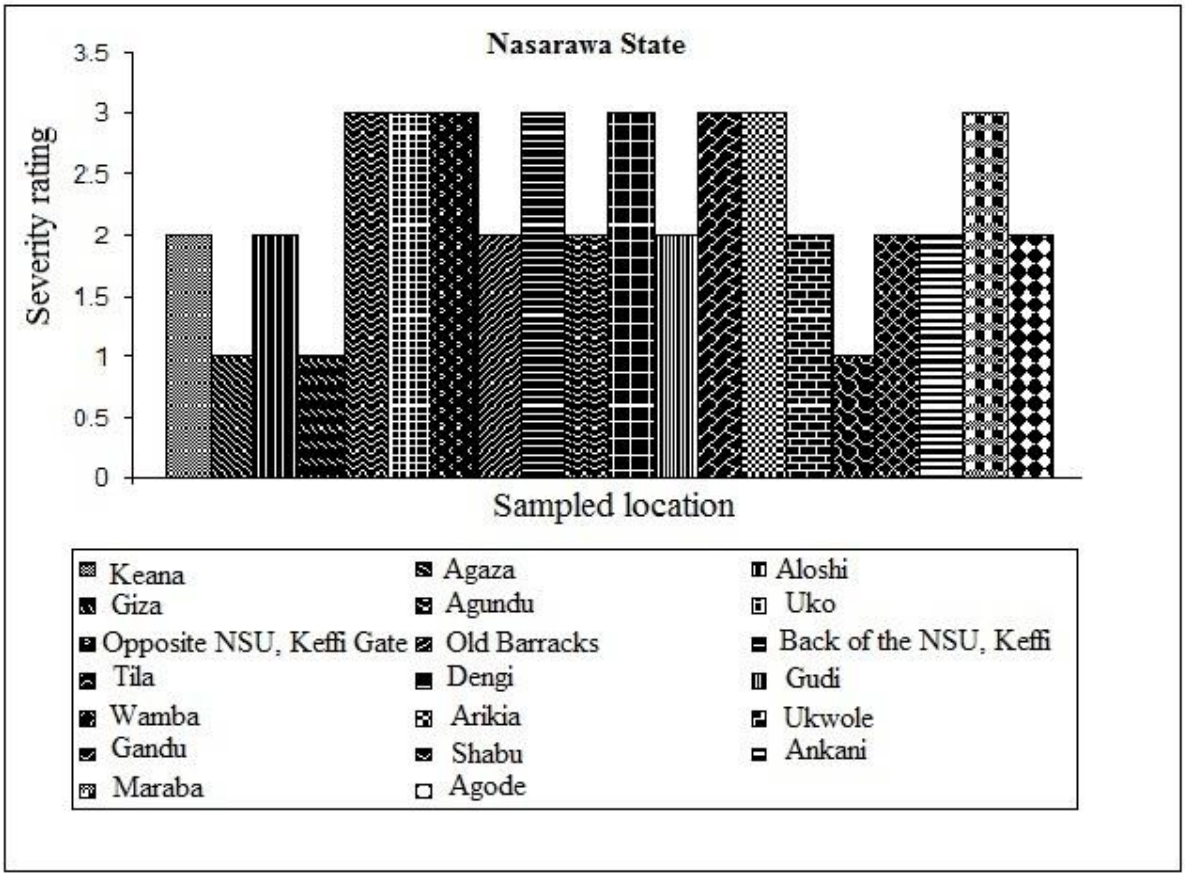

Figure 3: Severity Rating of Stem Borers in Surveyed Farms in Nasarawa State

CONCLUSION

Most of the farmers do not plant certified hybrid seeds. The cropping system practised by most farmers in the areas encourages a favourite breeding environment for the survival and infestation of stem borers. There was an incidence of stem borers in all the selected Local Governments of the State. The highest (3.0) stem borers' severity was found in Agundu in Kaena, Uko in Keffi LGAs, Dangi and Arikia in Wamba and Maraba in Lafia LGAs. In contrast, the lowest severity of stem borer infestation was recorded in Agaza and Giza, both in Kaena LGA and Gandu in Lafia LGA. *S. calamistis* was the only stem borer species in the studied location (Nasarawa, Nigeria).

RECOMMENDATIONS

Farmers should source their planting materials from seed companies or research institutes for certified and hybrid seeds resistant to maize stem borers' infestation. Farmers should adopt

cropping system(s) that discourage the breeding and survival of stem borers. Annual and or biennial farm surveys for the incidence and distribution of maize stem borers should be encouraged.

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DETERMINATION OF MICROBIAL LOAD AND SURVEY OF DIFFERENT PRESERVATION METHODS FOR DATES (*Phoenix dactylifera*) FRUIT IN MINNA MARKETS

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ABSTRACT

Fruits and vegetables have been a vital part of human diets, and there has been an increase in food contamination due to postharvest processing and preservation handling. This study was carried out to determine the microbial loads and survey the different preservation methods of Dates fruit. Six date fruits were obtained from two different markets (Kpakungu and Mobil) with a random selection of date fruit sellers using different or similar preservation methods. Samples were taken to the laboratory and subjected to a test to determine bacterial and fungal loads. The major bacteria isolated were (Bacillus aureus, Bacillus subtilis, Pseudomonas aeruginosa, Staphylococcus aureus and Escherichia coli). To help safeguard the well-being of end users and consumers of fruits and vegetables, proper postharvest processing and preservation methods should be in check by farmers/producers as well as buyers to reduce the alarming rate of contamination of mycotoxins and the presence of health-challenging microbes on fruits consumed directly or indirectly. Fruit vegetable sellers and consumers should ensure that the produce is more hygienic and fit for consumption and improve the handling process at their different ends. An example of using light salt solution to wash fruits before consumption.

Keywords: Bacterial, Contamination, Date, Fungi, Fruits, Markets, Microbes

INTRODUCTION

Date palm (*Phoenix dactylifera*) is considered a significant fruit crop in several African and Middle Eastern countries due to its nutritional value and health-promoting properties (Afshin *et al.,* 2019; WHO, 2019). The fruit is a source of several minerals, vitamins, carbohydrates, and fibre and is consumed regularly. Annual production in the Middle East was estimated at 5.1 million metric tonnes, and world production has been estimated at 7.2 million metric tonne s produced on an area of 11.2 million hectares, of which 11% are destined for export (Ecocrop, 2011; El-Deek*et al.,* 2010). Microbes are found all over the globe, with a few exceptions on Earth (Swanson *et al*., 2022), including sterilized surfaces. Hence, human activities cannot be wholly separated from those of microbes. Thus, many pathogenic microbes have found their way into fresh fruits and vegetables, a great source of a healthy diet for humans. Although some of these bacteria have been shown over time to cause harm, some bacteria are necessary for our daily lives (Hallen-Adams and Suhr, (2017) and help in digestion, decomposition, and the production of food such as cheese, bread, and yoghurt, such as some strains of *Lactobacillus, Bifidobacterium, Erwinia,* and *Streptococcus*. *Lactobacillus bulgaricus* is well-known throughout the world for the production of yoghurt (Chen, 2019). Some industries also utilize *Streptococcus thermophiles* to produce yoghurt. The growing demand for fresh fruits and vegetables has necessitated more significant production. The larger production of vegetables within the shortest possible time to meet the growing demand has placed them at a higher risk of contamination with pathogenic microbes, making the safety of consumers uncertain. Consumption of fresh fruits and vegetables increases as consumers strive to eat healthier diets. Production, handling, and packing processes may predispose certain produce to contamination with food-borne pathogens. Thus, a suitable preservation method is one of the most critical inputs contributing to fruit production because it increases the sustainability and longevity of produce.

Although the health benefits of fresh date produce are great, the proportion of food-borne disease outbreaks linked to contaminated produce has increased over the past few decades (Ailes *et al.,* 2008). Challenges in the postharvest treatments of dates include identifying appropriate packaging technologies and managing food safety issues, the latter of which includes contamination with mycotoxic fungi and contamination with human food-borne pathogens. Kurtzman (1987) reported that mould growth in foods consumed directly could result in direct exposure to mycotoxins, which are very harmful to humans.

Given the ongoing concern about the microbiological contamination of fresh fruits and vegetables, particularly date fruits, this research was initiated with the aim of identifying the types of microbial loads present, determining the most suitable storage method for date fruits, and comparing the microbial loads on date fruits under different postharvest storage methods. This would provide valuable insights into the best practices for preserving the safety and quality of date fruits.

METHODOLOGY

Study Location: The study was conducted at the Food Processing/Animal Production Laboratory of the School of Agriculture and Agricultural Technology, Federal University of Technology, Minna, Niger State.

Materials Used: The materials used were Date fruit (seeds), Culture media (Sabouroud Dextrose Agar (SDA) Nutrient Agar), Conical flasks (500ml), Test tubes, a Source of flame, a Syringe and needles (10ml), an Autoclave, Petri dishes, Distilled water (grams), a Pipette, an Oven, an Incubator, a Fungi Hood, salt, and water.

Source of Fruits: The samples were collected from different market locations in the Minna metropolis. Date fruits were selected from different local sellers in the markets after seeking information on their preservation method for the date fruit purchased. The locations with storage methods selected are listed below

1. Polyethene covering storage method at Kpakungu market
2. Powder application storage method one at Kpakungun market
3. Powder application storage method two at Kpakungun market
4. Polyethene and sack plus clothing storage method at Mobil market
5. Sack clothing bags one storage method at Mobil market
6. Sack clothing bags two storage methods at the Mobil market

Media Preparation: Serial dilution was used to enumerate bacterial and fungal loads, which is the step-wise dilution of a substance in solution and could be used to get more manageable results. Two different media were used: Nutrient Agar (NA) and Saboraud Dextrose Agar (SDA). 28g of Nutrient agar was dissolved in 1000 ml of distilled water, and 65g of Saboraud dextrose agar was also dissolved in 1000 ml of distilled water. After dispensing into distilled water, they were brought to heat to dissolve agar-agar completely. All the prepared media were

autoclaved at 121°C for 15 minutes, and they were brought out to cool to 40-45°C before the bacteria and fungi were inoculated.

Preparation of Diluent: Serial dilution was carried out on the samples by mixing 1mL of the sample into the first test tube with a micropipette. The sample aliquot was retaken from the first test tube. This was repeated until the last tube was achieved. 1 ml of the diluted sample was taken and dispensed into the sterile Petri dish, and about 20 ml of the molten agar was poured into the Petri dish and rocked gently for homogeneity. The culture plate was allowed to solidify and then transferred into the incubator. The culture plate containing the Nutrient agar was cultured at 370C for 24 hours, while that containing the Macconkey agar was cultured at 370C for 24 hrs. The resulting growth of the cultures was counted to the colony-forming unit per ml (CFU/ml). Nine mL of distilled water was dispensed into a test tube, i.e. six test tubes per sample and cork with foil paper, and were autoclaved for 15 minutes at 1210C, and the test tubes were cooled at room temperature.

Inoculation: Two test tubes to be used for serial dilution were arranged in the test tubes rack per sample, and 1g of the Dates fruit sample was introduced into the first test tube and was labelled as 10^1 and 1ml was taken from 10^1 and was introduced into the second test tube and labelled 102 and shaken. One mL out of 10^2 was taken into the Petri dish in an aseptic order for bacterial inoculation and another 1 ml into the second petri dish for fungi inoculation. The procedure was repeated to the remaining samples, and molten Nutrient Agar (NA) was introduced into the Petri dishes for bacteria and Saboraud Dextrose Agar (SDA) into the Petri dishes for fungi and were allowed to jell.

Counting of Viable Colony: The developed colony was counted by counting the cells using a colony click-counter machine and a pen. The number of colonies obtained was multiplied by the dilution factor, e.g., six colonies (6×105colony forming unit). It is expressed as 6×105cfu/g.
Statistical Tool: All collected data were subjected to a statistical Analysis of Variance (ANOVA) test using the Duncan Multiple Range Test (DMRT), with the mean separated at the 5% level of significance.

RESULTS AND DISCUSSION

Differences in Bacterial Loads Found on Fruits with Different Storage Methods Sourced from the Market

The effect of the storage method on the bacteria load present on the fruit from various locations is shown in Table 1. Polyethene with a sack plus clothing storage method at the mobile market had more bacteria in the fruit. The lowest count was recorded in the sample with clothing alone. The reason for the higher number under Polyethene with sack plus clothing storage method at Mobil market may not be unconnected with the fact that nylon does encourage heat build-up, and with heat build-up, bacterial presence is favoured. This is in line with the observations of Gil *et al*. (2015), who asserted that the use of postharvest handling mediums can encourage contamination.

Table 1: Difference in Bacterial Loads Found on Fruits with Different Storage Methods Sourced from the Market

Storage Method and Location	**Bacteria** (cfu/g)
Polythene covering K.market	14.33 x 10^6cd
Powder application K.market	23.67 x 10^6bc
Powder application K.market	14.00 x 10^6cd
Polythene/sack clothing bag M.market	46.00 x 10^6a
Sack clothing bags 1 M.market	28.00 x 10^6b
Sack clothing bags 2 M.market	6.00 x 10^6d
SE ±	3.24

Significant Variations in Fungi Loads on Fruits Due to Different Storage Methods Sourced from the Market

Table 2 presents the impact of the storage method on the fungi load found on fruits from various locations. The fungi count varied significantly, with the use of Sack Clothing Bag 2 resulting in the lowest population of fungi. This can be attributed to the sack material's higher aeration due to more holes, which discourages fungal growth.

Polyethene and sack plus clothing storage methods at the Mobil market had date fruits with higher fungi counts. The reason for this may not be unconnected with the heat produced when things are stored in polythene materials. In addition, most of these materials are hardly washed but subjected to continual usage, thus encouraging microbial build-up. This is in line with the conclusion of Acheampong (2015), who stated that containers used in washing vegetables by farmers and fruits and vegetable vendors are not mostly washed after use. Even if washed, the water is used for several cycles, allowing for cross-contamination of microbes with the recently washed ones since they are put in the same water as the first cycle.

Table 2: Differences in Fungi Loads Found on Fruits with Different Storage Methods Sourced from the Market

Storage Method and Location	**Fungi (**cfu/g)
Polythene covering K.market	34.67 x 10^6b
Powder application K.market	18.69 x 10^6cd
Powder application K.market	25.33 x 10^6bc
Polythene/ Sack clothing bag M.market	49.33 x 10^6a
Sack clothing bags 1 M.market	22.00 x 10^6bc
Sack clothing bags 2 M.market	8.33 x 10^6d
SE ±	4.51

KEY: K.market (kpakungun market). M.market (Mobil market)

Cross-Sectional View of Bacterial Isolated from Different Storage Methods and Locations

Cross-Sectional View of Bacterial Isolated from Different Storage Methods and Locations are shown in Table 3. From the chat, it can be concluded that the method of preservation may not be the reason for the reduction of microbial loads on the fruits. This is because similar preservation methods from the same location produced different results. For example, Sack Clothing 1 did not encourage the presence of *Bacillus aureus* and *Bacillus subtili* in the Mobil market location, but with Sack Clothing 2 at the Mobil market, these two bacterial loads were found. One of the isolated bacteria, *Bacillus cereus,* is an example of Gram-positive bacteria which is responsible for causing intoxication in food (Bhunia, 2018).

Table 3: Cross Sectional view of Bacterial Isolated from Different Storage Methods and Locations

METHOD OF STORAGE	*Bacillus aureus*	*Bacillus subtili*	*Pseudomonas aeroginosa*	*Staph aureus*	*E.coli*
Polythene covering K-Market	- -	++	- -	- -	++
Powder application K-Market	++	++	++	- -	- -
Powder application K-Market	- -	- -	++	++	- -
Polythene/S.clothing bag M-Market	++	++	- -	- -	++
Sack clothing bags 1 M-Market	- -	- -	++	- -	++
Sack clothing bags 2 M-Market	++	++	- -	- -	++

KEY:(++) means Samples with Storage Method has Bacteria. (- -) means Samples with Storage Method has no Bacteria. S. Clothing) means Sack Clothing Method. K. market means Kpakungun Market. M. market means Mobil Market.

Comparison of Bacterial Loads Found on Date Fruits from Markets and those treated with Salt Solution after Purchase

The comparison of bacterial loads found on date fruits from markets and those treated with Salt Solution after Purchase, as detailed in Table 4, highlights the crucial role of consumers in ensuring food safety. After treating the date fruits with a salt solution, the fungi load was significantly reduced, making them safer for consumption. This underscores the need for consumers to take responsibility for treating produce purchased from the market before consumption to prevent food poisoning. Acheampong (2015) emphasized the importance of

this, particularly for farmers, to ensure the repeated disinfection of containers before selling to consumers. By following this advice, consumers can significantly reduce their exposure to contaminants.

Table 4: Comparison of Bacterial Loads Found on Date Fruits from Markets and those Treated with Salt Solution after Purchase

Method of Storage	**Fungi (**cfu/g)
Polythene covering K.market	34.67 x 10^6b
Powder application K.market	18.67 x 10^6cd
Powder application K.market	25.33 x 10^6bc
Polythene/S.clothing bag M.market	49.33 x 10^6a
Sack clothing bags 1 M.market	32.00 x 10^6b
Sack clothing bags 2 M.market	8.33 x 10^6d
0.5% salt concentration/oven dry	25.33 x 10^6bc
1.0% salt concentration/oven dry	8.00 x 10^6d
SE±	4.00

CONCLUSION AND RECOMMENDATIONS

The presence of bacterial load on date fruits from Minna has been confirmed. From the storage method, i.e. polyethene covering, powder application, and sack clothing, there was no storage in which bacterial presence was not noticed, though the prevalence varied. The reasons for the high microbial load could be due to the postharvest handling from which these sellers source their produce. Proper treatment of fruits before consumption will also make produce consumption safer. A light salt solution for washing before consumption is recommended as a proven method of processing and handling date fruits.

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THE RESPONSES OF TOMATO (*Solanum lycopersicon L.)* IN GROWTH, YIELD AND NUTRITIONAL QUALITIES TO GROUNDNUT SHELL AND OTHER SOURCES OF NUTRIENT

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ABSTRACT

The study was carried out to evaluate the effect of granulated groundnut shells and other sources of nutrients (poultry droppings, burnt groundnut shell, NPK 10:10:10) on the growth and yield of tomatoes. The experiment comprised five treatments with three replicates each. The treatment consisted of 3 organic nutrient sources (poultry droppings, burnt groundnut shell, and raw groundnut shell) and one inorganic source of nutrients (NPK 10:10:10). They were applied at different rates depending on what quantity of the nutrient sources can supply the recommended kilogram (100) of Nitrogen per hectare. Groundnut shell was applied at the rate of 94.34 g per 20kg of soil, burnt groundnut shell was applied at the rate of 161.29g per 20kg of soil, poultry dropping was applied at the rate of 99.01g per 20kg of soil, a mixture of groundnut shell. Poultry dropping was also applied (groundnut shell was 47.17g+49.50g poultry droppings) = 96.67g per 20kg of soil, and NPK 10:10:10 was applied at 10g per 20kg of soil. The experiment was laid out in a completely randomized design. Data were collected on morphological parameters, including the number of leaves, plant height, stem girth, number of branches, days to first flowering, days to 50% flowering, days to first fruiting, number of fruits, and weight of fruits. Data collected were subjected to analysis of variance (ANOVA) using a Statistical Analysis System (SAS) package. Means were separated using Duncan's Multiple Range Test (DMRT), and statistical means were tested at a 5% significance level. The

result of the study showed that a mixture of groundnut shells and poultry droppings enhanced the growth and yield of tomatoes more than any other treatment used. This finding suggests that this specific combination of organic nutrient sources can be a more effective and sustainable alternative to inorganic sources for tomato cultivation.

Keywords: Groundnut shell, Growth, Nutrients, Organic, Yield

INTRODUCTION

Tomatoes are a very important vegetable cultivated and consumed in most parts of the world, from home gardens and greenhouses to large commercial farms, due to their wider adaptability to various agro-climatic conditions. The crop is rich in vitamin C and contains lycopene, a vital antioxidant that prevents cancers (Beckles, 2012). Tomato quality and yield are greatly reduced by nutrient shortage in the soil (Sainju *et al.,* 2003). Organic manure provides crops with essential nutrients when decomposed and acts as a soil conditioner (Makinde *et al.*, 2007). Soil organic amendments such as cow dung, goat manure and poultry manure are valuable sources of plant nutrients (Takahashi *et al*., 2010). Most developing countries are trying to eliminate expensive chemical fertilizers by supplementing them with some organic-based sources. A mixture of organic and inorganic fertilizers is a good soil fertility management strategy. Organic farming restricts the use of agrochemicals and offers a way to reduce the adverse effects of chemical fertilization (Aguilera *et al., 2013;* Aires *et al., 2013*). Although the most significant disadvantage of organic crop production has been low yields compared to intensive farming (Seufert *et al*., 2012), thus farmers choose to use industrial synthetic chemical fertilizers to grow vegetables (Matsumoto and Yamano, 2009). However, large-scale use of inorganic fertilizers can contribute to environmental pollution, such as groundwater contamination, eutrophication of waterways, soil acidification and increased denitrification, resulting in higher emission of nitrous oxide, which contributes to global warming (Molla *et al*., 2012). The need to examine the effect of different fertilizer sources on the growth and productivity of tomatoes is quite important as it helps farmers to make better choices that will reduce cost and improve yield while also considering ecological sustainability. Groundnut hulls make up around 25% of the several million tons of mass-produced hulls generated yearly but are not used. Most groundnut hulls are currently burned and discarded in forests. As a result, its collection and commercialization as an organic source of nutrients hold great promise as a potential substitute for chemical fertilizers and for controlling environmental pollution. Thus, this research was

conducted to evaluate the growth and yield of tomato crops in response to groundnut shells and other sources of nutrients.

METHODOLOGY

Study Location, Treatment Sources and Experimental Designs

The study was carried out at the screenhouse of the Department of Crop Production, School of Agriculture and Agricultural Technology, Federal University of Technology Minna, Niger State. Monarch Tomato seed was used in the research. It was sown in the seed tray and tinned to 30 seedlings per tray two weeks after sowing. The experiment was arranged in Completely Randomized Design (CRD) with five treatments (granulated groundnut shell, burnt groundnut shell, poultry dropping, mixture of granulated groundnut shell and poultry dropping, and NPK 10:10:10) replicated three times. A recommended nitrogen rate of 100 kg/ha was used to calculate the needed quantity per pot for the tomatoes. Treatment 1 (Granulated groundnut shell at 94.34g per pot. Treatment 2 (Burnt groundnut shell at 161.29g per pot. Treatment 3 Poultry dropping at 99.01g per pot. Treatment 4 (Mixture of poultry manure and groundnut shell = 47.17+49.50=96.67g. Treatment 5 (N. P. K 10:10:10 at 10g per pot. A total of 15 pots were filled with soil weighing 20kg per pot. The pots were arranged properly on a sturdy support. The organic treatments were applied a week before transplanting, while the inorganic treatments were applied two weeks after transplanting.

Pre-Planting Soil Analysis

The soil was slightly acidic. Table 1 shows the result of the physicochemical pre-planting analysis used to assess the soil fertility status. The result showed that the soil needed amendment before being used for tomato production, and thus, it was fit for use in a fertilizer experiment.

Transplanting and Management Practices

Disease-free, vigorous, and uniform-size seedlings were transplanted using the naked root method. The nursery bed was properly watered to help remove the seedlings without damage. Manual weeding was carried out by hand picking when weeds were noticed. Staking was done to keep the plant erect and for proper fruit development.

Table 1: Physicochemical Pre-Planting Analysis of the Sample of Experimental Soil

Properties	Values
Physical	
Sand (g kg^{-1})	800
Silt (g kg^{-1})	80
Clay (g kg^{-1})	120
Textural class	Loamy Sandy
Chemical	
PH (H_2O)	6.33
PH ($CaCl_2$)	5.6
Organic carbon (g kg^{-1})	2.3
Total nitrogen (g kg^{-1})	1.2
Available phosphorus (mg kg^{-1})	10.06
Exchangeable bases (cmol kg^{-1})	
Na+	0.16
K+	0.06
Mg2+	1.0
Ca2+	2.0
Exchangeable acid (cmol kg^{-1})	0.11

Data Collection

Plant height was measured from each replicate from the respective treatment once a week using a tape measure from the base to the apex of the plants. Leaves from each replicate from the respective treatment were counted at a two-week interval from two weeks after sowing.

Number of Fruits per Plant

The number of fruits per plant was recorded by counting the number of ripe fruits harvested on each plant.

Weight of Fruits per Plant

The fruit weight per plant was recorded by weighing the number of ripe fruits harvested on each plant.

Post Harvest Analysis

Three post-harvest analyses were carried out. Proximate analysis on the harvested fruit was carried out at the laboratory of the Department of Water Resources, Fisheries and Aquaculture, Federal University of Technology, Minna, Niger State, Nigeria, using the methods outlined by the Association of Official Analytical Chemists (AOAC, 2000). This was to determine which of the applied nutrients produced better fruit qualities. Post planting soil analysis was also carried out to know which of the treatments used leave the soil in a better condition than at the beginning. Plant tissue analysis was carried out to show the nutrient status of the plants and to indicate if the supplied nutrient was adequate.

Data Analysis

The data were subjected to analysis of variance (ANOVA), and means were separated using Duncan's Multiple Range Test (DMRT) at a 5% level of significance.

RESULTS AND DISCUSSION

Effect of Granulated Groundnut Shell and Other Nutrient Sources on The Number of Leaves of Tomato

The effect of nutrient sources on the number of tomato leaves at 2, 4, 6, and 8WAT are shown in Table 2. T5 (NPK 10:10:10) was consistently low in value in all the treatment, and differed significantly ($p \leq 0.05$) from the other treatments all through the weeks. The result obtained with T5 is not consistent with what is known with inorganic fertilizers especially that it raises root development (Scholl and Nieuwenhuis, (2004), which could aid in proper plant development.

Table 2: Effect of Granulated Groundnut Shell and other Nutrient Sources on the Number of Leaves of Tomato

	Number of Leaves			
Treatments	2WAT	4WAT	6WAT	8WAT
T_1	23.00[a]	56.00[b]	100.00[a]	155.00[b]
T_2	35.00[a]	71.00[a]	116.00[a]	171.00[ab]
T_3	36.00[a]	84.00[a]	129.00[a]	172.00[ab]
T_4	48.00[a]	89.00[a]	140.00[a]	202.00[a]
T_5	16.00[b]	39.00[b]	65.00[b]	73.00[c]
SE_+	4.18	7.12	8.74	12.28

[a, b] means on the same column with different superscripts are significantly different at P<0.05

T_1 = groundnut shell, T_2 = burnt groundnut shell, T_3 = poultry droppings, T_4 = groundnut shell and poultry droppings, T_5 = NPK 10:10:10

Effect of Granulated Groundnut Shell and Other Nutrient Sources on Plant Height

The effect of nutrient sources on plant height on tomatoes at 2, 4, 6 and 8 Weeks After Transplanting (WAT) are shown in Table 3. There were no significant ($p>0.05$) differences for the plant height at 2WAT across all the treatments. However, a different trend was observed for the remaining weeks, as there were significant differences ($p\leq0.05$) across all the treatments. T4 (groundnut shell and poultry droppings) was consistently high in value in all the treatments and differed significantly ($p\leq0.05$) from the other treatments all through the weeks. This suggests that T4 could be a more effective nutrient source for promoting plant growth.

Effect of Granulated Groundnut Shell and Other Nutrient Sources on Number and Weight of Fruits of Tomato

The effect of nutrient sources on number of fruit and weight of fruit are shown in Table 4. There were no significant ($p>0.05$) differences among the treatment means. However, the Table shows that T4(groundnut shell and poultry droppings) significantly influenced a higher number of fruits compared to the other treatments, demonstrating its impressive performance in fruit

production. Similarly, T4 (groundnut shell and poultry droppings) consistently produced fruit with a significantly higher weight compared to the other treatments, showcasing its effectiveness and the potential for increased yield.

Table 3: Effect of Granulated Groundnut Shell and other Nutrient Sources on Plant Height

	Plant height (cm)			
Treatments	2WAT	4WAT	6WAT	8WAT
T_1	23.33^{a}	39.00^{ab}	69.33^{b}	106.33^{c}
T_2	27.33^{a}	46.67^{ab}	86.00^{ab}	123.00^{b}
T_3	27.67^{a}	54.67^{a}	92.00^{a}	130.33^{ab}
T_4	33.67^{a}	63.33^{a}	105.00^{a}	138.00^{a}
T_5	15.67^{a}	25.00^{b}	53.00^{c}	59.67^{d}
SE_+	2.28	4.64	5.36	7.55

^{a,b,c,d} Means on the same column with different superscript are significantly different ($p<0.05$)

T_1 = groundnut shell , T_2 = burnt groundnut shell, T_3 = poultry droppings, T_4 = groundnut shell and poultry droppings, T_5 = NPK 10:10:10

Table 4: Effect of granulated groundnut shell and other nutrient sources on number and weight of Tomato

Treatments	Number of fruits	Weight of fruits (g)
T_1	2.0^{a}	29.0^{a}
T_2	1.0^{a}	32.0^{a}
T_3	3.0^{a}	45.6^{a}
T_4	4.0^{a}	107.0^{a}
T_5	2.0^{a}	76.6^{a}
SE±	1.11	26.39

T_1 = groundnut shell, T_2 = burnt groundnut shell, T_3 = poultry droppings, T_4 = groundnut shell and poultry droppings, T_5 = NPK 10:10:10

Proximate Analysis of Fresh Tomato Fruit

The result of the proximate composition of fresh tomato fruit is shown in Table 5. There were no significant differences (P>0.05) in the moisture content of the treatments. The ash contents were significantly different (P≤0.05). T3 and T4 showed highest level, followed by T2. There were significant (P≤0.05) differences in the crude protein content of the treatments. The highest significance level was observed in T4, followed by T3 and T2. For the fat content, T4 varied significantly when compared to the rest of the treatments and had the highest value, while T1 had the lowest value. No significant differences (P>0.05) were observed in the crude fibre contents among the treatments. There were significant differences (P≤0.05) in the NFE of the samples; T2 had the highest value, and the lowest value was obtained in T3.

Table 5: Proximate Analysis of Fresh Tomato Fruit

Treatments	MC (%)	CF (%)	CP (%)	Ash (%)	Fat (%)	NFE
T_1	30.40^{a}	0.68^{a}	0.70^{b}	0.04^{b}	0.24^{b}	1.27^{b}
T_2	30.07^{a}	0.70^{a}	0.87^{a}	0.05^{ab}	0.28^{b}	1.33^{a}
T_3	30.47^{a}	0.79^{a}	0.87^{a}	0.07^{a}	0.41^{a}	0.73^{d}
T_4	30.21^{a}	0.70^{a}	0.98^{a}	0.07^{a}	0.49^{a}	0.88^{c}
SE±	0.41	0.02	0.03	0.00	0.03	0.08

[a,b] Mean on the same column with different superscript are significantly different at p<0.05

T_1 = groundnut shell, T_2 = burnt groundnut shell, T_3 = poultry droppings, T_4 = groundnut shell and poultry droppings.

Tissue Analysis of Tomato Shoot

The result of the tissue analysis of tomato stalk is shown in Table 6 below. There were no significant (p≥0.05) differences in the Nitrogen contents of the treatments, T2 (burnt groundnut shell) had the highest value of (0.43%), while the lowest value was recorded for T1 (groundnut shell) and T3 (poultry droppings) (0.37%). The Potassium contents of the treatments varied significantly (p≤0.05), with T1 having the highest value (143.67mg/100g), while the lowest value (126.33mg/100g) was recorded for T4 (groundnut shell and poultry droppings). The phosphorus content of the treatments was highest in T4, and no significant differences (p≥0.05) were observed among the treatments. These findings lend credence to past research showing

that manures and other organic sources provide adequate nutrients plants need to develop and produce (Atiyeh *et al*., 2002; Ojeniyi, 2008; Mehdizadeh *et al.*, 2013).

Table 6: Tissue Analysis of Tomato Stalk

Treatments	N (%)	K (mg/100g)	P (mg/100g)
Groundnut shell	0.37[a]	143.67[a]	135.33[a]
Burnt groundnut shell	0.43[a]	134.00[b]	137.33[a]
Poultry Droppings	0.37[a]	131.33[b]	134.00[a]
Groundnut shell + Poultry droppings	0.41[a]	126.33[b]	139.33[a]
SE±	0.13	1.10	2.19

[a,b] Means on the same column with different superscripts are significantly different at $p<0.05$

Post Soil Analysis

The post-soil analysis of tomatoes is shown in Table 7 below. The result shows that the various treatments had no significant ($p>0.05$) differences in the post-soil parameters (O/C%, O/M%, and N%). However, the groundnut shell treatment had higher organic carbon and organic matter content than the rest. It revealed that the treatment could leave the soil better after a cropping season.

Table 7: Post Soil Analysis of Experimental Soil

Treatments	O/C (%)	O/M (%)	Nitrogen (%)
Groundnut shell	0.75	1.30	1.20
Burnt groundnut shell	0.53	0.91	1.60
Poultry Droppings	0.62	1.06	1.30
Groundnut shell + Poultry droppings	0.56	0.91	1.40

CONCLUSION AND RECOMMENDATIONS

In all the parameters, treatments with groundnut shells, either as a whole or in other forms, had the highest value and were significant in some of the analyses. The mixture of poultry droppings and groundnut shells produced plants with more leaves. It also produced taller plants and plants with a higher number of fruits and fruits that weigh higher. Also, groundnut shell treatment

showed the potential to leave the soil in a better condition after a cropping season, judging from levels of organic matter, organic carbon, and Nitrogen remnant in the soil in the post-harvest soil analysis.

Based on the findings from this study, groundnut shells should be considered an alternative source of nutrients either as a whole, being ploughed into the soil, or in combination with other nutrient sources like poultry manure. Researchers can focus more research on the potential of groundnut shells to change the world of vegetable production so that the full benefits can be discovered.

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