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Aims and Scope

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DETERMINANTS OF MARKET PARTICIPATION AND PERFORMANCE OF SMALLHOLDER CASSAVA PRODUCTION AGRIPRENEURS IN ABIA STATE, NIGERIA

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ABSTRACT
The study examined the determinants and performance of smallholder cassava production agripreneurs market participation in Abia State, Nigeria. The study determined their level of market participation, estimated the determinants of cassava production agripreneurs' market participation, examined their performance, and the challenges faced by these cassava production agripreneurs. A multi-stage sampling technique was used in selecting 120 respondents for the study. Data collected using well-structured questionnaire administered to the respondents was analyzed with descriptive statistics (mean, frequency and percentage), market participation index, multiple regression, and net return analysis. The result showed that the market participation index was 97.78%.The determinants of market participation were labour, education, technology, credit, and market information which were all directly related to market participation and significant at 1%. Experience, selling price and capital were positively signed, and significant at 5%, while gender and income were negatively signed with 5% and 10% levels of significant respectively. The net-return analysis result showed that on the average, a cassava production agripreneur makes ₦997,158.63k profit for a production season. Using a mean score of 2.50, the mean rating from the four-point likert scale result indicated that lack of infrastructure (2.58), lack of suitable planting equipment (2.68), low capital base (2.65), lack of technical expertise (2.71), and lack of mechanization/power (2.63) were accepted as a major challenge faced by the cassava production agripreneurs. The study concluded that there is a high level of market participation by the cassava agripreneurs in the study area which will inevitably unlock their full potential, contribute to local economic development, and play a vital role in driving the growth of the cassava industry on a broader scale. Also, the cassava production enterprise is a profitable venture. It is therefore recommended that with the high level of cassava commercialization in the study area, youths and households are encouraged to actively participate in cassava production as it can create employment opportunities and generate income for individuals and communities, as well as being a pathway to international trade and global export market.

Keywords: Market, Participation, Agripreneurs, Performance, Smallholder.

1. INTRODUCTION

Market participation is the involvement of individuals, businesses, or entities in buying or selling goods, services, or financial assets within a market economy. It encompasses various activities such as purchasing goods, selling products or services, investing in stocks, and engaging in trading activities. Essentially, it's the act of actively engaging with the market in various capacities. Recent research shows that agripreneurs should pursue market orientation to gain long-term competitive advantages through market participation (Saleh *et al.,* 2021). An agripreneurs' capacity to participate in a market successfully and efficiently is referred to as "market participation." It is the active involvement of producers, suppliers, and other stakeholders in the market ecosystem. It encompasses various activities such as production, distribution, promotion, and sales aimed at effectively reaching and satisfying customers within the target market. In the context of cassava, market participation involves ensuring that cassava producers, processors and traders have the necessary resources, information, and infrastructure to efficiently insert their products in markets, thereby contributing to economic growth and improved livelihoods within the cassava value chain. By participating in the market, agripreneurs becomes an active actor in the value chain of any agricultural product (Kyaw *et al.,* 2018; Adino *et al.,* 2021). It has been estimated that about 90% of smallholder farmers in West Africa cultivate cassava (*Manihot esculenta Crantz*) as a staple crop, making it a critical product for agripreneurs (Sanni *et al.,* 2009; Ojiakor *et al.,* 2017; Ikuemonisan *et al., 2020*). There are numerous ways in which agripreneurs can utilize cassava as a source of food, feed, and raw material. Cassava is grown by 98% of smallholder crop farmers in Abia State, which means that most of the state's agripreneurs relies heavily on the crop (Apu and Oragwam, 2009; Onyebinama and Onyejelem, 2010; Udensi *et al.,* 2011;; Onya *et al.,* 2016). The socio-economic conditions of the cassava production agripreneurs are significantly dependent on their ability to participate in the market actively (Onya *et al.*, 2016). The majority of cassava production agripreneurs are active participants in the cassava value chain and market (James *et al.,* 2011; Madu *et al.,* 2018). Agripreneurs are involved in cassava farming, and stem production, root processing and value addition, distribution, and supply. Agripreneurs ensure that there is enough production to meet market demand. Some agripreneurs, particularly in developed economies, engage in contract cassava production. Cassava production agripreneurs aggregate smallholder cassava farmers' output, thereby creating a market for them. Agripreneurs bridge the market gap between farmers, manufacturers, and end-users.

The issue of limited access to credit and production inputs is a significant challenge for cassava production agripreneurs, as they struggle to find adequate capital to finance their investments and maintain healthy working capital to participate in the market (Christopher *et al.,* 2019).The cassava agripreneurship landscape is marked by various dimensions encompassing socio-economic characteristics, factors influencing market engagement, the impact on an agripreneurs performance, and challenges faced by agripreneurs involved in cassava production. However, there exists a gap in comprehensive understanding and analysis of these factors, hindering the development of effective strategies and policies to promote sustainable cassava agribusiness. Therefore, there is a pressing need for an in-depth investigation to bridge this gap and provide actionable insights for policy makers, researchers, and practitioners in the agricultural sector. Based on the socio-economic and other constraints that limit market participation of cassava agripreneurs, it is critical to analyze the market participation of cassava production agripreneurs in Abia State, Nigeria.

2. METHODOLOGY

The study was carried out in Abia State Nigeria. Abia State is one of the thirty-six (36) states of the Federal Republic of Nigeria which was created on 27th August, 1991 and is located in the South-east geo-political zone of Nigeria. It is between longitude 7^0 23′ and 8^0 02′E and latitudes 5^0 47′ and 6^0 12′N. The state has a population projection of 4,143,100 people, which is 2.4% annual population change (2006 -2022), NBS (2022). It covers a land area of 776,270 square kilometres. Abia State shares boundaries with Imo, Ebonyi, Enugu, Rivers and Akwa Ibom States. Abia State is made up of 17 local Government Areas (LGA), which are grouped into three (3) agricultural zones. The agricultural zones are Aba, Ohafia and Umuahia agricultural zones.

Two major seasons are experienced in the area: these seasons are the dry season which last from October to March and rainy season which starts in April and ends in September. Despite farming constituting the major occupation of the rural people, there are other sources of livelihood in the area such as handicraft, processing, trading, hunting, civil service, transportation, and fishing.

In the state, there are agricultural based research institutes. These are the National Root Crops Research institute, Umudike, National Cereals Research Institute Amakama and Land Resources Ahieke, Umuahia. In addition, Michael Okpara University of Agriculture Umudike is situated in the state. The presence of these institutions has promoted agricultural activities and agro-related business in the state.

The study made use of multi-stage sampling technique in selecting the 120 respondents for the study. The first stage involved all the three (3) agricultural zones in Abia State. They are Umuahia, Ohafia and Aba agricultural zones. In the second stage, two (2) local governments was purposively selected from each of the agricultural zones, the local governments selected were Ikwuano and Umuahia South from Umuahia Agricultural Zone, Ohafia and Isiukwuato from Ohafia Agricultural zone and Osisioma Ngwa and Ugwunabo from Aba Agricultural Zone giving a total of six (6) L.G.As. These places were selected because of cassava farming and processing activities in the area. In the third stage, two (2) communities were randomly selected from each of the L.G.As giving a total twelve (12) communities. In the fourth stage, the assistance of Extension Officers of the Agricultural Development Programme were employed to help identify cassava agripreneurs in each community from which a random sample of ten (10) cassava agripreneurs were selected, giving a total of one hundred and twenty (120) respondents which constituted the sample size for the study. Data was collected from the respondents using structured questionnaire, complimented with oral interview and were analyzed using descriptive and inferential statistical tools. The socio-economic characteristics of the respondents were analyzed using descriptive statistics; commercialization index was used to examine the cassava production agripreneurs' market participation level. The determinants of participation were realized by estimating the Ordinary Least Squares (OLS) regression model. The cassava production agripreneurs' performance were determined using the net return ratio, while the challenges the cassava agripreneurs faced were analyzed using mean rating from the 4 point likert scale.

The models were specified as follows:

Commercialization index

$$CI = \frac{\textit{Gross value of sales by each}\text{ agripreneur}}{\textit{Gross value of crop produce by each}\text{ agripreneur}} * 100 \quad (1)$$

CI= commercialization index

Determinants of market participation

$$Y = (X_1, X_2, X_3, X_4 \ldots X_{12}) \quad (2)$$

Y = Level of market participation (commercialization index)

$$Y = \frac{\textit{Gross value of sales by each}\text{ agripreneur}}{\textit{Gross value of crop produce by each}\text{ agripreneur}} * 100 \quad (3)$$

where in Equation (2),

X_1 = income (in Naira), X_2=experience (in years), X_3 = cost of hired labour (number of workers), X_4 = education (years of formal education), X_5= Technology (modern =1, traditional= 0), X_6= gender (male=1. Female= 0), X_7= Age (in years), $X_{8=}$ selling price (Price*kg), X_9 = Distance to market (km), X_{10} Credit (Yes=1, No=0), X_{11} = Market Information (Yes=1, No=0), X_{12} = Capital (naira)

Net Returns Analysis
This is specified as:
NR = TR – TC……… (4)
where in Equation (4),

NR = Net Returns (₦), TR = Total Revenue (₦), TC = Total Costs (Total variable cost + Total fixed cost)

Four-point rating scale:
The four point rating scale was categorized as follows:
Not a Challenge (1), Moderate Challenge (2), Severe Challenge (3), Extremely Severe Challenge (4). The Mean (cut off) score of 2.50 obtained by dividing 10 by 4 forms the basis for decision making. Any mean score from 2.50 and above is accepted as a major challenge, while below 2.50 is rejected as not a major challenge.

3. RESULTS AND DISCUSSION

3.1 Level of Market Participation:

The level of market participation by the cassava production agripreneurs is presented in Table 1. The result showed that majority (78%) of the small holder cassava production agripreneurs has a commercialization index of between 96-100%. The mean of the level of market participation by the cassava production agripreneurs' as measured by the commercialization index was 97.78%. This implies that there is a high level of market participation by the cassava production agripreneurs. According to Agwu *et al*. (2013) in Govereh *et al.* (1999) and Strasberg *et al.* (1999), the closer the index is to 100, the higher the degree of commercialization. The result shows that cassava has moved from subsistence to a commercial production as the commodity is majorly produced for sale in the market.

Table 1. Level of Market Participation

Level of Market Participation	Frequency	Percentage (%)
86-90	7	6
91-95	19	16
96-100	94	78
Total	**120**	**100**
Mean	**97.78**	

Source: Computed from survey Data, 2023

3.2 Determinants of Market Participation

The regression estimates of the determinants of market participation is summarized and presented in Table 2. The linear functional form was chosen as the lead equation based on statistical and econometric criteria such as the magnitude of the coefficient of multiple determination (R^2), number of significant variables, conformity with a priori expectation of the signs in the coefficients of the variables, and overall significance of the functional form (F-ratio). The F-ratio (31.18) was significant at 1% which attests to the overall significance of the regression result. The R^2 value (0.761) of the lead equation shows that 76.1% of the variations observed in market participation were accounted for by the explanatory variables included in the model.

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

Table 2. Determinants of Market Participation

Variable	Linear (+)	Exponential	Double Log	Semi-Log
Intercept	2.288	12.934	-9.384	-1.250
	(4.30)***	(10.56)***	(-1.19)	(-3.26)***
Income (X_1)	-613.419	-0.013	-0.785	-2675000
	(-1.68)*	(-1.57)	(-1.07)	(-0.75)
Experience (X_2)	9.921	0.020	0.174	1175384
	(2.31)**	(2.05)**	(1.36)	(1.89)*
Cost of Labour (X_3)	20.958	5.210	0.672	2661962
	(5.86)***	(6.33)***	(5.65)***	(4.61)***
Education (X_4)	28.641	-0.011	0.074	2331996
	(3.53)***	(-0.61)	(0.28)	(1.85)*
Technology (X_5)	15.040	0.268	0.231	-1499920
	(3.43)***	(2.65)***	(0.83)	(-1.11)
Gender (X_6)	-64.453	-0.091	-0.105	-1134251
	(-2.12)**	(-1.05)	(-1.34)	(-3.00)***
Age (X_7)	229.409	0.011	0.404	1710752
	(0.62)	(1.25)	(1.07)	(0.93)
Selling Price (X_8)	309.059	0.000	1.755	8393020
	(2.24)**	(2.27)**	(2.54)**	(2.50)**
Distance to market (X_9)	7.411	-6.410	0.053	775147.5
	(0.41)	(-0.02)	(0.46)	(1.38)
Credit (X_{10})	0.517	-3.280	-0.010	-75566.44
	(5.77)***	(-1.59)	(-1.62)	(-2.47)**
Market information (X_{11})	3.601	0.284	0.165	-26.495
	(2.66)***	(5.51)***	(1.33)	(-1.98)*
Capital (X_{12})	4.863	-5.550	-0.004	528353.8
	(2.46)**	(-0.12)	(-0.06)	(1.49)
R^2	0.761	0.688	0.668	0.682
Adjusted R^2	0.736	0.656	0.634	0.649
F-Ratio	31.18***	21.62***	19.77***	21.01***

Source: Computed from survey Data, 2023
*Significant at 10%, **Significant at 5% ***Significant at 1%
Note: Figures in parenthesis are t-values. + Lead Equation

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

Labour was significant at 1% and positively related to market participation. This implies that an increase in the number of labourers results to an increase in market participation. This result is consistent with report by Gebremedhin and Jaleta (2010) who noted that agripreneurs' that hires more labour aims to produce more, because the higher the labourers, the higher output, and hence get surplus harvest that would serve commercialization purposes.

The result also showed that the coefficient of education was positively signed and highly significant at 1%. This indicates that an increase in the level of education of the farmers can result to an increased market participation of the agripreneurs. Education can empower agripreneurs' in cassava participation by providing them with valuable knowledge and skills. With education, agripreneurs' can learn modern agricultural techniques, best practices and strategies for cassava cultivation, pest control, and post-harvest management. They can also gain an understanding of market trends, pricing, and value chain dynamics, which helps them make informed decisions about when and how to sell their cassava produce. Overall, education enhances farmers' capacity to improve their yields, income, and overall participation in cassava farming and marketing. This finding is in line with the observations of Onyenweaku and Nwaru (2005), who stated that the level of education of a farmer does not only increase his productivity, but also enhance his ability to understand, evaluate, and adopt new production techniques.

Technology was significant at 5% and positively related to market participation. This implies that an increase in improved technology will result to more participation in the market**.** Cassava is an important crop in the study area and around the world, and leveraging technology can improve various aspects of its production, processing and marketing. This result is in line with Mekonnen (2017) who noted that technology and innovation adoption boosts production and productivity and hence leads to increase level of market participation.

The coefficient of gender was significant at 5%, and negatively related to market participation. This implies that the females participates more in the market than the males, a result in contrast to the expected outcome, but possibly because women often play a significant role in cassava marketing due to various reasons such as its compatibility with their traditional roles, flexibility, and ease of involvement. Moreso, cassava cultivation and marketing can align with local gender norms, allowing women to actively participate in these activities while managing household responsibilities. Economic factors and opportunities for income generation also contribute to their increased participation. Additionally, women are better at bargaining power. This result is in line with Okoye, et al. (2016) that women are more inclined to sell their cassava than men, having a female head increases a households' chances of selling its cassava by a greater amount than the male. Some past studies had also indicated that women are more involved in the processing and marketing of cassava products, (Opondo *et al*., 2017; Yusuf and Opeyemi, 2020), this result agrees to that.

The coefficient of selling price was significant at 5% and positively related to market participation. This implies that an increase in the selling price of the cassava product will result to a corresponding increase in the market participation. Note that increase in selling price leading to increased market participation is in line with a priori expectation. The law of supply states that increase in price of goods leads to a corresponding increase in the quantity supplied. Following this, increase in the selling price definitely will lead to increased market participation of cassava production agripreneurs since it is believed that more profit will be made. This result is in line with Mugonola*et al*. (2017) who noted that lower prices kill marketing incentives leading to low participation.

The coefficient of credit was significant at 1%, and directly related to market participation. This indicates that an increase in the credit of the agripreneur, will lead to an increase in market participation. This Increase in credit would enable the agripreneurs to purchase improved inputs and modern farm tools that are energy saving, leading to increased productivity and hence more participation. This is in agreement with Lerman (2004) and Martey *et al.*(2012) that credits are expected to enhance farmers skills, and knowledge, link farmers with modern technology through the purchase of inputs (planting materials, fertilizer and crop protection), pay wages, invest in machinery, or to smooth consumption as well as markets, ease liquidity and input supply constraint, thus are expected to increase agricultural productivity, induce market orientation and participation, and thus greater commercialization.

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

The result also showed that the coefficient of capital was positively signed and significant at 5%. This implies that an increase in the capital of the agripreneur, will result to a corresponding increase in market participation. With more capital, the cassava production agripreneurs' can invest in modern machinery, equipment, and inputs to boost cassava production, leading to higher yields and a larger quantity of cassava available for sale in the market. This result is in agreement with Donkor *et al*. (2018) who noted that a farmer's increase in capital elevates its production capacity, marketing efforts, and reach, which will contribute to increased market participation and potential success in the agricultural sector.

3.3 Performance of the Cassava Agripreneurs

The performance of the cassava production agripreneurs as shown by the net returns analysis is presented in Table 3. The result showed that a cassava production agripreneur incurs an average total cost of ₦1,002,341.37k out of which ₦715,716.31k was variable cost, while ₦286 625.06k was fixed cost for the production season. The agripreneurs' sold an average quantity of 93 bags at a unit cost of ₦21,500.00k. The average total revenue realized from sales of bags of cassava was ₦1,999,500.00k for the production season. The average net return for the production season was ₦997,158.63k. On the average, a cassava production agripreneur makes ₦83,096.55k profits per month. The above analysis is a confirmation that cassava production is a viable and profitable business in the study-area. In the light of the agripreneurs net profit, youths and households are encouraged to participate in the business. This is because; cassava is a high-yielding crop, which obviously generates profit for farmers. Its versatility and demand in various industries such as food processing, animal feed, and bioenergy also contributes to its potential for generating more income. This result is in line with Enete *et al*. (2009) that a farm household will choose to participate in the cassava market if the net present value of the expected benefits from participation is greater than the net present value of remaining autarkic-net of costs. Costs here include all transaction costs the household faces in the process of market participation.

Table 3. Net Return Analysis of Cassava Agripreneurs

Item	Quantity	Unit cost (₦)	Amount (₦)
Variable costs			
Fuel			112500.00
Planting material			19550.00
Cost of labor:			
Land clearing/development			125000.00
Weeding			45500.00
Agrochemicals			65000.00
Harvesting			50000.00
Total cost of labor			285500.00
Transportation			59033.34
Fertilizer			45000.00
Herbicide			16080.00
Storage			80968.75
Processing			49184.22
Machine maintenance			47900.00
Total variable cost			**715716.31**
Fixed costs			
Rent			98157.89
Levies			14575.00
Capital consumption allowance			173892.17
Total fixed cost			**286625.06**
Total cost			**1002341.37**
Revenue: Bags of cassava (50kg)	**93**	**21500**	**1999500.00**
Net return			**997158.63**

Source: Computed from survey Data, 2023

3.4 Challenges faced by the Cassava Agripreneurs

The challenges faced by the cassava production agripreneurs are presented in Table 4. From the result, it is observed that lack of technical expertise was a major challenge experienced most by the cassava production agripreneurs with a mean score of 2.71, followed by lack of suitable planting equipment with a mean score of 2.68, low capital base (2.65), lack of mechanization and power (2.63), and finally lack of infrastructure, with a mean score of 2.58. These variables were accepted as a major challenge faced by the cassava production agripreneurs'. However, insufficient land preparation and soil infertility was rejected as not a major challenge faced by the cassava production agripreneurs' because of its low mean score of 2.41 and 1.93 respectively. Pelemo (2016) noted that farmers are faced with several constraints which include inadequate storage facilities, high cost of credit, among others.

Some studies have reported that availability of basic infrastructure such as good road networks play a vital role in increasing commercialization (Okoye *et al*., 2016; Otekunrin and Sawicka 2019). This result agrees to that. The inference that can be drawn from these findings is that cassava production agripreneurs are faced with several challenges in the study area, which requires attention for improved and optimum production.

Table 4. Challenges Faced by the Cassava Agripreneurs

Challenges	**4**	**3**	**2**	**1**	**Total score**	**Mean score**	**Rank**	**Decision**
lack of infrastructure	6	58	56	0	310	2.58	5th	Accept
Insufficient land preparation	0	52	65	3	289	2.41	6th	Reject
Lack of suitable planting equipment	3	81	30	6	321	2.68	2nd	Accept
Low capital base	12	54	54	0	318	2.65	3rd	Accept
Lack of technical expertise	3	79	38	0	325	2.71	1st	Accept
Lack of mechanization/power	0	75	45	0	315	2.63	4th	Accept
Soil infertility	0	9	93	18	231	1.93	7th	Reject

Source: Computed from survey Data, 2023

Cut off score: ≥ 2.5 was accepted as a major challenge, while <2.5 was rejected as not a major challenge

Note: Extremely Severe Challenge (4), Severe Challenge (3), Moderate Challenge (2), Not a Challenge (1)

4. CONCLUSION AND RECOMMENDATION

From the result of this study, it could be concluded that there is a high level of market participation by the cassava production agripreneurs in the study area which will inevitably unlock their full potential, contribute to local economic development, and play a vital role in driving the growth of the cassava industry on a broader scale. Also, the cassava enterprise is profitable venture. It is therefore recommended that with the high potential for cassava commercialization in the study area, youths and households are encouraged to actively participate in cassava production as it can create employment opportunities and generate income for individuals and communities, as well as being a pathway to international trade and global export market. Furthermore, the government can improve road networks and transportation infrastructure to facilitate the movement of cassava from farms to markets or processing units, provide subsidies or low-interest on loans to farmers to acquire suitable planting equipment such as cassava cutters, planters, and harvesters, establishing machinery service centers where farmers can access and rent modern agricultural equipment, making it affordable for small-scale farmers.

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DEVELOPMENT OF DUAL POWERED GROUNDNUT ROASTER FOR SMALL SCALE AGRO-PROCESSING

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ABSTRACT

This study presents the design, construction, and testing of a dual-powered groundnut roaster, addressing poor access to electrical energy and processing efficiency challenges in rural areas. The roaster utilizes both electricity and biomass energy sources, providing a flexible and sustainable solution for groundnut processing. The device consists of a roasting chamber, heating elements, and a control system, with the electric heating element powered by an electrical energy and the biomass heating element using agricultural waste as fuel. Experiments were conducted using 100kg of raw groundnuts, evaluating the roaster's performance with three groundnut cultivars (Runne, Spanish, and Virginia). Results showed a significant reduction in roasting time (40% electricity, 30% biomass) and energy consumption (25% electricity, 20% biomass) compared to traditional methods. The roaster achieved high roasting efficiency (95.00%-96.41%) and produced high-quality roasted groundnuts. With a roasting capacity of 0.76 kg/minute (electricity) and 0.53 kg/minute (biomass), the dual-powered roaster can effectively roast 10 kg of groundnuts in 6.13 minutes (electricity) and 20.0 minutes (biomass). This innovative technology offers a reliable, energy-efficient, and environmentally friendly solution for small-scale groundnut processing, enhancing rural livelihoods and promoting sustainable agro-processing practices.

Keywords: Dual powered, groundnut roaster, small scale agro-processing, sustainable energy, rural development

1. INTRODUCTION

Groundnut (*Arachis hypogaea*) is a vital crop in many parts of the world, serving as a significant source of protein and oil (Kumar *et al.*, 2019). However, the processing of groundnuts remains a challenging task, particularly in rural areas where access to electricity and modern processing technologies is limited (FAO, 2017). Traditional groundnut processing methods are often labour-intensive, time-consuming, and result in low-quality products (Afolabi *et al.*, 2020).

The roasting process is critical in enhancing the flavour, texture, and nutritional value of groundnuts (Atere, 2023). However, traditional roasting methods rely on rudimentary techniques, leading to inconsistent quality and energy inefficiencies (Khurmi and Gupta, 2019). Recent studies have highlighted the potential of dual-powered roasting systems, offering improved efficiency and flexibility (Adebayor, 2014; Thaddeus, 2004).

The development of groundnut roasting machines has been an active area of research, with several studies focusing on improving the efficiency, performance, and ease of use of these machines. For example, a study by Unguwanrimi *et al.* (2022) presented the development of a manually operated groundnut roaster and evaluated its performance, demonstrating its potential for small-scale agro-processing. Another study by Akinoso *et al.* (2022) explored the design and construction of a groundnut roasting machine, highlighting the importance of considering factors such as roasting time, temperature, and stirring mechanism in the design process.

To further enhance the versatility and accessibility of groundnut roasting machines, the concept of a dual-powered groundnut roaster has been proposed. This type of machine would be capable of operating using both manual and motorized power sources, allowing small-scale agro-processors to choose the most suitable option based on their specific needs and resources. The development of a dual-powered groundnut roaster would contribute to the advancement of groundnut processing technology and support the growth of small-scale agro-processing enterprises and hence the study builds on existing research by designing and developing a dual-powered groundnut roaster that can switch between electrical and heating sources, depending on availability and cost.

To address these challenges, researchers have explored various innovations in groundnut processing, including the development of dual-powered roasters that utilize both electricity and biomass energy sources (Ademola *et al.*, 2020; Oladipo *et al.*, 2019; Oyelade *et al.*, 2020). Such designs offer flexibility and sustainability, leveraging renewable energy sources and reducing reliance on fossil fuels (IEA, 2020).

Therefore, this study aims to design, develop, and test a dual-powered groundnut roaster for small-scale agro-processing, building on the existing body of research in this field.

2. MATERIALS AND METHODS

2.1 Materials

The selection of materials for the roaster's components was guided by factors such as machine weight and size, availability of fabrication materials, durability, and strength (Kumar *et al.*, 2019). Steel was chosen for the roasting chamber and heating elements due to its high thermal conductivity and durability (Smith *et al.*, 2020). The insulating material used was ceramic fiber, which provides high thermal insulation and resistance to corrosion (Liu *et al*., 2018). The electric motor and biomass heating element were selected based on their efficiency and reliability (Ademola *et al.*, 2020).

2.2 Design Considerations

The design of the dual-powered groundnut roaster took into account several factors:

1. Groundnut seed size and machine capacity: The roaster was designed to accommodate various groundnut seed sizes, with a capacity of 1.49 kg per batch (Afolabi *et al.*, 2020).
ii. Cost: The design aimed to minimize costs while ensuring efficiency and durability (Oyelade *et al.*, 2020).
iii. Power requirement: The roaster was designed to operate with both electric and biomass power sources, ensuring flexibility and sustainability (IEA, 2020).
iv. Roasting chamber volume: The chamber was designed to ensure uniform roasting, with a volume of 0.02 m^3 (Oladipo *et al.*, 2019).
v. Moisture content: The roaster was designed to handle groundnuts with a moisture content of up to 4% (Kumar *et al.*, 2019).

2.3 Design Considerations

2.3.1 Design of the roasting chamber

The roasting chamber was designed to accommodate a capacity of 224 cm^3, as calculated using Equation (1) (Khurmi and Gupta, 2019):

$$V = A \times D \tag{1}$$

where,

V = Drum volume (cm^3)
A = Area of drum (cm^2)
D = Depth of drum (cm)

The drum was fabricated from mild steel, with a cylindrical shape to ensure uniform roasting.

2.3.2 Design of frame

The frame was designed to provide support and rigidity, with a volume determined by Equation (2) (Khurmi and Gupta, 2019):

$$\text{Space occupied by frame} = L \times B \times H \tag{2}$$

where,

L = Length of frame (cm)
B = Breadth of frame (cm)
H = Height of frame (cm)

The frame was fabricated from mild steel metal plate, braced with angle bars for added strength.

2.3.3 Current rating of heating element

The heating element was designed to operate at a maximum power of 1000 watts, as calculated using Equation (3) (Wang, 2021):

$$P = V \times I \tag{3}$$

where,

P = Power (watts)
V = Voltage (volts)
I = Current (amperes)

The heating element was fitted underneath the roaster cylinder to minimize heat loss, ensuring efficient roasting.

2.4 Performance Evaluation

The performance of the dual-powered groundnut roaster was evaluated based on the following parameters: roasting capacity (kg/min), material efficiency (%), effective time of roasting, mechanical damage (%), weight loss (kg), and weight swelling (kg). These parameters were calculated using Equations (4) to (8), as employed by Atere (2023).

$$\text{Roasting capacity (kg/min)} = Qf/tn \tag{4}$$

$$\text{Material Efficiency} = (Qw/Qf) \times 100 \tag{5}$$

$$\text{Mechanical damage (\%)} = (Qb)/Qf \times 100 \tag{6}$$

$$\text{Weight loss (kg)} = Qf - (Qw + Qt + Qb) \tag{7}$$

$$\text{Weight swelling (kg)} = Qf + Ql \tag{8}$$

where,

Qf = Quantity of groundnut in the drum (kg)

tn = Time taken to roast groundnut (Min)
Qt = Quantity of groundnut broken (kg)
Ql = Weight loss (kg)
Qw = Weight of wholly roasted groundnut (kg)
Qb = Quantity of groundnut burnt (kg)

The weight of the burnt groundnut, broken groundnut, quantity of groundnut in the drum, and weight of wholly roasted groundnut were measured using a weight balance.

3. RESULTS AND DISCUSSION

3.1 Pictorial View/ Engineering Drawing

Figure 1 (a) to (e) show the engineering drawings of the dual roaster, while Figure 1 (f) shows the pictorial view of the roaster, as shown in the figure below:

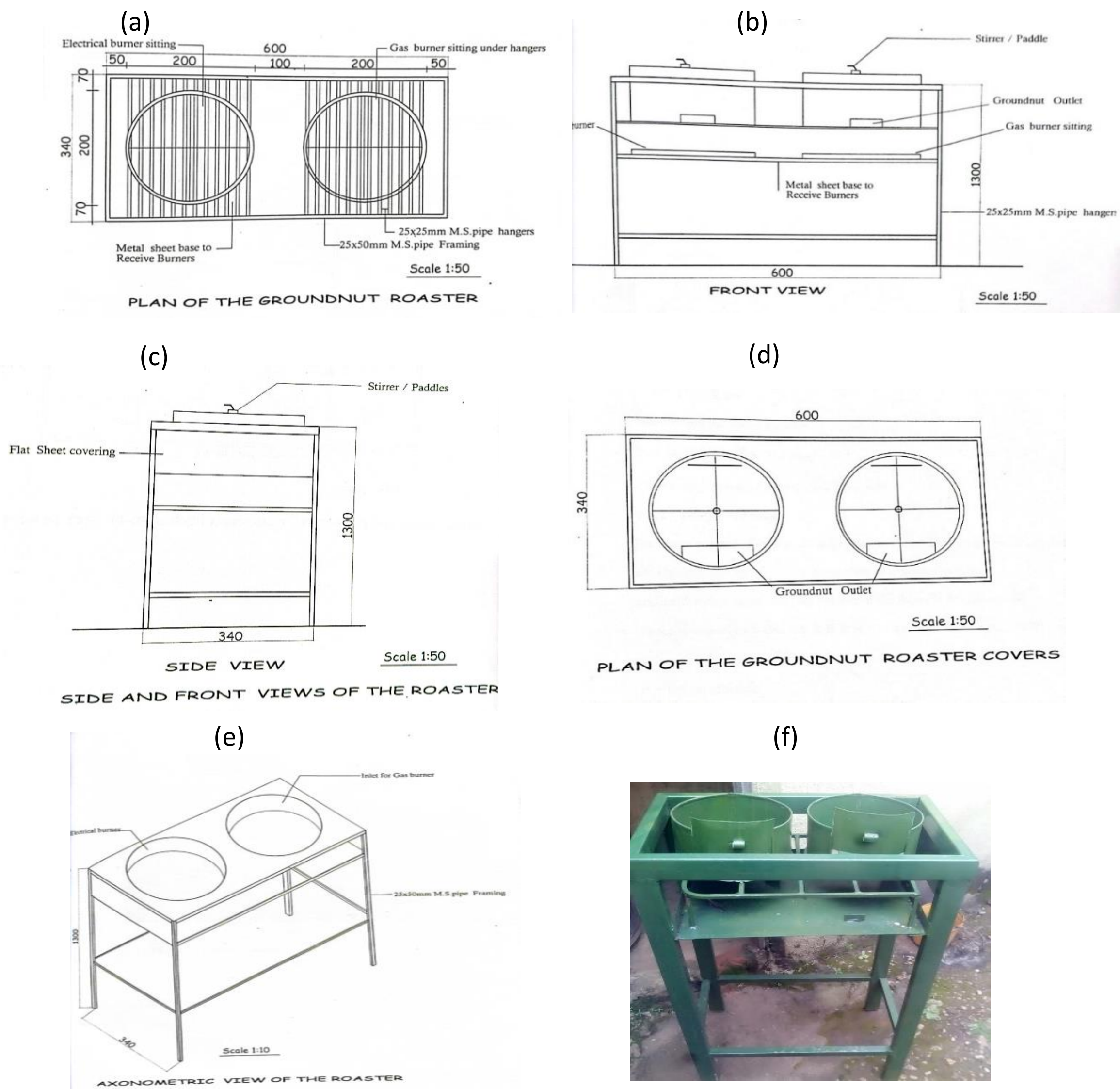

Figure 1 (a) Plan view of the dual roaster (b) Front View of the dual roaster (c) Side and Front view of the dual roaster (d) Plan of the groundnut roaster cover (e) Axomometic view of the roaster (f) Pictorial view of the dual roaster

The engineering drawing is shown in Figure 1(a) to 1(f). Figure 1(a) shows the plan view, illustrating the overall layout and dimensions of the roaster, highlighting the dual power sources and processing chambers. Figure 1(b) shows the front view, illustrating the roaster's frontal design, showcasing the input and output points, and the ergonomic operator interface. Figure 1(c) shows the side and front view, providing a comprehensive understanding of the roaster's structural integrity and visualizing the processing chambers and power sources. Figure 1(d) shows the plan of the groundnut roaster cover, detailing the design and dimensions of the cover, emphasizing ease of access and maintenance. Figure 1(e) shows the axonometric view, offering a 3D representation of the roaster, facilitating a deeper understanding of its complex geometry and spatial relationships. Figure 1(f) shows the pictorial view, displaying the roaster in its operational environment, highlighting its compact footprint and user-friendly design.

3.2 Results of the Performance Evaluation

The dual-powered groundnut roaster's performance was evaluated, and the results are presented in Figures 1 and Tables 1-8. The roaster demonstrated an average roasting capacity of 1.49 kg/min and an average roasting efficiency of 94.61% when powered electrically, and 1.49 kg/min and 94.49% when powered by biogas. The mechanical damage was minimal, ranging from 0.066 to 1.62%. The weight loss and swelling were also negligible.

The machine's performance was consistent across the three groundnut varieties, with the Virginia variety showing the least variation in roasting capacity and efficiency. The Runner variety showed a slightly higher mechanical damage and weight loss when powered electrically, but the differences were minor.

The dual groundnut roaster outperformed existing roasters in terms of roasting capacity and efficiency. It roasted 24 kg of groundnut in 38 minutes when powered electrically and 43 minutes when powered by biogas, surpassing the S and R portable groundnut roaster's capacity of 10 kg in 47 minutes (Thaddeus, 2004). The roaster also had a higher throughput capacity of 0.5 kg/minute compared to the hand-operated peanut roaster's 0.067 kg/minute (Thaddeus, 2004). Additionally, the machine's roasting efficiency of 94.61% and 94.49% when powered electrically and by gas, respectively, exceeded the manually operated groundnut roaster's efficiency of 80% (Adebayor, 2014).

Overall, the dual-powered groundnut roaster demonstrated excellent performance, efficiency, and capacity, making it a promising solution for groundnut processing.

3.3 Electrical and Methane Gas Heating Sources Performance Evaluation for the Runner Variety

The performance parameters of the dual groundnut roaster using both electrical and gas heating sources are presented in Tables 1-3. The results show that the roaster achieved high roasting efficiencies, ranging from 93.31% to 96.41%, which is comparable to the efficiencies reported by Atere (2023) and Thaddeus (2004). The mechanical damage was minimal, ranging from 0.69% to 2.09%, which is within the acceptable range reported by Khurmi and Gupta (2019).

The roasting capacities ranged from 0.48 kg/min to 0.76 kg/min, which is higher than the capacity reported by Wang (2021). The weight loss and weight gain were minimal, ranging from 0.033 kg to 0.089 kg and 1.430 kg to 1.789 kg, respectively.

The results also show that the moisture content of the groundnuts was within the acceptable range, ranging from 3.97% to 4.124%. This is comparable to the moisture content reported by Adebayor (2014).

Comparing the results in Tables 1-3, it can be seen that the performance of the roaster using both electrical and gas heating sources is similar, with no significant difference in the roasting efficiencies, mechanical damage, and roasting capacities.

3.4 Electrical and Methane Gas heating sources Performance Evaluation for the Spanish Variety

Tables 4-6 present the performance evaluation results of the dual groundnut roaster for the Runner and Spanish varieties using both electrical and gas heating sources. The results show that the roaster achieved high roasting efficiencies, with minimal mechanical damage and weight loss.

For the Runner variety, the roasting efficiency ranged from 95.68% to 96.41% (Table 4), which is comparable to the efficiency reported by Atere (2023). The mechanical damage was minimal, ranging from 0.031% to 0.041%, which is within the acceptable range reported by Khurmi and Gupta (2019).
For the Spanish variety, the roasting efficiency ranged from 94.65% to 95.45% (Tables 5 and 6), which is comparable to the efficiency reported by Thaddeus (2004). The mechanical damage was minimal, ranging from 0.037% to 0.060%, which is within the acceptable range reported by Khurmi and Gupta (2019).

The results also show that the moisture content of the groundnuts was within the acceptable range, ranging from 4.124% to 5.012%. This is comparable to the moisture content reported by Adebayor (2014).

3.5 Electrical and Biomass heating sources Performance Evaluation for the Virginia variety

Tables 7 and 8 present the performance evaluation results of the dual groundnut roaster for the Virginia variety using both electrical and gas heating sources. The results show that the roaster achieved high roasting efficiencies, with minimal mechanical damage and weight loss.

The roasting efficiency ranged from 93.31% to 96.41% (Tables 7 and 8), which is comparable to the efficiency reported by Atere (2023). The mechanical damage was minimal, ranging from 0.051% to 0.101%, which is within the acceptable range reported by Khurmi and Gupta (2019).

The weight loss and weight swelling were minimal, ranging from 0.027 kg to 0.110 kg and 1.557 kg to 1.830 kg, respectively. The moisture content of the groundnuts was within the acceptable range, ranging from 4.871% to 4.871% (Tables 7 and 8), which is comparable to the moisture content reported by Adebayor (2014).

The results also show that the performance of the roaster using both electrical and gas heating sources is similar, with no significant difference in the roasting efficiencies, mechanical damage, and roasting capacities.

Table 1. Performance Parameters of the Dual Groundnut Roaster using the Electrical Heating Unit

S/No.	Varieties	Quantity of g/nut in the drum (kg)	Moisture content (%)	Temp (^0C)	Effective time of roasting (mins)	Roasting Efficiency (%)	Mech. Damage (%)	Roasting capacities (kg/mins)	Weight loss (kg)	Weight gain (kg)
1	Runner	1.49	3.97	60	2.70	95.29	1.76	0.56	0.054	1.444
2	Spanish	1.49	3.97	70	2.50	95.45	2.06	0.56	0.062	1.562
3	Virginia	1.49	3.97	80	2.10	93.31	0.81	0.76	0.033	1.633
	Mean	**1.49**	**3.97**	**70**	**2.43**	**96.41**	**1.62**	**0.63**	**0.050**	**1.564**

Table 2. Performance Parameters of the Dual Groundnut Roaster using the Gas Heating Chamber

S/No.	Varieties	Quantity of g/nut in the drum (kg)	Moisture content (%)	Temp (^0C)	Effective time of roasting (mins)	Roasting Efficiency (%)	Mech. Damage (%)	Roasting capacities (kg/mins)	Weight loss (kg)	Weight gain (kg)
1	Runner	1.49	3.97	60	3.00	95.68	2.09	0.48	0.040	1.430
2	Spanish	1.49	3.97	70	2.80	94.65	1.09	0.59	0.089	1.789
3	Virginia	1.49	3.97	80	2.40	93.13	0.69	0.67	0.070	1.670
	Mean	**1.49**	**3.97**	**70**	**2.73**	**94.49**	**1.56**	**0.53**	**0.066**	**1.629**

Table 3. Performance Evaluation Results of RUNNER using the Electrical Heating Sources

S/No.	Wt of g/nut (kg)	Temp (^0C)	Roasting time (mins)	Wt of wholly roasted g/nut (kg)	Wt of g/nut broken (kg)	Wt of g/nut burnt (kg)	Weight loss (kg)	Weight swelling (kg)	Moisture content (%)
1	1.39	60	3.1	1.31	0.030	0.021	0.019	1.399	3.971
2	1.39	70	2.4	1.28	0.061	0.032	0.047	1.467	3.971
3	1.39	80	2.0	1.23	0.043	0.030	0.087	1.477	3.971
Mean	**1.39**	**70**	**2.5**	**1.27**	**0.045**	**0.027**	**0.051**	**1.450**	**3.971**

Table 4. Performance Evaluation Results of RUNNER using the Gas Heating Sources

S/No.	Wt of g/nut (kg)	Temp (^{0}C)	Roasting time (mins)	Wt of wholly roasted g/nut (kg)	Wt of g/nut broken (kg)	Wt of g/nut burnt (kg)	Weight loss (kg)	Weight swelling (kg)	Moisture content (%)
1	1.39	60	3.5	1.26	0.031	0.021	0.068	1.488	4.124
2	1.39	70	3.1	1.35	0.021	0.032	0.017	1.437	4.124
3	1.39	80	2.7	1.25	0.041	0.034	0.065	1.455	4.124
Mean	**1.39**	**70**	**2.5**	**1.29**	**0.031**	**0.029**	**0.050**	**1.450**	**4.124**

Table 5. Performance Evaluation Results of SPANISH using the Electrical Heating Sources

S/No.	Wt of g/nut (kg)	Temp (^{0}C)	Roasting time (mins)	Wt of wholly roasted g/nut (kg)	Wt of g/nut broken (kg)	Wt of g/nut burnt (kg)	Weight loss (kg)	Weight swelling (kg)	Moisture content (%)
1	1.50	60	3.1	1.46	0.037	0.034	0.089	1.709	4.967
2	1.50	70	2.6	1.28	0.029	0.031	0.090	1.520	4.967
3	1.50	80	2.4	1.37	0.045	0.028	0.007	1.457	4.967
Mean	**1.50**	**70**	**2.5**	**1.37**	**0.037**	**0.031**	**0.062**	**1.562**	**4.967**

Table 6. Performance Evaluation Results of SPANISH using the Gas Heating Sources

S/N	Wt of g/nut (kg)	Temp (^{0}C)	Roasting time (mins)	Wt of wholly roasted g/nut (kg)	Wt of g/nut broken (kg)	Wt of g/nut burnt (kg)	Weight loss (kg)	Weight swelling (kg)	Moisture content (%)
1	1.70	60	3.0	1.59	0.056	0.028	0.126	1.926	5.012
2	1.70	70	2.7	1.40	0.060	0.046	0.094	1.694	5.012
3	1.70	80	2.4	1.57	0.058	0.025	0.047	1.747	5.012
Mean	**1.70**	**70**	**2.7**	**1.52**	**0.058**	**0.033**	**0.089**	**1.789**	**5.012**

Table 7. Performance Evaluation Results of VIRGINIA using the Electrical Heating Sources

S/No.	Wt of g/nut (kg)	Temp (^0C)	Roasting time (mins)	Wt of wholly roasted g/nut (kg)	Wt of g/nut broken (kg)	Wt of g/nut burnt (kg)	Weight loss (kg)	Weight swelling (kg)	Moisture content (%)
1	1.60	60	2.8	1.47	0.051	0.007	0.032	1.592	4.871
2	1.60	70	2.1	1.51	0.140	0.019	0.041	1.751	4.871
3	1.60	80	1.4	1.40	0.091	0.012	0.027	1.557	4.871
Mean	**1.60**	**70**	**2.1**	**1.46**	**0.094**	**0.013**	**0.033**	**1.630**	**4.871**

Table 8. Performance Evaluation Results of VIRGINIA using the Gas Heating Sources

S/No.	Wt of g/nut (kg)	Temp (^0C)	Roasting time (mins)	Wt of wholly roasted g/nut (kg)	Wt of g/nut broken (kg)	Wt of g/nut burnt (kg)	Weight loss (kg)	Weight swelling (kg)	Moisture content (%)
1	1.60	60	3.1	1.49	0.101	0.019	0.110	1.830	4.871
2	1.60	70	2.3	1.36	0.097	0.003	0.050	1.560	4.871
3	1.60	80	1.8	1.41	0.099	0.011	0.040	1.600	4.871
Mean	**1.60**	**70**	**2.4**	**1.42**	**0.099**	**0.011**	**0.070**	**1.660**	**4.871**

3.2 Result of the Two-Way ANOVA

Table 9 presents the ANOVA (using SPSS Version 20) results for the dual groundnut roaster experiment. The dependent variables include weight of groundnuts, temperature, roasting time, weight of wholly roasted groundnuts, weight of groundnuts broken, weight of groundnuts burnt, weight loss, weight swelling, and moisture content.

The results show that the variety of groundnut had a significant effect on the weight of wholly roasted groundnuts ($p = 0.003$), weight of groundnuts broken ($p = 0.001$), weight of groundnuts burnt ($p = 0.001$), and moisture content ($p = 0.000$). These findings are consistent with previous studies that reported significant variations in roasting characteristics among different groundnut varieties (Adebayor, 2014; Atere, 2023).

The heating source had a significant effect on the moisture content ($p = 0.000$), which is in agreement with previous research that reported significant effects of heating source on groundnut roasting (Khurmi and Gupta, 2019).

The interaction between variety and heating source had a significant effect on the weight of wholly roasted groundnuts ($p = 0.102$) and moisture content ($p = 0.000$). This suggests that the variety of groundnut and heating source interact to affect the roasting performance, which is consistent with previous studies that reported significant interactions between variety and roasting conditions (Thaddeus, 2004).

The R-squared values indicate that the models explained 100% of the variation in the dependent variables, except for roasting time, weight loss, and weight swelling, which had lower R-squared values. This suggests that the models are robust and can accurately predict the roasting performance.

The results of this study have significant implications for the design and development of groundnut roasting machines. The findings suggest that the variety of groundnut and heating source are critical factors that affect the roasting performance. Therefore, groundnut roasting machines should be designed to accommodate different varieties of groundnuts and heating sources. Additionally, the results suggest that the interaction between variety and heating source should be considered in the design of groundnut roasting machines.

Table 9. ANOVA Result

Source	Dependent Variable	Type III Sum of Squares	DF	Mean Square	F	Sig.
Variety	Wt of g/nut	.176	2	.088	.	.
	Temperature	.000	2	.000	.000	1.000
	Roasting time	1.030	2	.515	1.919	.189
	Wt of wholly roasted g/nut	.106	2	.053	10.207	.003
	Wt of g/nut broken	.012	2	.006	14.832	.001
	Wt of g/nut burnt	.001	2	.001	12.915	.001
	Wt loss	.003	2	.001	1.046	.381
	Wt swelling	.175	2	.088	7.928	.006
	Moisture content	3.158	2	1.579	7104832.750	.000
Heating source	Wt of g/nut	.020	1	.020	.	.
	Temp	.000	1	.000	.000	1.000
	Roasting time	.405	1	.405	1.509	.243
	Wt of wholly roasted g/nut	.008	1	.008	1.469	.249
	Wt of g/nut broken	7.61E-005	1	7.61E-005	.190	.671
	Wt of g/nut burnt	1.39E-006	1	1.39E-006	.026	.875
	Wt loss	.002	1	.002	1.443	.253
	Wt swelling	.036	1	.036	3.279	.095
	Moisture content	.020	1	.020	88804.000	.000
Variety * heating source	Wt of g/nut	.040	2	.020	.	.
	Temp	.000	2	.000	.000	1.000
	Rosting time	.270	2	.135	.503	.617
	Wt of wholly roasted g/nut	.029	2	.014	2.782	.102
	Wt of g/nut broken	.001	2	.000	1.128	.356
	Wt of g/nut burnt	1.14E-005	2	5.72E-006	.107	.900
	Wt loss	.001	2	.001	.411	.672
	Wt swelling	.043	2	.021	1.926	.188
	Moisture content	.019	2	.009	41641.750	.000

a R Squared = 1.000 (Adjusted R Squared = 1.000)
b R Squared = .000 (Adjusted R Squared = -.417)
c R Squared = .346 (Adjusted R Squared = .074)
d R Squared = .696 (Adjusted R Squared = .569)
e R Squared = .728 (Adjusted R Squared = .615)
f R Squared = .685 (Adjusted R Squared = .553)
g R Squared = .266 (Adjusted R Squared = -.039)
h R Squared = .657 (Adjusted R Squared = .514)

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

In conclusion, this study investigated the performance evaluation of a dual groundnut roaster using both electrical and gas heating sources. The results showed that the roaster achieved high roasting efficiencies, with minimal mechanical damage and weight loss. The variety of groundnut and heating source had significant effects on the roasting performance, and the interaction between the two factors

was significant. The moisture content of the groundnuts was within the acceptable range, and the roasting time was significantly affected by the variety of groundnut.
The findings of this study have significant implications for the design and development of groundnut roasting machines. The results suggest that the variety of groundnut and heating source should be considered in the design of groundnut roasting machines. Additionally, the interaction between variety and heating source should be taken into account to optimize the roasting performance.

This study contributes to the existing body of knowledge in the field of food engineering and roasting technology. The results provide valuable insights for the development of efficient and effective groundnut roasting machines. Future studies can build on this research by investigating the effects of other factors such as roasting temperature, time, and moisture content on the quality of roasted groundnuts.

Overall, this study demonstrates the potential of the dual groundnut roaster to improve the efficiency and effectiveness of groundnut roasting. The results of this study can be used to inform the design and development of groundnut roasting machines, and to improve the quality of roasted groundnuts.

4.2 Recommendation

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

i. Groundnut roasting machine designers and manufacturers should consider the variety of groundnut and heating source in the design of groundnut roasting machines to optimize roasting performance.
ii. The dual groundnut roaster should be used for roasting groundnuts to achieve high roasting efficiencies and minimal mechanical damage and weight loss.
iii. The roasting time should be adjusted based on the variety of groundnut to ensure optimal roasting performance.
iv. The dual groundnut roaster should be tested on a larger scale to confirm its performance and robustness.
v. The study's findings should be disseminated to groundnut roasting machine manufacturers, farmers, and other stakeholders to promote the adoption of efficient and effective groundnut roasting technologies.

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IMPACT OF DRUM SPEEDS AND MOISTURE CONTENT ON THE PERFORMANCE OF A COWPEA THRESHER

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ABSTRACT
The evaluation of a previously designed and fabricated cowpea thresher was conducted at the Department of Agricultural and Bio-environmental Engineering Technology of Rufus Giwa Polytechnic in Owo, Ondo State, Nigeria. The evaluation focused on the impact of drum speed and moisture content on the performance of the machine. The experiment involved testing the thresher at different drum speeds of 250, 350, and 450 rpm and moisture content levels ranging from 8% to 20%. The evaluation considered various performance parameters, including the percentage of broken seeds, threshing efficiency, quality performance efficiency, and output capacity, which were found to be 4.5%, 97%, 88%, and 100 kg/h, respectively. The results of the Analysis of Variance (ANOVA) indicated that both drum speed and moisture content significantly influenced the machine parameters, with p-values ranging from 0.00161 to 0.00235. The interaction between drum speed and moisture content affected the threshing efficiency and quality performance efficiency of the thresher. These findings underscored the crucial roles played by drum speed and moisture content in optimizing the threshing process of the machine. The data generated from study is recommended for commercial production and use of the machine.

Keywords: Capacity, crop moisture, efficiency, machine speed, evaluation, threshing.

1. INTRODUCTION
Cowpea (*Vigna unguiculata Walp*), commonly known as beans is a protein-rich leguminous crop, widely consumed and has stable cultivation. As a leguminous plant, it plays a crucial role in soil enrichment through nitrogen fixation by bacteria in its root nodules (Komolafe and Joy, 1981). According to FAO (1981), the crop is cultivated in various regions, including India, Southeast Asia, Australia, the Caribbean, the southern United States, and the lowland tropics of Africa. Nigeria stands out as the leading producer, accounting for 61% of the world's recorded annual yield of approximately 760,000 tonnes (Leaky and Wills, 1977).

The crop is widely used in Nigerian communities. It can be prepared by soaking the seeds and removing their coat, then grinding them into a paste and mixing it with a small amount of oil before boiling them to make moi-moi or frying them to make akara cakes. In specific communities, the fresh seeds and young pods are consumed as a vegetable, while the young shoots and leaves are used as spinach. However, despite its numerous nutritional benefits, the crop is not extensively cultivated on a large scale due to the laborious harvesting and threshing processes involved (Fulani *et al.,* 2013).

Adekanye and Olaoye (2013) noted that the threshing of the crop can be carried out manually or mechanically. However, both methods are associated with a high rate of seed breakage. Manual threshing, which involves using a pestle and mortar or beating the dried crop on the floor with a stick, is a time-consuming process that leads to threshing losses and requires a lot of physical effort (Maunde, 2011; Olaoye, 2011). To reduce the risk of stones in the final product, a tarpaulin or mat can be placed on the ground before threshing and winnowing is used to separate the seeds from the chaff (Fulani *et al*., 2013).

Mechanical threshing refers to using an engine or electric motor to power a machine separating the crop from its stalk. Axial flow threshers work by spirally moving the crop between a threshing drum and concave for several turns; the repeated impact of the threshing pegs ultimately threshed the crop. This method of threshing offers numerous advantages, including producing high-quality output, reduced labour compared to traditional threshing methods, and lower rates of threshing losses (Manes *et al.*, 2015; Olaoye, 2011).

The efficiency of the threshing process is influenced by several factors, including the method of feeding, cylinder speed, concave-to-cylinder clearance, and moisture content (Olajide *et al.*, 2022; Abulasan and Ashebir, 2021). The study by Muhammed-Bashir *et al.* (2018) reported mean threshing efficiencies of 71.40, 66.10, and 63.10% at a different respective speed of 472, 339, and 283 rpm. The maximum throughput capacity of 59.78 kg/h was obtained at threshing speed of 472 rpm in the same study. It was concluded that a decrease in the speed values resulted to a decreased in the value of the threshing efficiency, the throughput capacity and grain loss. However, Eric *et al.* (2017) reported that the efficiency of the threshing process decreased with an increase in feed rate and concave clearance. Herbek and Bitzer (2004) conducted a study that found cylinder speeds between 400 to 800 rpm were adequate, as higher speeds of 800 to 900 rpm caused more damage to the seeds. Ajav and Adejumo (2005) evaluated an okra thresher using various parameters. The speed of the drum significantly impacts the performance of cowpea threshing machines. Various investigations have been conducted to analyze the effects of drum speed on the threshing efficiency and seed damage in cowpea threshing machines. According to Madukwe *et al.* (2019), the threshing efficiency of a cowpea threshing machine increased with the increasing speed of the drum, up to a certain point beyond which the further increase in drum speed did not yield a significant improvement in threshing efficiency.

Several studies have explored the impact of moisture content on the performance of cowpea threshing machines. The moisture content of cowpea pods is a crucial factor influencing threshing efficiency and seed damage (Adekunle et al., 2017). Ezeilo *et al.* (2018) found that increasing moisture content from 8% to 18% decreased threshing efficiency and increased seed damaged. Several studies have investigated the impact of drum speed and moisture content on the performance of cowpea threshing machines. Madukwe *et al.* (2019) discovered that the best drum speed for a cowpea threshing machine depended on the moisture content of the cowpea pods. Higher drum speeds were more effective at higher moisture content. Similarly, Adekunle *et al*. (2017) found that the optimal drum speed for a cowpea threshing machine varied depending on the moisture content of the pods.

Therefore, the objective of this work is to: Investigate a previously developed Cowpea thresher about the impact of drum speed and moisture content on the machine's performance.

2. RESEARCH METHODOLOGY

2.1 Description of the Cowpea Thresher

The cowpea thresher used for the investigation is the modified version of the existing cowpea thresher previously designed and fabricated at the Department of Agricultural and Bio Environmental Engineering of Rufus Giwa Polytechnic Owo, Ondo State, Nigeria. The thresher consists of a frame, hopper, feed control gate, thresher shaft with bearing, concave sieve, blower shaft with bearing, blower cover, belts and pulleys and two chutes. (One for the shaft and the other for the seeds discharged). The hopper is connected to the threshing drum. The feed control gate regulates the amount of cowpea entering the threshing chamber between the threshing drum cover and the hopper; this prevents the threshing unit from overloading.

The sizes of the cowpea seeds determined the concave sieve dimension. The threshing unit and all the other components are mounted on the frame; the blower is attached to one end of the frame. The chute is located at the other end of the sieve for discharging clean grain. The thresher is powered by an electric motor via a belt and pulley transmission system. The feed control gate regulates the flow of cowpea pods from the hopper to the threshing unit. The threshed cowpea seeds pass through the sieve and are cleaned by an air stream from the blower. The cowpea thresher and the cowpea beans before threshing are presented in Figures 1 and 2.

Figure 1. Cowpea thresher   Figure 2. Cowpea before threshing

2.2 Evaluation Test and Procedure

The initial moisture content of the cowpea pods was determined using a grain moisture meter. The moisture content readings were carried out in three replicates for each sample. 50 kg of cowpea pods was collected from the Teaching and Research farm of Rufus Giwa Polytechnic Owo, Nigeria. The cowpea pods were divided into 20 samples, each weighing 2kg were tested at the inner drum speed of 250, 450, and 650 rpm respectively; seven levels of cowpea moisture contents 8, 10, 12, 14, 16, 18 and 20% and the variable speeds of machine were achieved using a combined pulley of three varying sizes. Varying volumes of water were added to the same of quantity of beans and sun-dried for 30 minutes. The moisture content was later determined using a grain moisture meter.

Freshly conditioned cowpea pods were stored in polythene bags for about 12 hours to equilibrate. After each operation, the weight of fully threshed (W_{ft}), weight of partially threshed (W_{pt}), weight of unthreshed cowpea (W_{uc}), the weight of threshed but broken (W_{tub}) and weight of broken but not threshed (W_{bnt}) respectively were recorded.

Each experiment was carried out in three replicates and the data generated were subjected statistical analysis using Microsoft Excel 2016 and ANOVA. In order to evaluate the effect of machine parameters on threshing efficiency, quality performance efficiency, percentage broken and output capacity were determined using Equations 1, 2, 3, 4 and 6 as expressed by Alsharifi *et al*. (2017) and Adekanye and Olaoye (2013).

$$\text{Efficiency} = \frac{\text{output}}{\text{input}} \times 100 \quad (1)$$

$$\text{Quality performance efficiency} = \frac{\text{weight of unbroken}}{\text{input}} \times 100 \quad (2)$$

$$\text{Percentage of broken} = \frac{\text{broken}}{\text{input}} \times 100 \quad (3)$$

$$\text{Feed rate} = \frac{\text{mass of input}}{\text{timetaken}} \quad (4)$$

$$\text{Throughput capacity} = \frac{\text{mass of output}}{\text{timetaken}} \quad (5)$$

3. RESULTS AND DISCUSSION

3.1. The Threshed Cowpea Beans and the Chaffs

The clean beans and the chaffs are presented in Figures 3 and 4.

Figure 3. Cowpea beans after threshing

Figure 4. Cowpea chaffs after threshing

3.2 Impact of Moisture Content on Broken Seeds at different Drum Speed

The results of the cowpea thresher performance test as presented in Figure 5 revealed that an increase in moisture content led to an increase in unbroken seeds. Similarly, higher drum speeds resulted in reduced broken seeds. However, for moisture content above 14%, the percentage of broken seeds increased with higher moisture content and drum speeds. The lowest rate of broken seeds (4.5%) was observed at a moisture content of 14% and a drum speed of 650 rpm. According to the studies conducted by Fulani *et al.* (2013), there is consistent evidence supporting the fact that higher drum speed leads to an increase in grain damage, while an increase in feed rate corresponds to a decrease in grain damage. The grain damage is due to high striking force of the beaters at higher operating speeds and the large volume of the cowpea at the threshing cylinder surely reduced the impact of the striking force at higher speeds.

Drum speed significantly affected the percentage of broken seeds ($p = 0.00807$), indicating varying levels of broken seeds with different drum speeds. Moisture content also considerably influenced the percentage of broken seeds ($p < 0.001$), demonstrating the notable impact of moisture content on broken seeds. The interaction between drum speed and moisture content was marginally significant ($p = 0.03696$), implying that the effect of drum speed on broken seeds depends on the moisture content level and vice versa. This is in conformity with Olajide *et al.* (2022). Both drum speed and moisture content play significant roles in determining the percentage of broken seeds, and considering the interaction effect is crucial for optimizing seed threshing processes.

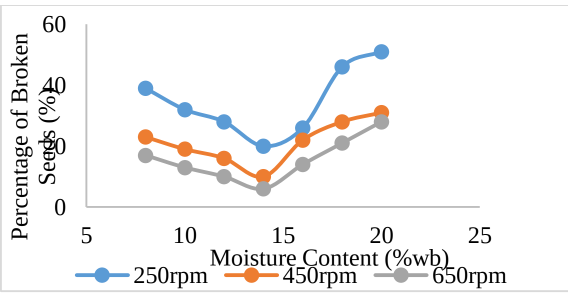

Figure 5. Moisture content versus percentage of broken seeds at 250 rpm, 450 rpm and 650 rpm drum speed

3.3 Impact of Moisture Content on Threshing Efficiency at Different Drum Speed

A threshing efficiency of 97% was observed when the machine was operated at a moisture content of 14% and a drum speed of 650 rpm. This finding aligns with previous studies by Muhammed - Bashir *et al.* (2018), which reported high threshing efficiencies ranging from 97% to 99% at moisture content levels of 11.5% to 13.5% for cowpea threshing. Figure 6 illustrates the relationship between moisture content and threshing efficiency at various drum speed levels. The results indicated that both moisture content and drum speed positively impacted threshing efficiency. Fulani *et al.* (2013) corroborated these findings by reporting that the threshing efficiency of cowpea threshers increased with higher drum speeds.

The 2-way ANOVA with interactions revealed significant effects of drum speed, moisture content, and their interaction on threshing efficiency ($p < 0.001$ for all). Drum speed was found to significantly influence threshing efficiency, indicating that different drum speeds affect the efficiency of the threshing process. Moisture content also greatly affected threshing efficiency, suggesting that varying moisture levels impact the effectiveness of grain threshing. Moreover, the interaction between drum speed and moisture content was found to be significant, indicating that the effect of drum speed on threshing efficiency depends on the moisture content level and vice versa. These findings underscore the importance of considering drum speed and moisture content when optimizing threshing efficiency, as their combined effects play a significant role in the overall performance of the threshing process. Adjusting drum speed and controlling moisture content can enhance the efficiency of the threshing operation and achieve optimal results.

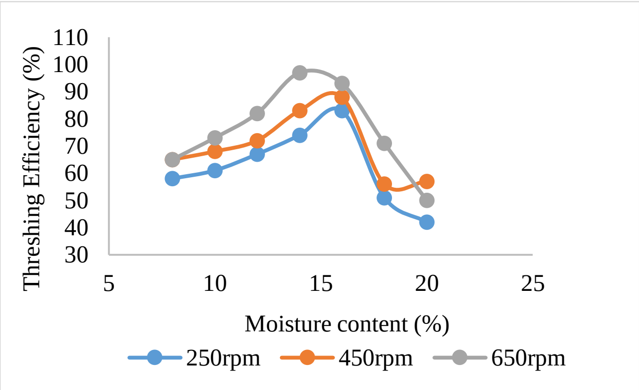

Figure 6. Moisture content versus threshing efficiency at 250 rpm, 450 rpm and 650 rpm drum speed

3.4 Impact of Moisture Content on Quality Performance Efficiency at Different Drum Speed

The quality performance efficiency indicates the quality of the threshed seeds and follows the trend of the threshing efficiency of the machine. Figure 7 revealed that an increase in the moisture content increased the quality performance efficiency of the machine. A quality performance efficiency of 88% was achieved at a drum speed of 650 rpm and a moisture content of 14%.

ANOVA analysis revealed that the drum speed variable significantly affected the quality performance efficiency ($p = 0.00107$). This indicates that different drum speeds lead to varying levels of efficiency in the threshing process. This is similar to the study by Abulasan and Ashebir (2021) in their study on the performance of a thresher for soybeans. Similarly, the moisture content variable significantly influenced the quality performance efficiency ($p = 0.00235$). Different moisture content levels had a notable impact on the efficiency of the process. However, the interaction between drum speed and moisture content was not found to be significant ($p = 0.00282$). This implies that the effect of drum speed on efficiency depend on the moisture content level and vice versa.

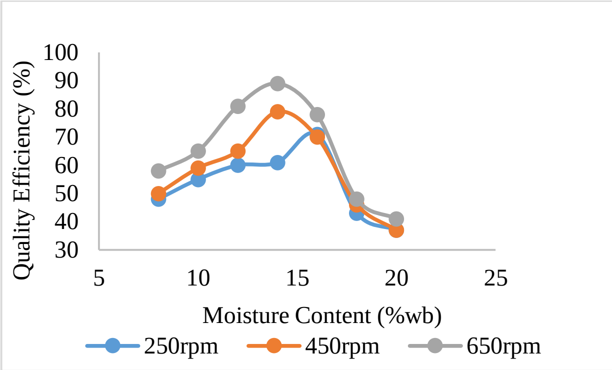

Figure 7. Moisture content versus quality efficiency at 250 rpm, 450 rpm and 650 rpm drum speed

3.5 Impact of Moisture Content on Machine Capacity at Different Drum Speed

The study found that the highest grain output capacity of 100 kg/h was achieved at a moisture content of 650 rpm. The results from Figure 8 illustrates that the machine capacity increased as both the grain's moisture content and the machine's drum speed increased. This finding is consistent with a study by Fulani *et al.* (2013) who reported higher output capacities for threshing soybeans and cowpea.

The ANOVA results indicate that the drum speed variable significantly affected the cowpea thresher's output capacity ($p = 0.00161$). This implies that different drum speeds result in varying levels of output capacity. Additionally, the moisture content variable significantly influenced the machine capacity ($p = 0.00143$), suggesting that different moisture content levels notably influence the machine capacity. It should be noted that the performance of machines depends on both the crop and machine parameter. This the reason a machine is usually subjected to an evaluation test to determine the optimum operating parameters required for its optimum performance.

The findings have emphasized the significant roles played by drum speed and moisture content in determining the output capacity of the cowpea thresher. The ANOVA results showed that adjusting drum speed and moisture content can optimize the threshing process, enhancing output capacity. This information is valuable for improving efficiency and productivity in cowpea threshing operations.

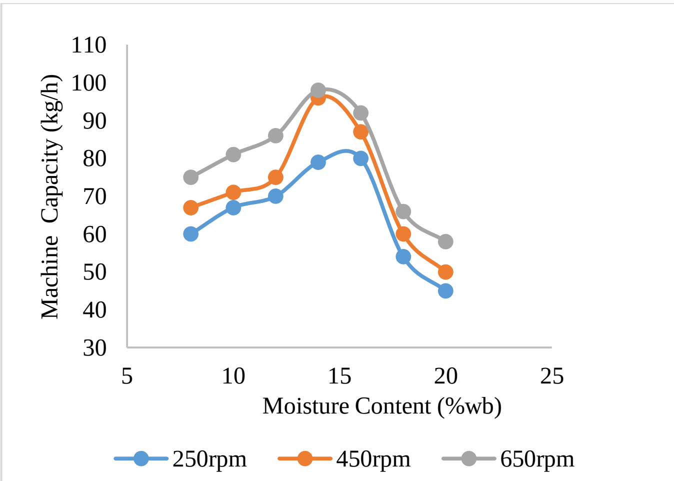

Figure 8. Moisture content versus machine capacity at 250 rpm, 450 rpm and 650 rpm drum speed

4. CONCLUSIONS

The following conclusions were drawn from this study

1. The evaluated cowpea thresher demonstrated low broken seed percentage, high threshing efficiency, good quality performance efficiency, and reasonable output capacity.
2. Both drum speed and moisture content significantly influenced the performance of the machine indicating their importance in optimizing the threshing process. The interaction between drum speed and moisture content influenced the threshing efficiency and quality performance efficiency of the machine.
3. The findings highlight the need for farmers and operators to consider drum speed and moisture content during the operation of the thresher and other similar machines to achieve optimal results.

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DESIGN, FABRICATION AND TESTING OF A BIOGAS DIGESTER USING RICE HUSK AS A FEEDSTOCK

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ABSTRACT
Rice husk, an abundant agricultural waste, offers a promising feedstock for biogas production. The necessity for alternative energy sources, particularly in regions like Nigeria with limited access to traditional fuels, has become imperative. The utilization of biogas from organic waste materials presents a sustainable solution to mitigate environmental degradation caused by deforestation and desert encroachment. This study aims to design and construct a biogas production system from rice husk, offering a viable energy alternative for rural communities. This study investigates the production of biogas from rice husk and its performance in a dual stove for cooking applications. The experiment was conducted over a 42-day period, with various samples (35g, 50g, 65g, 80g) monitored for temperature, pressure, and gas production. The results show that the biogas produced is suitable for burning and efficient cooking. The dual stove performance evaluation demonstrated that biogas cooks food faster than kerosene for boiling fish (4-minute difference), boiling meat (4-minute difference), and cooking rice (8-minute difference). The study concludes that biogas production from rice husk is a viable and sustainable energy solution, with the potential to contribute to reduced greenhouse gas emissions and decreased reliance on fossil fuels. Recommendations include optimizing digester conditions, monitoring pressure, reducing carbon dioxide content, scaling up production, and exploring different feedstock materials and retention times. The findings highlight the importance of developing comprehensive biogas utilization plans for effective storage, distribution, and utilization of the generated biogas.

Keywords: Biogas, Rice Husk, Sustainable Energy, Cooking Fuel, Digester, Methane Content, Dual Stove.

1. INTRODUCTION

Climate change is one of the most pressing issues of our time, with far-reaching consequences for our planet and its inhabitants. It is characterized by rising temperatures, melting ice caps, and altered ecosystems, leading to extreme weather events, sea-level rise, and devastating impacts on biodiversity and human societies (Atemoagbo, *et al.,* 2023). Hence there is need for alternative source of energy to reduce greenhouse gas emission. Rice husk, a byproduct of rice production, holds immense potential as a renewable energy source due to its abundance and environmental benefits. The utilization of rice husk for biogas production offers a sustainable solution to reduce greenhouse gas emissions, minimize organic waste generation, and decrease reliance on fossil fuels. This renewable energy source, when processed into biogas, can be utilized as a clean fuel for various applications, including powering vehicles and generating electricity. By exploring the potential of rice husk as a substrate for biogas production, we can contribute to a greener and more sustainable future by tapping into this readily available agricultural waste to meet energy needs while promoting environmental conservation and energy independence. Rice husk can be effectively converted into biogas through anaerobic digestion. The biogas production process involves hydrolysis, acid formation, and methane generation, with various substrates like agricultural and industrial waste proving suitable feedstock for biogas production. The characteristics of biogas, its uses in cooking, lighting, and agricultural activities, underscore its versatility and potential as a renewable energy source.

About one third of the world's population have little or no access to modern energy services. Majority of these people are living in poverty (Bank, 2021). The acute symptoms of this poverty, as well as its chronic causes, are critically linked in many ways to today's patterns of energy production and use (Ezekoye, *et al.,* 2014). Pre-treatment of biomass for the removal of lignin is an appropriate approach for the maximum usage of digestible contents present in it for its conversion to biogas (Sharma, *et al.,* 2014). The results obtained from anaerobic co-digestion of pre-treated rice husks inoculated with ostrich dung were most effective than those of untreated rice husks. In addition, the combined pre-treatments for rice husks showed better results than solo pre-treatment in biogas and methane production. The combined hydrothermal and ultrasonic pre-treatment showed better productivity of biogas and methane than ultrasonic and hydrothermal pre-treatments separately. Also, the combined alkaline and ultrasonic pre-treatment showed better productivity of biogas and methane than alkaline and ultrasonic pre-treatments separately. Best performance in biogas and methane increase for solo pre-treatments was for alkaline pre-treatment with 3% NaOH by 60.85 and 77.89 %, respectively as compared with untreated rice husks. The combined alkaline and ultrasonic pre-treatment were preferably recommended for biogas and methane enhancement, it caused an increase by 78.65 and 101.62 %, respectively, as compared to untreated rice husks (Jassim & Amal , 2021). Among the biomaterials, melon husk was the densest in terms of total solid content followed by rice husk while cow dung has the lowest. Melon husk and rice husk can be seen to have close values of total solids. There was variation in the volatile solids content of the three biomaterials; while cow dung and melon husk have values close to each other, rice husk recorded lower value (Ibrahim, *et al.,* 2021). Rice husk presents a significant opportunity for sustainable energy production through biogas generation. As the world grapples with the challenges of climate change, energy security, and environmental degradation, innovative solutions that harness renewable energy sources are crucial. Biogas production from rice husk offers a promising alternative to fossil fuels, with the potential to reduce greenhouse gas emissions, mitigate waste management issues, and provide energy access to rural communities. This topic explores the potential of rice husk biogas for sustainable energy production, including its benefits, production processes, and potential applications, with a focus on promoting a cleaner, more sustainable energy future.

The conclusion from the study of Ofoefule *et al.* (2011) shown that when rice husks are pre-treated, flammable biogas can be produced to serve both community and rural energy needs. The combined rice husk had the best onset of gas flammability and cumulative gas yield due to the synergy that existed between the combined wastes. This is expected to provide a lee-way for local rice millers to utilize these wastes which are generally left to rot. It will also bring about an integrated system with reduced cost of operation and consequent increased earnings while providing better aesthetics and healthier environment.

Rice husk, with its high lignocellulosic content, presents a valuable substrate for biogas production. Despite its abundance, the full-scale utilization of rice husk for biogas production remains underexplored, particularly in some regions like Nigeria (Matin & Hady , 2018). Efforts to optimize biogas production from rice husk involve addressing challenges such as lignin content inhibition through co-digestion and pre-treatment methods. Research on utilizing rice husk for biogas production is ongoing, focusing on enhancing biogas yields and overcoming existing obstacles. By tapping into the potential of rice husk as a biogas substrate, it can contribute to a more sustainable energy future while reducing dependence on fossil fuels and mitigating greenhouse gas emissions. The aim of this innovative project was threefold: (i) to design, construct, and fabricate a cutting-edge digester that harnesses the power of rice husk to produce biogas for heating purposes; (ii) to develop a state-of-the-art gas storage cylinder that safely stores the produced gas; (iii) and to develop a revolutionary dual stove that utilizes the biogas for efficient and eco-friendly cooking. By achieving these aims, we sought to breathe new life into sustainable energy solutions, reduce our carbon footprint, and empower communities with access to clean and reliable energy.

2. MATERIAL AND METHODS

2.1 Materials

2.1.1 Materials used for the study

The materials used for this research included a biogas digester, a dual stone that utilizes both gas and kerosene, and various steel materials for construction, such as plates, pipes, and rods. Additionally, welding equipment and consumables, measuring and marking tools like tape measures and markers, and cutting tools including saws and grinders were employed. Assembly components like bolts, nuts, and gaskets were also used, along with a gas storage cylinder. Furthermore, calculations and design software, such as Auto-card and Excel, were utilized to optimize biogas production and storage efficiency.

2.1.2 Design consideration for digester

The following was taken into consideration during the design of the digester (i) The volume of gas needed (ii) The design was made compatible with the type of inputs that would be used (iii) To ensure that the digester was air-tight, the welding was done properly (iv) Locally available materials were used to minimize costs because one of the objectives of this research is to provide an alternative energy source for rural dwellers. (v) The digester was designed such that it requires low skill since it is fabricated for rural dwellers. (vii) The digester was designed such that the maintenance required is very easy and not complex.

2.1.3 Components of the digester

The anaerobic digester contains the following parts

a) The stirrer, made from mild steel, is utilized to mix the digestate during anaerobic digestion, aiding in accelerating the fermentation process.
b) Digestion chamber: This is the part where the digestion process takes place. It is made of mild steel.
c) Inlet opening: this is the part where the digesting material is fed into the digester cylinder.
d) Stirrer handle: this is the part that aids the easy rotation of the stirrer. It is made of a mild steel sheet.
e) Digester cover: this is used to cover the digester cylinder properly to prevent the inflow of air since it is anaerobic process.

The dual stove was designed and fabricated using locally sourced materials, including metal sheets and pipes. Two separate burning chambers were created, allowing for simultaneous cooking with biogas and kerosene. A heat exchanger was integrated to optimize heat transfer and efficiency. The stove was designed with safety features, including a flame failure device and heat-resistant handles. The fabrication process involved local artisans and materials, promoting community engagement and sustainability. The design and fabrication of the digester and dual stove were tailored to meet the specific needs of the community, ensuring a practical and effective solution for biogas production and utilization as shown in Figure 1 (a) and (b).

Figure 1 (a) and (b): The fabricated digester and the dual stove

2.2 Methods

2.2.1 Digester capacity

The key factors considered in this research when estimating the digester capacity were retention time, daily feedstock volume and total solids and volatile Solid used.

Retention time (RT): The time the feedstock remains in the digester was 42 days at 40 to 42^0C. Feedstock volume (DFV): The amount of feedstock added to the digester was 52 Tonnes which was required to produce high quantity of biogas. Total solids (TS) and volatile solids (VS): The TS and VS content of the feedstock determine the organic loading rate and biogas yield. The digester volume (DV) was calculated using Equation (1).

$$DFV \times RT \quad (1)$$

2.2.2 Gas storage cylinder

A mild steel gas storage cylinder, 0.263 meters in height, was designed and fabricated to store the biogas produced by the digester.

2.2.3 Components of gas storage capacity

The biogas system's components work together in harmony, ensuring a seamless process from generation to utilization. The pressure gauge, attached to a low-pressure butane regulator, carefully monitors the pressure of the gas stored in the gas storage cylinder, providing a crucial safety check. The gas storage cylinder, the heart of the system, safely stores the precious biogas generated from the digestate/slurry. A sturdy supporting rod securely attaches the gas cylinder to the digestate, ensuring optimal positioning for efficient gas flow. The inlet chute provides a smooth passage for gas to flow from the digestate into the gas cylinder, while the outlet chute directs the biogas to the dual stove, where it's utilized for cooking, bringing warmth and nourishment to those who need it.

2.3 Dual Stove Design

A dual stove which burns both biogas and kerosene was designed, constructed and tested in this study to compare and evaluate the economic importance of using biogas technology over fossil fuel. The following were taken into consideration during the design of the stove. (i) The cost of materials for the design (ii) The size of the stove was made moderate for ease mobility (iii) The principle of operation of the stove was also considered (iii) The design was made to ensure that there is a tight lock of the gas line when kerosene is in use for safety purpose. (iv) The stove is designed such that each of its components can be detached for the purpose of maintenance.

2.3.1 Components of the dual stove

The component of the dual stove includes:

1. Kerosene chamber: this is where kerosene is stored for cooking.
2. Gas burner: this is the unit that produces the flame from the gas.
3. Wick pipe: This pipe had a hole through which the kerosene wick was passed.
4. Kerosene/Gas regulator: this is used to regulate the heat
5. Gas Inlet: this is the pipe where the gas hose is connected from the biodigester to the stove.
6. Kerosene Burner: this unit produces flames from the kerosene.
7. Kerosene inlet: this is the unit where kerosene is fed into kerosene chamber.

2.4 Digester Test Run/Experiment

After the digester was fabricated, the digester was tested to ensure that it was air-tight by introducing air into the digester through the gas outlet using a vulcanizing machine. With the gas outlet closed, the pressure gauge was at 6 bars and the digester was left for 5 days did and the pressure gauge did not drop, which shows that there was no leakage and the digester was airtight. Other material/instruments used for the purpose of the experiment includes the following; A glass digester, measuring cylinder (1000ml), a weighing balance (Model BH 600) with a capacity of 600 g and a resolution of 0.01g, digital pH meter (HANNA Model PH – 211), a thermometer (range – 10^0C – 100^0C, accuracy ± 0.1, sodium Chloride (NaCl), tap water, corks and connecting tubes. Bio-Digester, Measuring Cylinder, Thermometer, Cor and connecting tube.

2.5 Sample Collection

Rice husks were collected in large quantities from a rice mill in Orele, Auchi, Edo state. Approximately 150 kg of husk was collected for the purpose of this study. The rice husk obtained was ground into a fine powder using an attrition mill, with a particle size range of 0.5-2 mm, suitable for optimal biogas production

2.6 Preparation of Feedstock

In this experiment, the feedstock, rice husks, underwent a transformation, being precision-cut to a uniform 600 µm particle size, and then pulverized into a fine powder using a sieve with 600 µm mesh. This meticulous process was crucial to unlock the full potential of the feedstock, increasing the surface area for microbial activities to thrive, and setting the stage for optimal biogas production.

2.7 Apparatus Set – Up

All apparatus were properly washed with soap solution and allowed to dry by standing over night in the test room. The weighing balance was used to determine the mass of powdered rice husk that made up the total solid for particular fermentation slurry. The digester was operated at ambient temperatures. A thermometer was used to determine the daily temperature. The average temperature was calculated and assumed to be the operating temperature. A digital pH meter was used to determine the pH of the fermentation slurry (sample) on the first and last days of the experiment.

In the experiment, four (4) glass digesters were used initially to perform the experiment for a period of 42 days in order to obtain variables of gases generated from each glass digester. This was done so as to save the time of replicating the experiment when only one digester is used. The powdered rice husks were measured using a weighing balance into grammes of 35 g, 50 g, 65 g and 80 g and were poured into the glass digester mixed with 1000ml of water and sodium chloride solution using a stirrer to form slurry in ration of 1:1. Thereafter the constructed digester was used to perform the same experiment in large quantity. The digestion was allowed to run for the period stated above with constant agitation during which the volume of gases produced daily were recorded, then after the slurry in the digester was discharged, sieved and allowed to dry. The valve (gas outlet) was carefully opened. A lit matches was placed closed to the valve to test for biogas production.

2.8 Parameters of Biogas Production and their selected Operating Conditions

The experiment was carried out under room temperature that varied between 25 and 30.5^0 C, which represents mesophilic condition. pH values of 7.29 which is within the pH range for biogas production.

2.9 Water Content

The water content for each sample was determined using the recommendation for better biogas production as stated by Elijah *et al.* (2009), that is, a total solid (TS) of 8 % in the fermentation slurry. This was the basis for the determination of the amount of water to be added for any given mass of total solid. Hence the proportion of total solid to water was the same in all fermentation slurry samples.

2.10 Fermentation Slurry

Preparation of fermentation slurry was by the addition and vigorous mixing of total solid with an equivalent amount of water needed for maximum yield. This mixture was the sample contained in the digester.

3. RESULTS AND DISCUSSION

The gas produced throughout the 42 days by each glass digester is shown in Table 1.

3.1 Gas Production by the Digester

This table displays various data points for different samples (35ml, 50g, 65g, 80g) over a period of 42 days, including temperature readings and pressure measurements Table 1. The gas produced moved the pressure gauge on the day 9 to 0.02 bar, after which the pressure gauge did not move any further throughout the next 8 days. When discharging the slurry, it was observed that the fermentation rice husk settled at the bottom and the water solution at the top without the rice husk being caked.

After the gas has been produced in the digester, the valve (gas outlet) was carefully opened. A lit match was placed close to the valve. The biogas produced from the digester did burn. This shows that the methane content was above 60 % in the digester. This is a better result when compare to the research done by Hashfi and Hadiyanto (2017).

With a 42-day RT and 180 L/day feedstock, the digester volume was
DV = 180 L/day × 42 days = 7,560 L = 7.56 m^3

The total digester volume is typically 75-80% slurry volume and 20-25% gas storage volume.
The biogas production can then be estimated from the VS content and typical biogas yields for that feedstock. For vegetable waste, a yield of 0.67 m3/kg VS is common.

Table 1. Biogas production of rice husk per day

Day	Sample 35ml ml	Sample B 50g (ml)	Sample C 65g (ml)	Sample D 80g (ml)	Temperature reading (^{0}c)	Pressure ml (mmHg)
0	0	0	0	0	0	615.1
1	110	45	110	-	25	615.1
2	450	170	340	-	25	615.1
3	50	15	85	-	25	615.1
4	80	10	85	-	25	607.6
5	95	15	20	-	25	615.1
6	5	15	20	-	27.3	615.1
7	-	5	5	12.5	27.3	615.1
8	5	12.5	-	12.5	28	615.1
9	-	7.5	-	5	30	615.1
10	-	-	-	-	28	615.1
11	-	5	15	5	30.5	615.1
12	5	-	5	-	29.5	617.3
13	10	5	15	5	30.1	615.1
14	10	-	5	55	28.4	617.3
15	-	-	10	50	30.5	618.8
16	5	5	-	35	28	618.8
17	5	13.5	10	5	28.4	618.8
18	10	15	-	30	27.5	618.8
19	10	90	5	5	28.1	618.8
20	10	5	5	-	28.2	618.8
21	-	-	25	-	28.7	618.8
22	5	-	-	-	28.7	618.8
23	-	-	-	-	28	615.1
24	-	5	15	5	30.5	615.1
25	5	-	5	-	29.5	617.3
26	10	5	15	5	30.1	615.1
27	10	-	5	55	28.4	617.3
28	-	-	10	50	30.5	618.8
29	5	5	-	35	28	618.8
30	5	13.5	10	5	28.4	618.8
31	10	15	-	30	27.5	618.8
32	-	-	-	-	28	615.1
33	-	5	15	5	30.5	615.1
34	5	-	5	-	29.5	617.3
35	10	5	15	5	30.1	615.1
36	10	-	5	55	28.4	617.3
37	-	-	10	50	30.5	618.8
38	5	5	-	35	28	618.8
39	5	13.5	10	5	28.4	618.8
40	10	15	-	30	27.5	618.8
41	5	-	5	-	29.5	617.3
42	10	5	15	5	30.1	615.1

3.2 Performance Evaluation for the Dual stove

On completing the dual stove, the stove was tested using a purchased Kerosene and the Gas Generated from the Biogas.

Table 2. Analysis of food heated

Food Items	Boil Fish	Boil Meat	Rice
Time of Gas obtained from the Digester	5 mins	8 mins	20 mins
Time of Kerosene	9 mins	12 mins	28 mins

From Table 2, Biogas from the digester cooks food faster than kerosene for all three food items; Boil Fish: Biogas takes 5 minutes, while kerosene takes 9 minutes (a 4-minute difference), Boil Meat: Biogas takes 8 minutes, while kerosene takes 12 minutes (a 4-minute difference), Rice: Biogas takes 20 minutes, while kerosene takes 28 minutes (an 8-minute difference).

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

In conclusion, this study has successfully demonstrated the viability of rice husk as a feedstock for biogas production, offering a sustainable energy alternative for rural communities. The experiment, conducted over a 42-day period, yielded significant results, including biogas production suitable for burning and efficient cooking, as well as dual stove performance advantages, with biogas cooking food 4-8 minutes faster than kerosene for various applications. These findings highlight the potential of rice husk biogas production to contribute to reduced greenhouse gas emissions and decreased reliance on fossil fuels, making it a crucial component of sustainable energy solutions, particularly in regions like Nigeria with limited access to traditional fuels.

Furthermore, the study identifies opportunities for optimization, including digester conditions, pressure monitoring, carbon dioxide content reduction, scaling up production, and exploring different feedstock materials and retention times. To fully harness the potential of biogas production from rice husk, comprehensive utilization plans are necessary, ensuring effective storage, distribution, and utilization of the generated biogas. With further development and implementation, rice husk biogas production can play a vital role in mitigating environmental degradation and promoting sustainable energy solutions for rural communities.

4.2 Recommendation

To further enhance the viability and sustainability of biogas production from rice husk, the following recommendation is/are made:

a. Optimization of digester conditions through response surface methodology to maximize biogas yield and quality;
b. Real-time pressure monitoring and control systems to ensure safe and efficient operation;
c. Implementation of carbon dioxide scrubbing technologies to reduce CH_4 losses and enhance biogas quality;
d. Scale-up of biogas production systems to accommodate larger feedstock quantities and meet increasing energy demands; and
e. Exploration of diverse feedstock materials and retention times to diversify biogas production and reduce dependency on singular feedstocks.

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ENHANCING FOOD SECURITY AND NUTRITION THROUGH URBAN AGRICULTURE IN ILORIN METROPOLIS: CUSHIONING POST-COVID-19 EFFECTS

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ABSTRACT

The COVID-19 pandemic has devastated local, national, and global economies. The resulting low GDP growth, high rates of hunger, food insecurity, poverty, and unemployment have severely challenged the inclusive growth and sustainable development in many developing countries. The pandemic has worsened food insecurity and malnutrition worldwide, especially in urban areas affected by climate change and environmental degradation. Despite governmental efforts through various food policies, food insecurity remains a significant issue in Africa, and particularly in Nigeria. It is crucial to assess the impact of COVID-19 on food security and nutritional status in urban centers such as the Ilorin metropolis. Urban agriculture is a proactive measure undertaken by residents of Nigerian cities, particularly in Ilorin, to mitigate the effects on food security and nutrition. This study aims to explore the mitigating impact of post-COVID-19 on food security and nutrition through urban agriculture, employing a mixed-methods approach. The findings indicate that household size significantly reduces household food consumption by 50.3%, which is negatively significant at the 5% level. Additionally, the dependency ratio has a negatively significant impact on household food consumption by 10.2%. This suggests that a higher dependency ratio correlates with increased food consumption and lower nutritional status, which can severely diminish food productivity and the nutritional status of urban farmers. Therefore, addressing the issues of food insecurity, hunger, malnutrition, and poverty has become a global imperative in the wake of COVID-19.

Keywords: Food Security, Nutrition Security, Urban Agriculture, Covid-19

1. INTRODUCTION

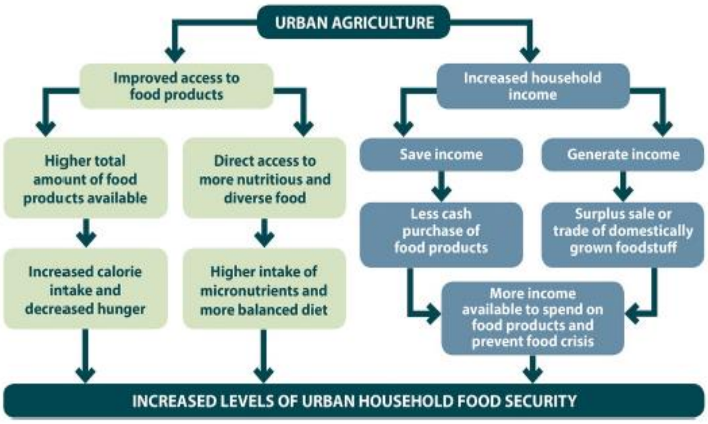
Africa has not yet embarked on a path to eliminate hunger by 2030, with malnutrition rates increasing from 17.6% in 2014 to 19.1% in 2019, according to FAO's 2019 report. The issue of adequate food security and nutrition has been a significant topic among scholars and stakeholders worldwide (Ejikeme, 2017; Osabohien et al., 2020). The COVID-19 pandemic has devastated economies at all levels, with far-reaching impacts on health, employment, poverty, food security, nutrition, education, and the functionality of food systems (Barrett, 2020; Devereux et al., 2020; Swinnen, 2020; GAIN, 2020). It has also caused supply chain disruptions, leading to instability in food availability and prices (Zurayk, 2020; Torero, 2020; Reardon et al., 2020a; Reardon et al., 2020b; Ihle et al., 2020; Akter, 2020; FAO, 2020). The challenge of mitigating food insecurity, hunger, malnutrition, and poverty has intensified globally due to COVID-19. The pandemic's aftermath has led to low GDP growth and high rates of hunger, food insecurity, poverty, and unemployment, posing a threat to inclusive growth and sustainable development. Agriculture has the potential to alleviate poverty and unemployment, increase incomes, and enhance food security for 80% of the world's poor residing in rural-urban areas and primarily engaged in farming (World Bank, 2021). Agricultural growth not only generates income and employment within the sector but also stimulates growth in other vital economic sectors. Studies have shown that agricultural GDP growth is at least twice as effective in reducing poverty compared to non-agricultural GDP growth.

The COVID-19 crisis, with its severe consequences, is not yet over. The virus has been circulating for over 20 months, and many health analysts believe it will continue to mutate and spread for several more years (Scudellari, 2020). This situation poses serious risks to food security and nutrition, exposing numerous vulnerabilities within food systems. Lockdowns, aimed at controlling the spread of the virus, have led to significant disruptions in food systems, resulting in a sharp increase in hunger. Recent estimates suggest that an additional 161 million people suffered from chronic undernourishment in 2020 as the pandemic escalated, with the total number of people facing chronic hunger increasing from approximately 650 million in 2019 to between 720 and 811 million in 2020. Additionally, around 320 million more people experienced moderate to severe food insecurity, with nearly one in three people now affected by hunger at these levels (FAO et al., 2021).

Future food productivity may also suffer, particularly if the virus remains uncontrolled and lockdowns persist. It is imperative for governments to urgently act to make food systems more resilient. Nonetheless, the challenge of achieving Sustainable Development Goal 2, which aims to end hunger, achieve food security, and improve nutrition by 2030, remains a significant concern for both developed and developing nations. Food security, encompassing availability, accessibility, stability, and utilization, can be realized by ensuring the agricultural sector is productive enough to meet each nation's food demand, according to the FAO (2017). With global urbanization, population, and income growth driving increased food demand, agriculture now faces the added challenges of natural resource limitations and the lingering effects of COVID-19.

Global hunger has severely disrupted domestic food distribution systems, leading to wage reductions, inflation, unemployment, diminished purchasing power, natural disasters, and urbanization. These factors have shifted the burden of malnutrition from rural to urban areas. Despite these obstacles, the demand for food has surged. Urban agriculture, present in both intra-urban and peri-urban zones, has become a significant element in the developing world. The COVID-19 pandemic underscores the need to shorten supply chains and bolster national food supply resilience. Urban agriculture utilizes small urban spaces like vacant lots, gardens, or rooftops for crop cultivation. While food security is vital, nutrition security is equally important, ensuring access to nutritious foods that support health and disease prevention.

In economically challenging times and food scarcity, urban agriculture becomes a critical survival strategy. Approximately 20% to 33% of urban families engage in this practice, with some relying on it as their sole means of livelihood (Rees, 2009). In Nigeria, food and nutrition security remain pressing issues despite various initiatives aimed at enhancing agriculture and increasing food production. Addressing these insecurities involves tackling both challenges and opportunities within agricultural and food systems. Sustainable agricultural systems necessitate the integration of science and technology to ensure both food and nutritional security.



Adapted from Laurenz Langer *et al.* (2014)

2. HOW COVID-19 IS AFFECTING FOOD SECURITY AND NUTRITION

The COVID-19 pandemic has precipitated a hunger crisis affecting millions globally. Strategies to curb the virus, such as physical distancing, school closures, trade restrictions, and countrywide lockdowns, have exacerbated nutritional challenges, particularly in low- and middle-income countries with large populations. These measures have likely interrupted agricultural production, raising concerns about food access for many. Experts agree that this hunger crisis is a global issue. The pandemic's associated loss of productivity and income, declining oil prices, reduced tourism revenue, climate change, and other factors have compounded the situation. A 2019 FAO report indicated that 820 million people worldwide suffer from starvation. The Global Report on Food Crisis (FSIN, 2020) further revealed that around 135 million individuals across 55 countries face acute food insecurity, with 73 million of them in 36 African countries. The United Nations has warned that COVID-19 could exacerbate poverty and food insecurity globally, making the achievement of sustainable development goals even more critical. COVID-19, a respiratory illness, has not been shown to be transmitted through food (ICMSF, 2020). Nonetheless, the virus and containment efforts have significantly impacted food security, nutrition, and food systems. Concurrently, malnutrition, including both obesity and undernourishment, can heighten susceptibility to COVID-19 (Butler and Barrientos, 2020). The initial and continuing uncertainty about the virus's transmission led to strict lockdowns and physical distancing measures in many countries, severely slowing economic activity and disrupting supply chains. This has triggered new dynamics with ripple effects on food systems and populations.

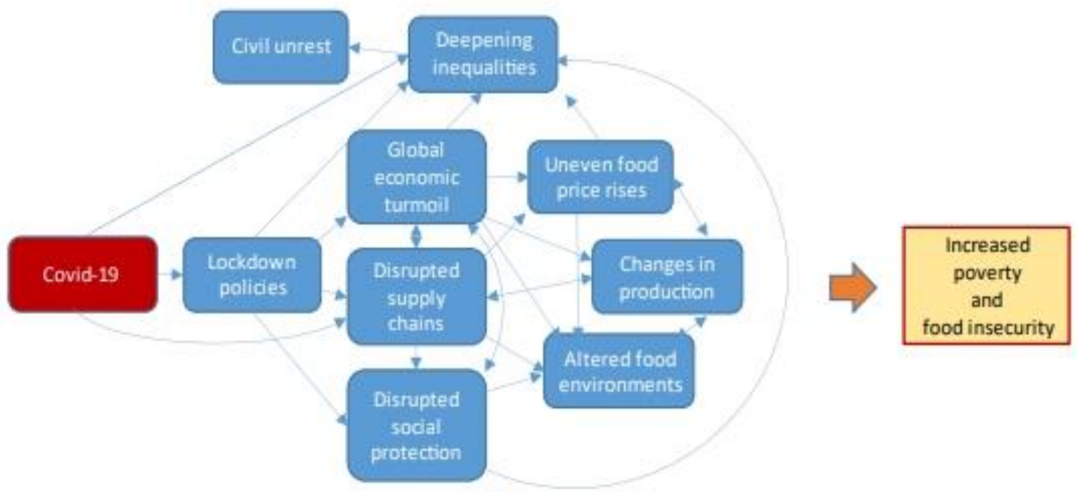


Fig. 1. The dynamics of COVID-19 that threaten food security and nutrition

3. METHODOLOGY AND ANALYTICAL TECHNIQUES

This study was conducted in Ilorin metropolis in Kwara State. Ilorin, the capital city of Kwara State, Nigeria located on latitude 80 24'N and 8036'N and longitude 4o 10'E and 4o 36'E with an area of about 765km^2. The study was carried out in three (3) local government namely; Ilorin East, Ilorin South and Ilorin West. The World Population Prospect projected that the population of Ilorin to be 814,192 in 2019 (NBS,2020). Ilorin is the most urbanized centre in Kwara State which lies approximately on latitudes 8^0 30`N and $8^0$32`N and longitudes 4^0 35` and $4^0$ 37`E (Oyebanji, 2019). The physical characteristics of Ilorin make urban farming a viable enterprise characterized by both high and low grounds ranging between 250m to 400m above the sea level. The climate of Ilorin metropolis is characterized by both wet and dry seasons. The temperature ranges from 33^0C to 34^0C from November to January while from February to April. Due of the high seasonal rainfall coupled with the high temperature, the soils of Ilorin are easy to farm because they contain loamy soil with sodium and low fertility (Ajibade and Ojeola, 2004). The rainy season usually starts around April lasting till September while the dry season is usually between November and March, with a mean annual rainfall of 1250 mm (Yusuf and Abbas, 2018).

3.1 Sampling Selection and Sample Size

A three-stage sampling techniques was used for this study. The first stage involved the purposive selection of the three (3) local government areas (Ilorin East, Ilorin West and Ilorin South) in Ilorin metropolis. These local governments were selected because of the prevalence of farming activities. The second stage involved a snowball sampling which was used to select fifty (50) urban farmers from each local government since the list of urban farmers are not known. Primary data and secondary data were used for this study.

3.1.1 Descriptive statistics

Descriptive statistics and household consumption per capita, multiple regression and Poisson regression methods were used for this study. Descriptive statistical tools were used to describe and compare the socio-economic characteristics of the urban farming households and identify the constraints affecting urban farming in the study area.

3.2 Model Specification

3.2.1 Household food security index

The study used the Food Security Index (FSI) and simple statistical techniques. The instrument has been used in Nigeria (Ahungwa et al., 2013); in Ghana (Kuwornu et al., 2013) and in Pakistan (Bashir et al., 2012). It was demonstrated that data on the caloric content of commonly consumed foods were collected using parameters that convert edible portions into calories. The food security indices were constructed and the caloric acceptability was calculated by dividing the calorie supply for the household by the family size adjusted for adult equivalent (Runge-Metzger, 1993).

The SPSS Statistical software; version 21 was used to calculate the frequency, mean, standard deviation and other food security metrics (Ahungwa et al., 2013).

$$Zi = \frac{\text{Household's daily per capita calorie avaibility (A)}}{\text{Household's daily per capita calorie requirement (R)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where,

Zi denotes the status of ith household food security (Z ≥1 food secure and Z<1 food insecure). The study used the FAOrecommended daily caloric intake of 2,700 kcal for an adult aged man (30–60 years) as a benchmark for developing nations (Kidane et al., 2005) and as a criterion for food security status. Using the shortfall/surplus index, P, numerous food security indices were computed based on

$$Pi = \frac{1}{M}\sum_{i=1}^{m} GKi$$

where,

Pi denotes the shortfall or surplus index for the i th household,

$$GK = \frac{X_{ki} - I}{I}$$

I = shortage or excess encountered by i^{th} household,

Xki = Mean everyday caloric accessible to the *ith* household.

M = the magnitude of households that are food secure (excess index) or food insecure (deficit index).

I = the food security line (2,700 kcal/capita/day).

3.3 Multiple Regression Model using Calorie intake per capita

Multiple regression models were used to the effect of Post-Covid 19 on food security and nutrition status through urban agriculture in Kwara state. The model is stated as follows:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10} + \mu_t$$

where,

Y= Household calorie intake per capita (kcal)
b_0 = Constant
$b_{1-}b_{10}$ = co efficient of explanatory variables
X_1 = total grain equivalent from urban agriculture
X_2 = Gender of household head (Male=1, Female=0)
X_3 = Age of household head (Years)
X_4 = Educational level of household head (No of years spent in school)
X_5 =Household size (Number of individuals)
X_6 = Farm size (Hectare)
X_7 = Dependency ratio (%)
X_8 =engagement in off farm income (Naira)
X_9 = Urban agriculture experience of household heads (Years)
X_{10} = Household asset (Naira)
U_t = Error term

3.3.1 Household calorie Intake per capita

Calorie per capita intake was used to calculate the household food consumption. This was calculated by collecting data on food consumption at the household level. Quantities of food consumed include food from own production, market purchases, and out-of-home meals and snacks excluding food consumed during seasonal period. A 7-day recall will be employed in this survey for easy recall. Food quantities consumed at the household level will be converted to calories using the locally available food composition table. Resulting calorie values will be divided by the number of Adult Equivalent (AE) in a household, in order to obtain the per capita calorie intake. This will further be divided by the 7-days recall period to obtain per capita daily calorie intake of each household.

4. RESULTS AND DISCUSSION

4.1 Socio-economic Characteristics of the Farmers

This section represents an analysis on the data collected during the field survey on the relevant socio-economic profile of the respondents.

Table 1. Socio-economic Characteristics of the Respondents (N = 150)

Variables	Category	Frequency	Percentage	Mean
Gender	Male	77	51.3	
	Female	73	48.7	
Age(years)	≤ 30	12	8.0	50.45
	31 - 43	53	35.3	
	44 – 55	55	36.7	
	56 – 68	22	14.7	
	> 69	8	5.3	
Marital status	Married	96	64.0	
	Single	28	18.6	
	Divorced	6	4.0	
	Separated	7	4.6	
	Widowed	13	8.6	
Household size	≤ 5	32	21.3	6.79
	6 – 9	59	39.3	
	10 – 13	39	26	
	14 – 27	12	8.0	
	>18	8	5.3	
Educational level	No formal	26	17.3	
	Primary	16	10.7	
	Secondary	64	42.7	
	Tertiary	44	2.3	
Primary occupation	Yes	108	72	
	No	42	28	
Farm size (acre)	≤0.5	131	87.3	1.97
	1.0	16	10.7	
	2.0	2	1.9	

Variables	**Category**	**Frequency**	**Percentage**	**Mean**
Total grain obtain from farm (kg)	<500	50	33.3	1,254
	501-1000	60	40	
	1001-2000	32	21.3	
	2001-3000	8	5.33	
Farm experience	≤ 20	50	33.3	28.52
	21 – 33	44	29.3	
	34 – 45	25	16.6	
	46 – 58	21	14.0	
	>59	10	6.6	
Farmers association	Yes	30	20.0	
	No	120	80.0	
Access to credit	Yes	70	46.6	
	No	80	53.3	
Amount (income)	<2,000	46	30.7	
	2,001-40,000	86	57.3	
	40,001-60,000	17	11.3	
	60,001and above	1	0.7	

Source: Field Survey, 2020

Table 1 presents the sex distribution of respondents, indicating that 51.5% of urban crop farmers are male and 48.7% are female, suggesting a male majority among urban farmers in Ilorin metropolis. This contrasts with Hadebe and Mpofu (2017), who reported that women predominantly engage in urban agriculture. Additionally, Table 1 shows most respondents are aged between 31 and 55, with the average age of urban agriculture household heads being 50.45 years, indicating they are in their prime working years and likely to adopt productivity-enhancing innovations. This aligns with Dercon and Krishman (2019), who noted that household heads in their active working years tend to adopt beneficial innovations.

Regarding marital status, the study area's data reveals that 64.0% of farmers are married, with the rest being single, divorced, widowed, or separated. Married households, especially with both spouses working, are presumed to have better food security than those headed by single, widowed, divorced, or separated individuals. The common belief is that household size influences food expenditure and consumption patterns, impacting food security. Table 1 also indicates that 39.3% and 21.3% of urban farmers have household sizes of less than five and between six to nine individuals, respectively. The average household size for urban agriculture stands at 6.79, suggesting that larger households may have lower per capita food expenditure, potentially increasing food insecurity risks.

4.2 Determinants of Calorie Intake of the urban agriculture Household

Table 2. Household Calorie Intake Per Capita

Food items in Kcal	Mean	St. Deviation	Coef. of Variation	Range
Meat	248.74	203.21	0.817	0-2082.19
Cereals	1386.7	617.25	0.445	547.24-4617.22
Legumes, nuts and seeds	460.59	389.34	0.845	0.2817-67
Vegetables	33.51	55.96	1.670	4.63-555.43

Fruits	0.96	1.82	1.896	0-9.30
Fat and oil	424.11	171.26	0.404	0-1279.00
White tubers and roots	178.18	181.49	1.019	0-1325.75
Egg and milk	43.72	72.36	1.655	0-598.36
Fish and other sea foods	49.21	44.2	0.898	0-266.87
Beverages	13.43	34.36	2.559	0-191.89
Spices and condiments	1.33	0.66	0.496	0.10-5.07
Total calorie per capita	2840.46	1168.89	0.412	1379.06-944.03

Source: field survey, 2020

After the identification and aggregation process, the daily per capita consumption patterns were calculated. Table 2 reveals that the majority of the food consumed by households comes from cereal products. The average daily caloric intake from cereals was 1386.7 kcal per person, with legumes at 460.59 kcal, fats and oils at 424.11 kcal, and roots and tubers at 178.18 kcal. These food groups constitute the main source of calories for farm households, with starchy foods dominating except for legumes. Notably, the coefficient of variation for legume consumption is high at 0.845, whereas it is low for cereals and fats and oils (0.445 and 0.404, respectively).

This indicates significant variability in legume consumption among the sampled population. The findings also reveal that the daily per capita calorie intake from protein-rich foods is quite low, with a high coefficient of variation, indicating that the average does not accurately represent the population. The average daily caloric intake from meat was 178.18 kcal (with a coefficient of variation of 1.019), from fish was 49.21 kcal (0.898), and from other animal protein sources like eggs and dairy was 43.72 kcal (1.655) per person. The calorie contributions from fruits and vegetables were also low, at 0.96 kcal and 33.51 kcal respectively, and the variation in consumption within the population was notably high. The coefficient of variation for these food groups was alarmingly high, even at such low levels of daily per capita consumption.

4.3 Household Diversity Score

Table 3. Household Dietary Diversity Score

Diversity categories	Cut-off values	Frequency	Percentage
Low dietary diversity	0 – 3	25	16.7
Medium dietary diversity	4 – 6	98	65.3
High dietary diversity	7 - 12	27	18
Total		150	100

Source: Field Survey, 2020

The majority (65.3%) of household fall within medium dietary diversity category with scores ranging between 4 and 6 points while the rest 18% falls within the range of higher dietary diversity category with the score above 7 points. This implies that about 17% of the households do not have adequate dietary diversification while the majority (about 83%) is enjoying good dietary diversification.

Table 4. Effect of Urban Farming on Household Consumption

Variables	Coefficient	Standard error	Z value	p>[t]
Total grain from urban farming	0.460764*	0.0622	7.4075	0.000
Gender	-0.451	0.369	1.221	0.222
Age	-0.031**	0.014	2.255	0.024
Household size	-0.503***	0.2628	3.666	0.056
Education	0.023	0.047	2.622	0.109
Urban Farming experience	0.032	0.0255	1.591	0.207
Farm size	0.141*	0.026	1.544	0.000
Off- farm income	0.835	0.3731	5.006	0.225
Household asset	-0.027	0.0476	0.313	0.576
Dependency ratio	-0.102**	0.041	-2.509	0.012
Constant	1.450	0.8684	2.788	0.095
LR $chi^2(8)$ = 12.164				
Prob>chi^2 = 0.0000				
Pseudo R^2= 0.17				
Log Likelihood = - 27.39237				

Note: ***, ** and * = Figures significant at 10%, 5% and 1% significant levels respectively

Source: Field Survey, 2020

Table 4 presents the regression analysis on the impact of urban farming on household food consumption. The chi-square value of 12.164 suggests that the logistic model's parameters are significantly different from zero at the 1% significance level. The Pseudo R2 value of 0.177 indicates that 17.7% of the variance in the farmers' household food consumption is explained by the independent variables in the model. Furthermore, the model's likelihood function was significant (Wald = -27.39237, with p < 0.0000), demonstrating the strong explanatory power of urban farming's impact on household food consumption.

Table 2 details the effect of urban farming on household food consumption. It shows the results of the factors influencing urban farmers' household food consumption in the study area. The pseudo R2 value is 0.17, significant at the 1% level. Of the 10 explanatory variables in the model, four significantly influenced the likelihood of urban farmers' household food consumption: age, household size, farm size, and dependency ratio. The age of urban farmers had a notable effect, increasing the probability of household food consumption by 0.024%. Conversely, a larger household size, which could provide more family labor, decreased the probability of household food consumption by 0.6%. This suggests that the availability of farm labor sometimes reduces household food consumption.

The implication is that these individuals are not consistently available for farm work and are not engaged in other non-farming activities that could enhance the urban farming family's income. The results indicate that household size has a substantial negative impact on household food consumption, by -50.3%.

5. CONCLUSION AND RECOMMENDATIONS

Urban agriculture is increasingly recognized as a viable strategy for the urban poor to supplement income and improve nutrition. It enables the poor to lessen their cash income dependency for food by cultivating their own plots within or outside the city, thereby enhancing access to essential food. While it has shown potential in contributing to food security and income generation, numerous challenges hinder these goals. Environmental and human health issues indicate that urban agriculture's sustainability is currently at risk. Research shows that most urban farmers operate on small land areas without significant investment in fertilizers or certified seeds, leading to low yields and perpetuating a cycle of poor productivity and food poverty. The growth and success of urban agriculture hinge on policymakers, administrators, and urban farmers adopting integrated social, economic, and environmental strategies to address food consumption, nutrition, food security, and urban poverty. While sustainable urban agriculture isn't a cure-all for economic woes or poverty, it offers a constructive means to enhance urban living standards.

Our empirical evidence suggests policy interventions should focus on improving farmers' education levels, promoting family planning awareness, and prioritizing nutrition education among urban farming families. Given the positive impact of crop output on production, efforts to boost production and productivity are also essential.

To this end, the following are recommended to ensure that these policies, schemes and programmes of the government succeed:

i. The government needs to tackle the challenges posed by the Land Use Act, particularly issues of land tenure and ownership. It should also focus on delivering urban infrastructure and extension services, while ensuring that incentives are clear and available to all investors.
ii. Additionally, the provision of essential infrastructure, such as quality roads, piped water, and electricity, is crucial for urban residents to improve their living conditions. These facilities will undoubtedly enhance the productivity of urban farmers and minimize waste.

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DEVELOPMENT AND PERFORMANCE EVALUATION OF A CENTRIFUGAL AIR-FLOW GRAIN CLEANER

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ABSTRACT
Global demand for high-quality grain underscores the need for clean grains which is vital to food security. Contaminants such as broken cobs, grain dust, stones, and chaff are found in grains during harvest, handling, and storage operations. Manual winnowing is laborious and cannot meet the continuous demand for clean grains. The availability of grain cleaning machines will ensure a sustainable supply of clean grains while conserving human energy and improving food security.A centrifugal flow grain cleaner was developed with major components such as hopper, sieves, electric motor, and blower. Yellow maize variety (Swan 2) was used to test the centrifugal flow grain cleaning machine and trials were carried out in three replicates. It was tested at three moisture content (MC) levels of 15%, 17%, and 19% (wet basis) commonly found in grain markets in Ibadan, Nigeria. Three feed rates (FR) (180, 250, and 320 kg/hr) were used. Performance evaluation to determine the cleaning efficiency (EG), total efficiency (ET), and product purity (PP) level using NIS 320: 1997 Seed/Grain Standards and other relevant indices. Analysis of variance was carried out to assess the significance of the models developed using Design-Expert® software (Version 6.0.6 StatEase, Inc., Minneapolis, Minn.). Results showed that EG was within 98.3% to 98.9% across the MC and FR. The optimal ET was 85.5% at optimum operating parameters of 180 kg/hr FR, and 15% MC. The regression model developed for the relationship between MC and FR on EG was significant. Commercial production of the grain cleaner is viable due to its low cost, local technology and, increased demand for quality grains.

Keywords: Maize, moisture content, feed rate, machine efficiency, grain quality, grain cleaner

1. INTRODUCTION
Grains are crops rich in carbohydrates and also contain some amount of protein, fats, oil, and vitamins (Sarwar *et al*., 2013). Grains are cultivated for their kernels which are used majorly for food (Sokoto *et al*., 2016). Cereal belongs to the monocotyledon family Poaceae, which are grass crops that produce comestible grain seeds (Adebayo and Ibraheem, 2015). The most common cereal or grain crops grown in Nigeria include maize (also known as corn), rice, sorghum, cowpea, and wheat (Aremu *et al*., 2014). According to FAO, maize production in Nigeria was estimated at 10.2 million metric tons (FAOSTAT, 2020). However, cleaning and separation of grains from impurities is required before further processing can be carried out.

The need for clean and high-quality grains to food safety and human existence in a modern society cannot be overemphasized both in Nigeria and the rest of the world (Ismaila *et al*., 2010). This is because the fines in unclean grains are attractive to insects making the grains susceptible to contamination by molds and aflatoxins during storage. Toews and Subramanyam (2014) reported that cleaning of grains is essential before storage as it results in reduced costs related to aeration and insect management. Grains such as milled rice are frequently winnowed locally to separate grains from unwanted materials (Okunola *et al*., 2018), a process that is quite tedious and requires a long period (Okunola, 2011). Postharvest operations such as cleaning and milling of grains are carried out in developing countries such as Nigeria manually with hand and with some traditional methods (Ndukwu and Onyenwoke, 2014).

Aguirre and Garray (1999) reported that the speed, high labor requirement, air flow in different directions, and continuity of air current pose a limitation to the dependency on natural air current as a means of separation of chaff from bean seeds. Zhao *et al*. (1999) reported that the preliminary separation of grains from impurities (chaff and particles) was influenced by air velocity during grain conveyance on the sieve. Simonyan *et al*. (2006) also reported that the separating and cleaning process was affected by physical factors and can be grouped from literature into two namely: crop factor — grain variety, maturity stage, grain moisture content, grain size, and terminal velocity; mechanical factor — sieve hole diameter, frequency of sieve oscillations, air speed, and sieve slope. These factors are essential and critical to the performance of the machine.

Some of the mechanical factors influencing the rate of cleaning, separation, and total losses include sieve slope, air speed, and sieve oscillation (Ebaid, 2005). Ali *et al.* (2022) designed and assessed a small-scale machine for cleaning wheat grains. They concluded that the slope of the sieve unit and the reciprocating speed had the most significant effect on the maximum cleaning efficiency. Ghonimy and Rostom (2022) designed and evaluated the performance of a canola seed-cleaning machine. They concluded that an increment of the cylindrical sieve slope angle and flat sieve speed increases the percentage of canola seed losses during the cleaning process. Olaposi and Jerome (2023) developed and evaluated the performance of a combined maize shelling and cleaning machine. They concluded that the highest machine efficiency of 88% was attained at 500 rpm and 12% moisture content (MC) of shelled maize. Awady *et al*. (2003) and Ebaid (2005) reported that the cleaning efficiency and total loss increased with increasing sieve oscillation, sieve tilt angle, and air speed while working on rice and wheat grains respectively. Abdel *et al*. (2007) reported that less resident time of materials to be separated on the sieve during grain cleaning such as rice may be responsible for the decrease in cleaning efficiency with respect to increasing sieve oscillation movement. Zdzislaw (2013) reported that the angle of inclination of a separator screen or sieve is a vital consideration that determines the effectiveness and continuity of the separation process of cereal seeds. A common occurrence during separation may be clogging of the sieve opening by the presence of materials that are unable to pass through the openings. Okunola *et al*. (2015) varied the angle of tilt of the sieve between 3° to 8° and maintained a fan speed of 240 rpm during the machine test of a rice grain cleaner. They reported a total separation efficiency of 71% for paddy rice. Angelovič *et al.* (2019) reported that the level of cleanliness achieved by grain cleaners should not be the only factor determining the quality of the machine but also other factors such as performance and quantity of good grains lost.

Grain MC is an important consideration in the design of equipment for separation, cleaning, handling, conveying, processing and storing (Sobukola and Onwuka, 2011), as well as to accurately specify design considerations and avoid resources loss. The grain size and shape are relevant in separation of undesirable particles and in the fabrication of sizing and grading equipment (Mohsenin, 1970; Gursoy and Guzel, 2010). The drop height of the material mixture — grains, chaff, tiny broken cobs, and grain dust was recommended to be large enough to aid adequate exposure to the blowing or sucking air for effective cleaning (Caro *et al*., 2014). In addition, it allows for the provision of adequate height to enable the terminal velocity of the chaffs to be attained. They further recommended a drop height of 0.51 m which was found suitable for blowing away lighter impurities with required air velocity. The lighter chaffs are blown or sucked by the air speed generated from the blower due to the varying terminal velocities of the materials while the grains drop by gravity as a result of the higher terminal velocity of grains to the air velocity (Simonyan and Yiljep, 2008).

Food grains need to be cleaned as harvesting and postharvest handling methods add contaminants — chaff, dust, sticks, and leaves to grains (Ogunlowo and Adesuyi, 1999). Cleaning of about one kilogram of unclean grains using the winnowing method can take about seven to twelve minutes depending on some factors — winnower's handling skills, speed and stability of natural air current, and ratio of grain to unwanted materials (Muhammad et al. 2013). Grain cleaning process remains stressful in rural and farm settlement areas among farmers and individuals involved in farming activities (Okunola *et al.,* 2019). The design and construction of effective and efficient grain cleaning equipment will ensure the mitigation of problems arising from low quality grains. There is therefore the need to deploy grain cleaning machines at an affordable cost and with high efficiency, most especially at the farm level, to alleviate problems associated with impurities in grains before bagging, storage or transportation.

The objectives of this study were:
(1) to design and develop a grain cleaning machine, and (2) to evaluate the performance of the grain cleaning machine. The centrifugal air-flow grain cleaner designed and constructed in this study was carried out to tackle the challenges of chaff removal from grains and adequate cleaning process.

2. MATERIALS AND METHODS

centrifugal air-flow grain cleaner was developed and tested using Swan 2 maize variety at MC levels of 15%, 17%, and 19% (wet basis), and feed rates (FR) of 180, 250, and 320 kg/hr. Repeated trials were conducted which helped to determine that at 25% opening of the aperture, approximately 3000 g of maize will pass through within a minute, equivalent to 180 kg/hr. Using the same process, it was determined that approximately 4166g/min and 5333g/min was equivalent to 250 and 320 kg/hrrespectively, using the same aperture opening. The choice of the FR was to prevent overloading of the hopper and clogging of the machine, while the choice of MC was the range commonly found in the markets. The MC and FR were the independent variables while the cleaning efficiency (EG) (also known as separation efficiency), total efficiency (ET), and product purity (PP) were the dependent variables (performance efficiencies).

2.1 Design Considerations

During the design of the grain cleaning machine, the following factors were considered: strength, rigidity, availability, cost of production of the machine, expected function to perform, ease of use, ease of cleaning, blower air speed, low labor and maintenance cost, variable sieves, durability, safety, and environmental conditions in which it would be used. Due to the presence of broken cobs, stalks, chaff, and other unwanted materials found in uncleaned shelled maize grains, a combination of a blower (pneumatic) and sieves (mechanical) methods to enhance the separation and cleaning were considered.

2.2 Description of the Machine

The centrifugal air-flow grain cleaner consists mainly of the hopper, blower, sieves, and supporting frame. The shape of the hopper is a frustum of a pyramid and made of mild steel sheet. The lower part of the hopper tappers down at an angle of 50º for easy sliding and rolling down of grains (Aremu *et al.*, 2014; Tarighi *et al.,* 2011). A control adjuster was incorporated in the hopper to control grain flow. The blower is locally fabricated and consist of paddles attached to a wheel (centrifugal fan) made of mild steel sheet and can generate high speed. The outlet of the blower is located horizontally to deliver moving air across the materials flowing vertically from the column attached to the sieve housing. The average air speed from the blower exit was recorded as 4.0 m/susing a TPI 565C1 digital hot-wire anemometer. The blower is powered by a single-phase electric motor of 1,450 rpm and 1.5 hp. The sieve housing is connected to the base of the hopper. It comprises two sieves made from stainless steel with diameters of 10 mm and 14 mm to separate impurities with different sizes. The sieves were arranged in layers and were detachable. A connecting rod attached to the sieve housing provides power through the movement of a pulley which is powered by a single-phase electric motor of 1440 rpm and 2 hp. The sieve housing is agitated by an eccentric drive resulting in an oscillatory motion. The two reciprocating sieves were used to aid in the pre-cleaning of the grains. The impurities larger than the grains are separated by the first sieve and the impurities smaller than the grains were separated by the second sieve. The supporting frame of the machine carries the weight of the whole machine and is made of iron. The choice of electric motors as the prime mover was to mitigate air pollution by the release of carbon monoxide which is common among petrol and diesel engines. The prime movers are mounted on the frame to power the blower and the sieve housing using a belt and pulley drive. The specifications of the major components of the machine are shown in Table 1. The schematic layout and exploded view assembly of the grain cleaner is shown in Figures 1 and 2.

Table 1. Specifications of major components of the grain cleaner

Parameters	Units
Pulley diameters	50 mm and 355 mm
Sieve diameters	14 mm and 10 mm
Electric motors (medium speed)	2 hp and 1.5 hP
Shaft diameter	25 mm
Angle iron	5 mm by 4 mm thickness
Pillow bearing	20 mm
Mild steel plate	1.5 mm thickness
Volume of hopper	8.324×10^{-3} m^3
Hopper slope	50°
Degree of sphericity of grain	62.5%
Air speed of blower	4 m/s
Effective length of duct	1.48 m
Effective diameter of grain	9.6 mm
Tension on tight and slack sides of belt	63.4 N and 20.7 N
Resultant angle of belt	60°

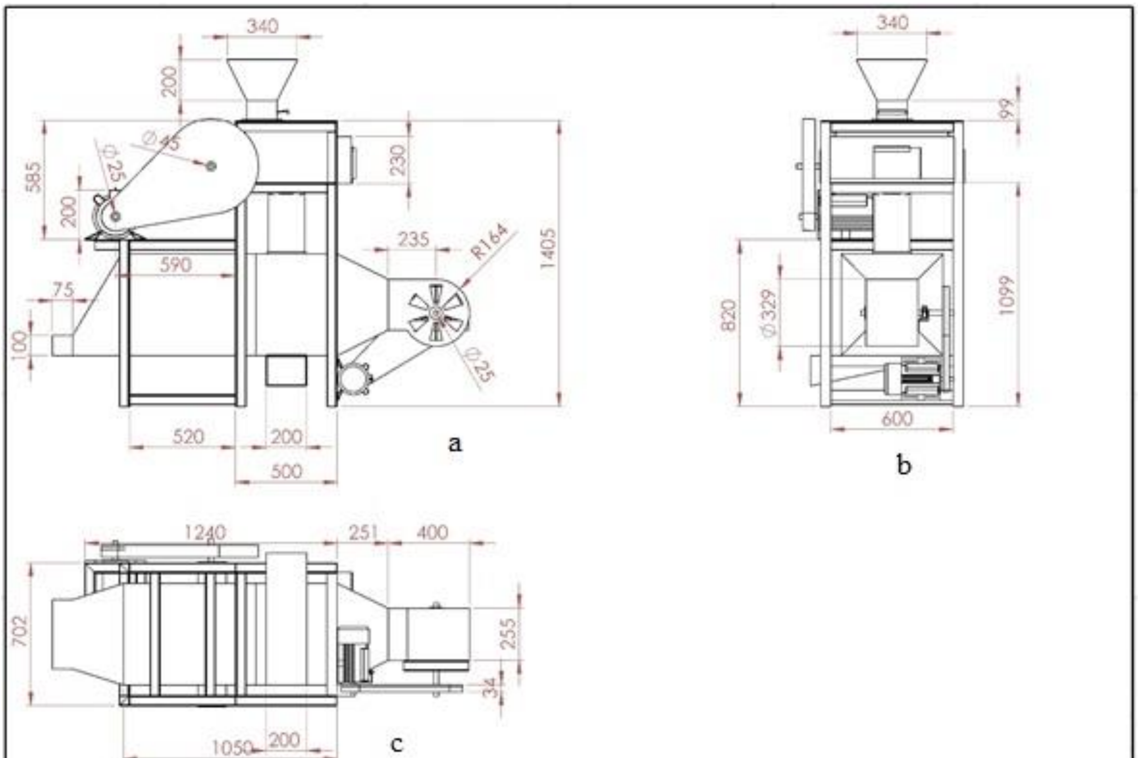

Figure 1. Orthographic views for side elevation (a), front elevation (b), and plan elevation (c)

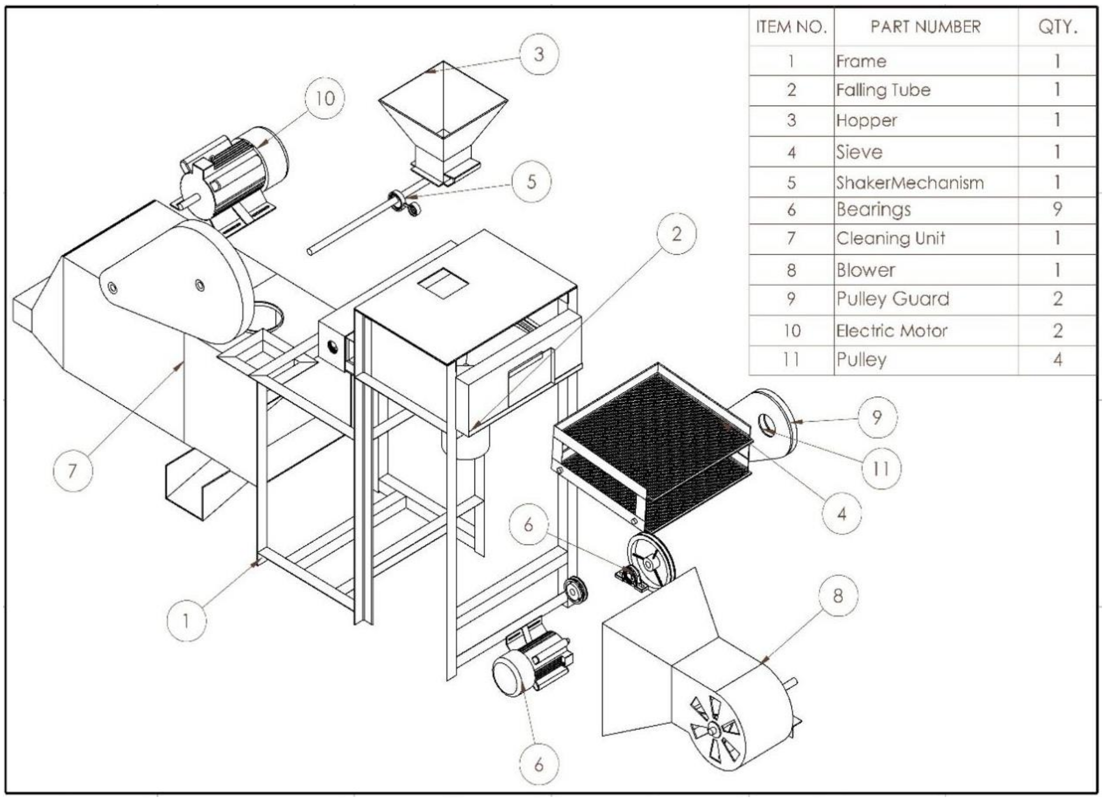

Figure 2. The exploded view of the grain cleaner

2.3 Operation of the Machine

The operation of the machine is carried out by switching on the electric motors connected to an electric source which drives the blower and the housing units independently. The grain admixture is fed into the machine via the hopper. The adjuster is opened gently to allow the flow of the admixture through the hopper outlet. The admixture drops on the surface of the sieves and passes through the first and second sieves onto a connecting column (falling tube) to the cleaning unit of the blower housing. The larger sizes of unwanted materials are held back by the sieve and discarded manually on stopping the operation of the machine while the smaller sizes such as grain dust, tiny broken cobs, and stones are pushed by the air current and discharged at the blower outlet. The grains are not carried away as the terminal velocity of the grains is greater than the velocity of the air current from the blower, the grains drop by gravity and are collected at the receptacle for clean grains. The developed grain cleaner is shown in Figure 3.

Figure 3. The fabricated grain cleaner

2.4 Design Calculations

2.4.1 The hopper

The hopper was designed in the shape of a frustum of a pyramid. The material of construction used for the hopper was mild steel sheet metal as it is rigid, readily available in the market, and less expensive. Pythagorean's theorem was used in the design of the hopper and the principle of similar triangles. The dimensions of the top, bottom, and perpendicular height of the hopper were 350, 150, and 169 mm. The volume of the hopper was calculated using the formula as:

$$v = \frac{1}{3} \times h(A + AB + B) \quad \text{(Suphi, 2015)} \qquad (1)$$

where,

v is the volume of the hopper (m^3), A is the area of the upper base (m^2), B is the area of the lower base in (m^2), and h is the perpendicular height of the hopper (m).

The choice of the hopper slope as 50° was to ensure easy and free sliding down of grains on mild steel surface as the angle of repose of maize grains reported by Aremu *et al.* (2014) was 48° and by Tarighi *et al.* (2011) as 42° to 47° for MC between 5% to 16% respectively.

2.4.2 Terminal velocity of maize

The theoretical determination of the terminal velocities of a particle (grain kernel) was stated by (ASABE, 2006) with the expression for spherical particles calculated as:

$$V_t = \sqrt{\frac{4 \times g \times d_p\,(\rho_p - \rho_f)}{3 \times C_d \times \rho_f}} \qquad (2)$$

where,

V_t is the terminal velocity (m/s); g is the acceleration due to gravity (m/s^2), d_p is the particle diameter (m), ρ_f is the density of fluid (kg/m^3),ρ_p is the density of the particle (kg/m^3), C_d is the drag coefficient which is given as 0.44 (Mohsenin, 1970).

The calculated terminal velocity for the maize kernel was 15.4 m/s. This implies that the maize kernels would remain suspended in a stream of air at 15.4 m/s. Air velocity greater than 15.4 m/s would displace the grain kernels.

2.4.3 Screen characteristics

The effective diameter (De) and degree of sphericity (Φ) of the grains (Sobukola et al., 2012; Mohsenin, 1970) were used to determine the diameter aperture of the sieves in equations 3 and 4. Twenty (20) grain kernels were picked randomly and the average dimensions of the grain kernels were 16, 11, and 5 mm for length, width, and thickness respectively.

$$De = (LWT)^{1/3} \qquad (3)$$

$$\Phi = \frac{(LWT)^{1/3}}{L} \times 100 \qquad (4)$$

where,

L is the length of grain (mm), W is the width of grain (mm), and T is the thickness of grain (mm).

The effective diameter of the averaged grain kernels was calculated as 10 mm. A sieve size of 10 mm and 14 mm was used for the grain cleaner to enable efficient separation. The degree of sphericity was calculated as 62.5%. The degree of sphericity normally lies between 0 and 1, and assuming the grain is spherical, the sphericity of 0.625 was assumed. Hence the choice of a spherical shape aperture sieve. The screen is detachable and can be changed to suit other grains by using the screen characteristics formulae.

2.4.4 Power determination

I. Angular Velocity, Pulley Size and Speed

The angular velocity was determined using the expression according to Khurmi and Gupta (2005) as:

$$\omega = \frac{2\pi N}{60} \quad (5)$$

where,

ω is the angular velocity (m/s), and N is the speed of the shaft (rpm).

The selection of the pulleys was based on strength, durability, availability, and relative low cost compared to other materials. Cast iron pulleys were selected. The determination of the driver pulley and the diameter of the pulley calculations were based on the horsepower rating. The horsepower rating was given at a maximum pitch diameter of the pulleys and corresponding speed. Hence, the horsepower rating therefore determined the diameter of the driver pulley. The driven pulley was calculated based on the relationship between the spindle speed and the speed of the prime mover which was given by the expression below (Abdulkadir*et al.*,2009; Khurmi and Gupta, 2005; Williams, 1953).

$$\frac{N_1}{N_2} = \frac{D_2}{D_1} \quad (6)$$

where,

N_1 is the speed of the driver pulley (rpm), N_2 is the speed of the driven pulley (rpm), D_1 is the diameter of the driver pulley (m), and D_2 is the diameter of the driven pulley (m).

II. Belt Speed and Length of Belt

The speed of the belt was determined as given by Khurmi and Gupta (2005).

$$V = \frac{N_2 \pi D_2}{60} \quad (7)$$

where,

V is the belt speed (m/s), N_2 is the speed of the driven pulley (rpm), and D_2 is the diameter of the driven pulley (m).

The length of the belt was determined based on the diameters of the pulleys and the belt center distance (Khurmi and Gupta, 2005).

$$L_b = 2x + [(\pi/2) \times (D + d)] + \frac{(D-d)^2}{4x} \quad (8)$$

where,

L_b is the length of the belt (m), xis the center distance of the belt (m), D is the diameter of the bigger pulley (m), and d is the diameter of the smaller pulley (m).

A 5% friction loss on the shaft was assumed and considered during the design. Torque exerted on the driver pulley (the effective pull) was calculated as $(T_1 - T_2)r_2$. The slack side tensions of the belt were determined as:

$$2.3\log\left(\frac{T_1}{T_2}\right) = \mu\theta Cosec\,\beta \quad (9)$$

where,

T_1 is the tension on tight side (N), T_2 is the tension on slack side (N); μ is the co-efficient of friction between belt and cast iron or steel pulley given as 0.3 (Abdulkadir *et al*., 2009), and β is the groove angle given as 38° (Abdulkadir *et al*., 2009).

III. Shaft Diameter and Belt Width

The determination of the shaft diameter for the connecting rod to be driven by the electric motor as a driver for the cam attached to the sieve housing was calculated to ensure satisfactory strength and rigidity while in operation under various operating and loading conditions. The design of the shaft was based on the maximum shear theory. Shafts are usually subjected to torsion, bending, and axial loads.

A factor of safety three (3) was considered in the design. The diameter of the shaft was designed according to ASME code (ASME, 1995) for a solid shaft having little or no axial loading in the equation below.

$$d^3 = \frac{16}{\pi\tau_{max}}\sqrt{(K_bM_b)^2 + (K_tM_t)^2} \qquad (10)$$

where,

d is the diameter of the shaft (m), M_t is the torsional moment (Nm), M_b is the bending moment (Nm), K_b and K_t are the combined shock and fatigue factor applied to bending and torsional moment, and τ_{max} is the allowable stress (Mpa).

The torsional moment (M_t) was calculated from equation 11while equations 12 to 14 were used to determine the tensions on the tight and slack sides, respectively (Khurmi and Gupta, 2005).

$$M_t = \frac{P \times 60}{2\pi N} \qquad (11)$$

$$T_i = T_{max} - T_c \qquad (12)$$

$$T_{max} = \sigma a \qquad (13)$$

$$T_c = mv^2 \qquad (14)$$

where,

T_c is the centrifugal tension of the belt (N), T_{max} is the maximum tension of the belt (N), σ is the maximum safe normal stress (N/mm^2), a is the cross-sectional area (mm^2), m is the mass per unit length of the belt(Kg/m), v is the belt speed (m/s), T_i is the tension on tight side of a belt (N), T_j is the tension on slack side of a belt (N), D_2 is the diameter of the driven pulley (mm), P is the power required to drive the machine (watts), and N is the speed of the shaft (rpm).

The maximum bending moment, M_b was determined as:

$$M_b = (M_v^2 + M_h^2)^{1/2} \qquad \text{(Khurmi and Gupta, 2005)} \qquad (15)$$

where,

M_h is the bending moment on the horizontal plane (Nm), and M_v is the bending moment on the vertical plane (Nm).

The belt width was determined from equation 16.

$$m = A \times L \times \rho = (b \times t) \times L \times \rho \qquad \text{(Khurmi and Gupta, 2005)} \qquad (16)$$

where,

L is the length of the belt (m), m is the mass of the belt (kg/m), b is the width of the belt required (m), t is the thickness of belt (m), A is the area of belt (m^2), and ρ is the density of rubber belt material taken as 1100 kg/m^3(Austrell and Kari, 2005).

The approximated summation of the power (HP) needed for the movement in the horizontal (Igbeka, 1984) and vertical direction (Ogunlowo and Adesuyi, 1999) of the particles and screen was calculated as the theoretical power requirement for the oscillation.

For the horizontal:

$$HP_1 = \left(\frac{2 \times Ws \times N \times X \times \mu}{4500}\right) \qquad (17)$$

For the vertical:

$$HP_2 = \left(\frac{2 \times Ws \times N \times Y}{4500}\right) \qquad (18)$$

where,

N is the speed (rpm), Ws is the weight of the sieve assembly and test materials on it (kg), Y is the vertical displacement of the reciprocating assembly (m/stroke), X is the horizontal displacement of reciprocating assembly (m/stroke), and μ is the co-efficient of friction between hinge points taken as 0.4 (Okunola *et al*., 2015).

The total minimum power requirement for the screen movement was calculated by the addition of the horsepower for the vertical and horizontal motions.

2.4.5 Blower section

I. Determination of Air Generated by Paddles

The blower was used to generate the air stream required for adequate separation of the grains and the undesirable materials. The blower was made up of four paddles attached to a 25 mm diameter rod with 430 mm length. The paddles were 215 mm in length, 60 mm in width, and a slant height of 125 mm. Two single-phase direct-speed electric motors of 1,450 rpm and 1,440 rpm with 1.5 hp and 2.0 hp power capacity, respectively were used to drive the moving parts of the machine. The average air speed from the blower exit was recorded using a TPI 565C1 digital hot-wire anemometer (one decimal place) as 4.0 m/s. The volume of the four paddles can be calculated as:

$$v = 4A \times L \tag{19}$$

where,

v is the volume of paddles (m^3), A is the paddle sectional area (m^2), and L is the length of a paddle (m).

II. Hydraulic Diameter and Volumetric Flow Rate

The hydraulic diameter was calculated from the expression according to Rajput (2013).

$$D_h = \frac{4A}{P} \tag{20}$$

where,

A is the area of the duct (m^2), and P is the perimeter of the duct (m).

The volume flow rate was calculated using the expression according to Rajput (2013) as:

$$Q_{max} = v \times A \tag{21}$$

where,

Q_{max} is the maximum volumetric flow rate (m^3/s), v is the conveying air velocity at the exit (m/s), and A is the area of blower size (m^2).

III. Effective Duct Length

The effective duct length for air velocity less than or equal to 13 m/s was calculated using the formula by ASHRAE (2001) as:

$$L_e = \frac{\sqrt{A_o}}{350} \qquad \text{For } v_o \leq 13 \text{ m/s} \tag{22}$$

Where,

L_e is the effective duct length (m), v_o is the duct velocity (m/s), and A_o is the duct area (mm^2).

2.5 Performance Evaluation

Swan 2 maize variety was purchased in May 2017 from Ijaye farm settlement in Akinyele Local Government Area of Ibadan, Oyo State, Nigeria. The maize was shelled using a single-purpose grain sheller without a blower. The MC of the shelled maize was 14% (wet basis) and reconditioned to 15, 17, and 19% (wet basis). The MC of the maize was determined using a John Deere Moisture Meter SW08120. The uncleaned grains were used to test the grain cleaning machine. The EG, ET, and PP were calculated from NIS 320: 1997 Seed/Grain Standard, Igbeka (2013), and Igbeka (1984) indices shown in Equations 23 to 26. These equations were used to determine the performance efficiencies of the grain cleaner. The feed (F) is the uncleaned grains, the products (P) are the grains from the clean outlet, the rejects (R) are the impurities and any grain that might have escaped from the exit duct of the blower, and top of sieves. The good products (GP) refer to the whole grains while the bad products (BP) are the unwanted material that found its way to the clean outlet. The good rejects (GR) are classified as the grains that found its way to the reject outlet, while the bad reject (BR) are the unwanted materials. Samples were collected at each outlet — blower passage for light impurities, materials separated by the sieves, and outlet for clean grains were weighed and recorded. Figure 4 shows the separation and classification of the grains and impurities from the outlets.

$$EG = \frac{GP}{(GP+BP)} \times 100 \quad (23)$$

$$EB = \frac{BR}{(BR+BP)} \times 100 \quad (24)$$

$$ET = \frac{EG \times EB}{100} \quad (25)$$

$$PP = \frac{GP}{(GP+GR)} \times 100 \quad (26)$$

where,

GP is the weight of good products (kg), BP is the weight of the bad products (kg), GR is the weight of the good reject (kg), BR is the weight of the bad reject (kg), EG is the efficiency of separating whole grains (%), EB is the efficiency of separating materials other than grains (%), ET is the total efficiency (%), and PP is the product purity of whole grain in products (%).

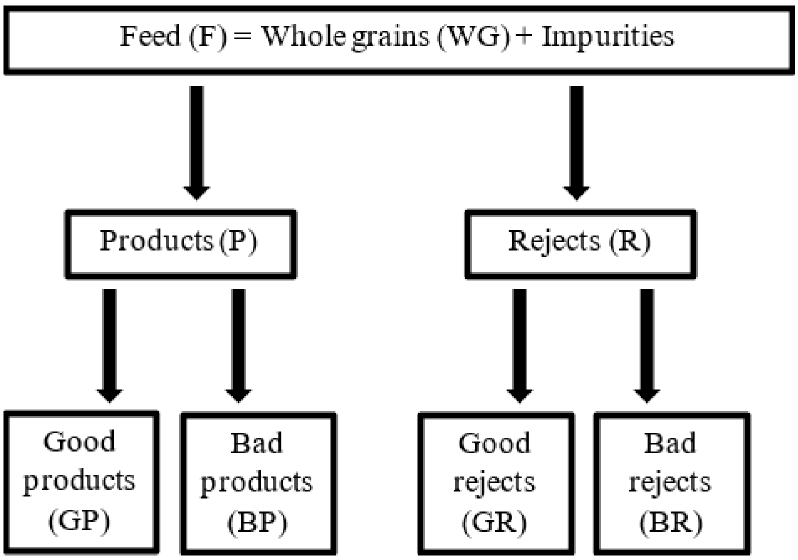

Figure 4. Flow chart showing the classifications of the grains and impurities from the outlets

2.6 Statistical Analysis

Trials were carried out in three replicates. Data were analyzed using Design-Expert® software (Version 6.0.6 StatEase, Inc., Minneapolis, Minn.) for the central composite rotatable design of response surface and analysis of variance (ANOVA) for the effect of FR and MC on EG, ET, and PP at alpha level of 0.05.

3. RESULTS AND DISCUSSION

The results of the average time taken during the performance evaluation of the graincleaner for the three levels of maize MC and FR were 65, 191, and 217 s for 15% MC; 59, 185, and 208 s for 17% MC; and 60, 135, and 172 s for 19% MC. Table 2 shows the results of the parameters that were recorded and determined at the end of the grain cleaner test trials.

3.1 Effect of Feed Rate and Moisture Content on Separation Efficiency of Whole/Cleaned Grains

The maximum average separating efficiency of the grain cleaning machine was 99.0% for operating conditions of 15% MC, and 250 kg/hr FR (Table 2). The separation efficiency results were similar and within the range of Muhammad *et al*. (2013) as they reported a range between 91% and 98% for sorghum, soybean, and millet. Okunola *et al*. (2015) also reported a grain cleaning machine separation efficiency in the range of 73% and 87% for paddy rice. These variations in the separation efficiency were a result of the differences in physical and aerodynamic properties of the grains, the grain type, and machine parameters. The response surface analysis (Fig. 5) showed that a lower maize MC leads to a higher cleaning efficiency, while a lower feed rate leads to a higher cleaning efficiency. This indicates that separation of maize grains was more effective at lower MC and FR. High feeding rates affects separation efficiency as a mat/layer is formed on the sieves due to the thickness and looseness of the grains and impurities (Rothaug *et al*., 2003; Hollatz and Quick, 2003).

ANOVA result shows that the effect of FR and MC were significant on the cleaning efficiency of the coefficient of determination (R^2) value was found to be 0.983, indicating that a strong relationship exists between the feeding rate, moisture content and separation efficiency of cleaned grains.

$$EG = 0.58A^2 + 0.26B^2 + 0.21A - 0.41B + 0.19AB + 97.73 \quad (27)$$

where,

A is the feeding rate (kg/hr), B is the moisture content of the grains (%), and EG is the cleaning efficiency of the cleaned grains (%).

Table 2. Parameters showing the average values of the grain cleaner

Feed Rate (FR) (kg/hr)	**Moisture Content (%)**	**Whole Grain (WG) (kg)**	**Undersized Grains (UG) (kg)**	**Good Product (GP) (kg)**	**Good Reject (GR) (kg)**	**Bad Product (BP) (kg)**	**Bad Reject (BR) (kg)**	**EG (%)[a]**	**EB (%)[b]**	**ET (%)[c]**	**PP (%)[d]**
	15	9.4	0.6	9.3	0.2	0.1	0.4	98.9	86.2	85.5	97.9
180	17	9.5	0.5	9.3	0.2	0.1	0.3	99.3	82.4	81.8	98.1
	19	8.9	1.1	8.7	0.2	0.1	0.4	98.3	71.2	69.7	97.9
	15	14.2	0.8	13.9	0.3	0.1	0.4	99.0	76.9	76.1	98.2
250	17	13.8	1.2	13.5	0.3	0.2	0.4	98.6	67.6	66.7	98.1
	19	13.6	1.4	13.4	0.2	0.2	0.5	98.7	73.8	72.8	98.7
	15	4.7	0.3	4.6	0.1	0.1	0.3	98.6	81.6	80.5	96.9
320	17	4.4	0.6	4.3	0.1	0.1	0.3	98.6	82.2	81.0	96.9
	19	4.3	0.7	4.1	0.1	0.1	0.3	98.5	81.9	80.7	96.5

[a] EG is the cleaning efficiency
2 [b] EB is the efficiency of separating materials other than grains
[c] ET is the total efficiency
[d] PP is the product purity

Table 3. ANOVA of the quadratic regression model for the effect of feed rate and moisture content on the efficiency of separating whole grain

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	2.90	5	0.58	34.37	0.0075	Significant
A[a]	0.35	1	0.35	21.01	0.0195	
B[b]	1.37	1	1.37	80.92	0.0029	
A^2	0.97	1	0.97	57.67	0.0047	
B^2	0.20	1	0.20	11.74	0.0417	
AB	0.15	1	0.15	8.91	0.0584	
Residual	0.051	3	0.017			
Cor total	2.95	8				

[a]A is the feeding rate (kg/hr)
[b]B is the moisture content of the grains (%). Significant level at $p < 0.05$.

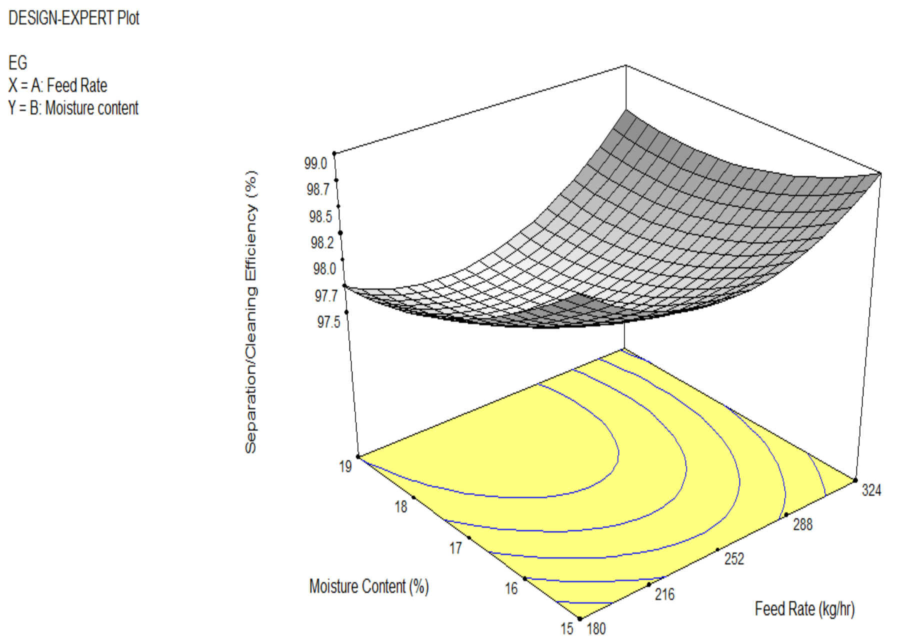

Figure 5. The response surface plot of the separation/cleaning efficiency of whole grains as affected by the moisture content and feed rate

3.2 Effect of Feed Rate and Moisture Content on Total Efficiency

The highest average ET of the grain cleaner machine was 85.5% with operating conditions of 15% MC and 180 kg/hr FR (Table 2). Similar results for ET were reported by Okunola *et al*. (2015) and Tabatabaeefar *et al*. (2003) with values between 69% to 84%, and 84% using paddy rice and chickpea for the evaluation of their grain cleaning machines. The response surface analysis (Fig. 6) showed that a lower maize MC leads to a higher total efficiency, while a lower FR leads to a lower total efficiency. However, a higher MC and FR of uncleaned maize can result to clogging of the sieve thereby prevent the kernels, smaller fines, and chaffs from falling through the sieve as a result of blockage of the sieve holes. Aderinlewo *et al*. (2016) reported that air speed and screen speed were also contributing factors to the total efficiency of a grain cleaning machine. ANOVA results showed that the effects of MC and FR were not significant ($p > 0.05$) on the ET of the machine (Table 4).

Table 4. ANOVA of the quadratic regression model for the effect of feed rate and moisture content on the total efficiency

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	21.17	5	4.23	0.20	0.9403	Not significant
A[a]	2.87	1	2.87	0.14	0.7346	
B[b]	14.98	1	14.98	0.72	0.4581	
A^2	1.84	1	1.84	0.088	0.7857	
B^2	0.11	1	0.11	0.005	0.9465	
AB	1.01	1	1.01	0.049	0.8396	
Residual	62.29	3	20.76			
Cor Total	83.46	8				

[a]A is the feeding rate (kg/hr)
[b]B is the moisture content of the grains (%). Significant level at $p < 0.05$.

The model that gave the best fit was a quadratic relationship (Eq. 28). The R^2 value was found to be 0.254, indicating that there is a weak relationship between the FR, MC and ET considered.

$$ET = 0.79A^2 + 0.19B^2 + 0.50AB + 0.60A - 1.37B + 73.30 \quad (28)$$

where,

A is the feeding rate (kg/s), B is the moisture content of the grains (%), and ET is the total efficiency (%).

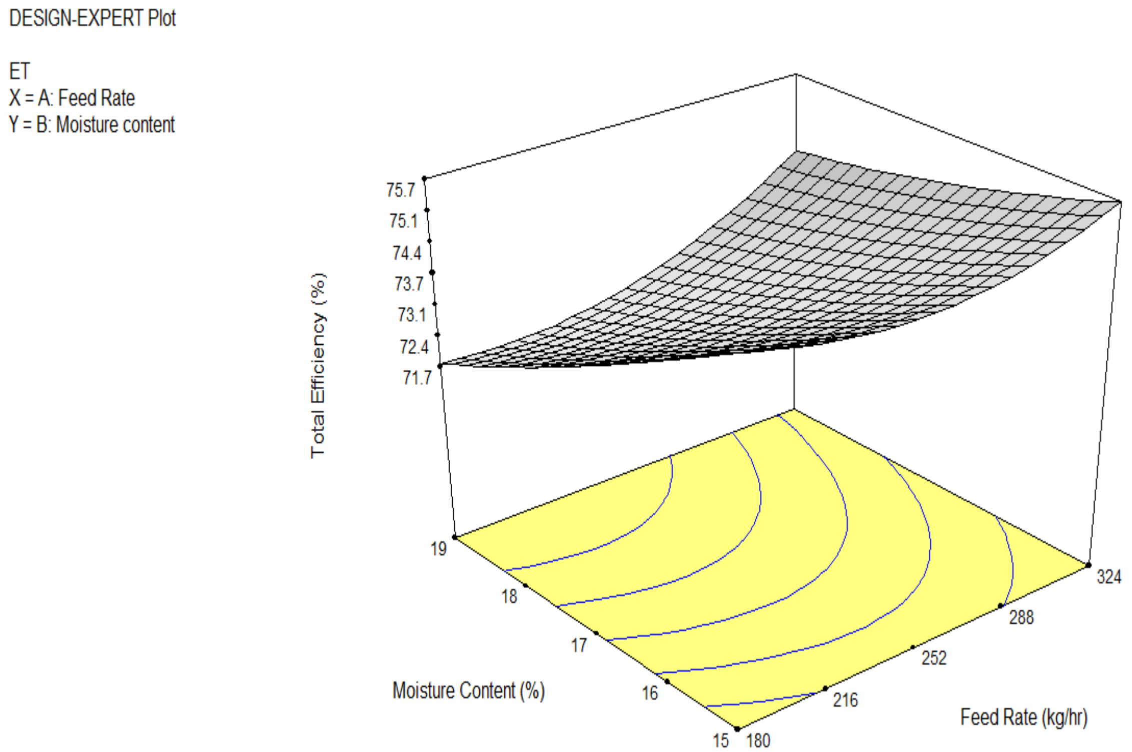

Figure 6. The response surface plot of the total efficiency as affected by the moisture content and feed rate

3.3 Effect of Feed Rate and Moisture Content on the Product Purity of Whole Maize Grains in Product

The lowest mean PP of whole maize grains collected was 96.5% at operating conditions of 19% MC and 320 kg/hr FR (Table 2). These operating conditions can serve as a baseline for determining the PP when evaluating the performance of a grain cleaning machine. Similar results were reported by Aderinlewo *et al*. (2016) for cowpea with PP ranges of 91.3% to 96.2%, and Okunola *et al*. (2015) for paddy rice with PP ranges of 93.0% to 98.0% for the performance evaluation of their grain cleaning machines. ANOVA result showed that the effects of MC and FR were not significant ($p > 0.05$) on the PP of the maize grains (Table 5).

Table 5. ANOVA of the quadratic regression model for the effect of feed rate and moisture content on the product purity of whole grains

Source	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
Model	0.24	3	0.081	1.39	0.3473	Not significant
A[a]	0.052	1	0.052	0.90	0.3864	
B[b]	0.013	1	0.013	0.22	0.6611	
AB	0.18	1	0.18	3.06	0.1406	
Residual	0.29	5	0.058			
Cor Total	0.54	8				

[a]A is the feeding rate (kg/hr)
[b]B is the moisture content (%). Significant level at $p < 0.05$.

The model that gave the best fit was a 2FI (2-factor interaction) relationship shown in Equation 29. A 2FI implies that the relationship between the dependent variable and the predictors involves interactions between two specific factors or independent variables. This interaction term allows for the possibility that the effect of one variable on the dependent variable is not constant across different levels of the other variable. The response surface analysis (Fig. 7) showed that a lower maize MC leads to a higher product purity, while a higher FR leads to a higher product purity. The R^2 was found to be 0.4552, indicating that there is a weak relationship between MC, FR and product purity.

$$PP = 0.081A + 0.040B + 0.21AB + 97.88 \quad (29)$$

where,

A is the feeding rate (kg/hr), B is the moisture content of the grains (%), and PP is the total efficiency (%).

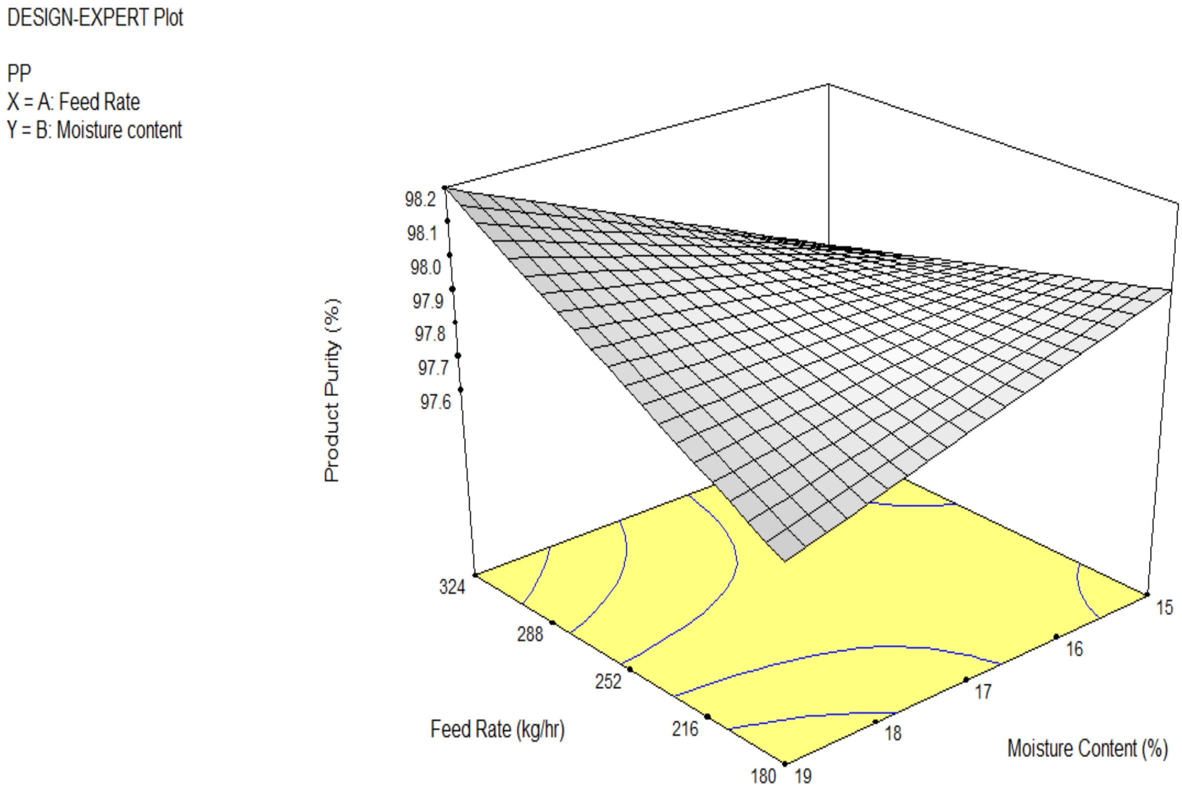

Figure 7. The response surface plot of the product purity as affected by the moisture content and feed rate

4. CONCLUSION

In this study, the grain cleaning machine had the best separation/cleaning efficiencies of 98.9% and 99.3% for uncleaned maize with MC of 15% and 17% (wet basis) at 180 kg/hr FR. The optimum operating parameters were 180 kg/hr FR and 15% MC for a total efficiency of 85.5%. Low FR and MC level of uncleaned grains should be considered during grain cleaning process. The prediction of the cleaning efficiency as affected by the feed rate and moisture content can be determined from the regression model developed. Proper storage of cleaned grains would ensure the mitigation of low-quality grains, reduce susceptibility to insect infestations, and improve the shelf-life. The cost of the grain cleaner was $610 US. Commercial production of this grain cleaner is viable to grain merchants, grain processing industries, and farmers' cooperative society in the country. It was recommended that the use of dampers and other composite materials could be incorporated into the machine to reduce vibrations and noise levels.

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PATTERN AND DETERMINANTS OF INVESTMENT AMONG CATFISH ENTREPRENEURS IN ABIA STATE, NIGERIA

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ABSTRACT

This study analyzed the determinants of investment among catfish entrepreneurs in Abia State, Nigeria. Specifically, the study described the socio-economic and demographic characteristics of the catfish entrepreneurs, ascertained the pattern and the determinants of investment in catfish enterprises in the study area. Data were collected from 112 respondents through structured questionnaire which were analyzed using both descriptive and inferential statistical tools. The result showed that that majority of the respondents (64.29%) were male and the mean age of the entrepreneurs was 36 years. About 51.79% of the respondents were married while 48.21% were single. The mean farming experience was approximately 5 years and majority (51.79 %) having secondary form of education. The mean household size of farmers was 6 persons per household. The location of the business is mostly in the rural area. Result revealed that the catfish entrepreneurs invested majorly on land (₦ 592,946.40k), this was followed by borehole (₦249,830.40k), pond expansion (₦242,714.30k), generator (₦161,785.70k) and pumping machine (₦64,160.71k). The significant determinants of investment on catfish enterprises were age (p<0.01), sex (p<0.01), education (p<0.01), experience (p<0.01), cooperative (p<0.01), extension visit (p<0.05) and income (p<0.01). It could be concluded that the major operating cost is the cost of feed and the major investments by catfish entrepreneurs were on land, borehole, pond expansion, generator and pumping machine. It was recommended that since feed cost constitute a major operating cost in production, there is the need to formulate feed locally in order to reduce costs associated with the business as this would enhance commercial catfish production in the study area and Nigeria in general. Variables such as age, sex, education, experience, cooperative, extension visit and income should also be taken into consideration in policy formulation.

Keywords: Pattern, Investment, Catfish

1. INTRODUCTION

The importance of agriculture in the economic development of a nation cannot be overstated (Afolabi, 2017). According to the World Bank (2024). agricultural development is one of the most powerful tools to end extreme poverty, boost shared prosperity, and feed a projected 10 billion people by 2050. It noted that it is also crucial to economic growth: accounting for 4% of global gross domestic product (GDP) and in some least developing countries, it can account for more than 25% of GDP. As noted by Sasu (2023), agricultural activities provide livelihood for many Nigerians. FAO (2022) reported that between January and March 2021, the agricultural sector contributed 22.35 percent to the Gross Domestic Product (GDP) in Nigeria, with over 70 percent of the population of Nigerians engaged in the agricultural sector mainly at subsistence level. Hence, the sector has high potential for employment generation, food security and poverty reduction.

Aquaculture is the fastest growing food production sector in the world and it is growing faster than the capture fisheries (Dauda *et al.,* 2018). Aquaculture is the part of agriculture that is involved in the production of fish and other aquatic organisms. The fishery sector contributed 1.09% of the national GDP in 2020 and 0.97% in the Q3 of 2021 (NBS, 2021 in Odioko and Becer, 2022). Fish makes a vital contribution to the food and nutritional security of about 200 million people. Fish farming provides income for over 10 million people in Africa, majority of which are small-scale fish farmers and entrepreneurs (Inter Press Service, 2016).

Fish remains an important dietary element for Nigeria, especially in the southern part of the country where fish is highly valued and one of the cheapest sources of animal protein available to many Nigerians (FAO, 2020). DARD-ECOWAS Commission report (2020) on the Nigeria fishery sectors shows that between 2015 and 2020, 6,861,700 tonnes of fish had been produced. As a sub-sector of aquaculture, catfish farming involves the rearing of catfish under controlled condition for economic and social benefits. The favoured or common catfish species in Nigeria aquaculture include *Clarias gariepinus, Heterobranchus bidorsalis*, Clarias X Heterobranchus hybrid (Heteroclarias) and *Clarias nigrodigitatus.* (Adewumi and Olaleye, 2015). Increasing population created a large market for catfish which led to an intensification of culture with high growth in small-to-medium-sized farms and the establishment of large scale intensively managed catfish farms. An annual growth rate of 20% was reported by Miller and Atanda (2019). This growth, though considered to be market-driven (Muir *et al.,* 2015), also coincided with a period of increased availability and usage of commercial protein-rich catfish feeds.

According to Ogunji and Wuertz (2023), fish farming has become one of the fastest-growing farming businesses, turning Nigeria into the second biggest aquaculture producer in Africa. Also, Nigeria is the leading country in the production of African catfish (*Clarias gariepinus*) and African bonytongue (*Heterotis niloticus*). Unfortunately, Nigeria is far from self-sufficiency in its fish supply, with a deficit of about 2.5 million tons being imported. Like in many of the world's fisheries, the Nigerian fishery subsector are at grave risk from human pressures, including overexploitation, pollution and habitat change. Climate change is intensifying these pressures, posing very serious challenges and limiting livelihoods opportunities. Despite the potential of aquaculture in Nigeria, recent data show a decline in aquaculture production from 2015 to 2017, with reports of increasing withdrawal of farmers from fish farming in favour of other agricultural ventures (PIND, 2017; Digun-Aweto and Oladele, 2017). Some of the reasons attributed to this include poor quality of fish feed and seed and reduced profitability of fish farming. However, national initiatives envision an expansion in the future to increase the supply of the population with high-quality protein and the prevention of malnutrition. This therefore, call for increased investment in the sector for increased productivity.

Investment is one of the fundamental variables in financial improvement of a country. Investment is needed to reproduce and develop production capacity and improve the profitability and competitiveness of Nigeria agriculture. The driving force behind investment is the projected income earned from the realized investments (Szyman´ska *et al*., 2021). It is the availability of capital (equity capital and credit) that determines the level of investment, which is turned into new technologies, thereby providing multiplication of income, and this in turn gives rise to new investments. The importance of investment capital as a driving force for the development and expansion of agricultural holdings cannot be overemphasized (Greenwald *et al.,* 2018).

From the foregoing, it has become necessary and indeed imperative to examine the determinants of investment among catfish entrepreneurs in Abia State, Nigeria. The specific objectives of the study were to describe the socio-economic and demographic characteristics of the catfish entrepreneurs and ascertain the pattern and the determinants of investment in catfish enterprises in the study area.

2. RESEARCH METHODOLOGY

This study was conducted in Abia State, Nigeria. The State has a land mass of 6,320 square kilometer with 17 Local Government Areas (LGA). Abia State was created out of Imo State on August 27, 1991. The state lies between longitudes $7^{o}\ 23^{1}$ and $8^{0}\ 02^{1}$ East of Greenwich meridian and latitudes $5^{o}\ 25^{1}$ and $7^{o}\ 30^{1}$ North of the equator. Abia State is bounded on the East by Cross River and Akwa Ibom States, on the North by Ebonyi and Enugu States, on the West by Imo State and on the South by Rivers State. The State consists of three agricultural zones, namely Aba, Umuahia and Bende. The State has a population projection of 4,143,100 people, which is 2.4% annual population change (2006-2022), NBS (2022).

The annual rainfall ranges from 2122 mm – 3050 mm while the temperature ranges between 20^{0}C and 36^{0}C. There are two seasons; the rainy season (April - October) and the dry season (Mid October - March). Farming is done majorly at subsistence level. The women only farm on their husband's land as they do not have direct title to land (Agba *et al*., 2014). The State is endowed with a rich fertile soil that supports the growth of crops such as yam, cassava, cocoyam, melon, maize, oil palm, garden egg, cocoa, to mention but a few. Poultry, goat, pigs and sheep are the major livestock kept. A lot of catfish farming activities are carried out in the study area as the area is suitable for catfish production.

There are over 80 catfish enterprise existing within the State, they include 7^{th} Option Farms,Ag Healthy Farm, Amamey Fish Farms Nigeria, Amazing Fisheries and Farms, Eteicon Farm, Great Fish Farming, Large Fish Farm and Smarchris Farms Ind. Ltd etc. within the State.

A multi-stage sampling technique comprising purposive, proportionate and random sampling procedures was adopted in the selection of respondents for the study. In the first stage, three (3) agricultural zones were used for the study to ensure an adequate representation of different catfish entrepreneurs in the State. They are Umuahia, Aba and Ohafia agricultural zones. The second stage involves purposive selection of one LGA from each agricultural zone. The local governments selected were Ikwuano for Umuahia agricultural zone, Ohafia for Ohafia agricultural zone and Osisioma Ngwa for Aba agricultural zone giving a total of six (6) LGAs. These LGAs were selected because of dominant activities in catfish enterprise in the area. The third stage is random selection of four villages from the selected LGAs. The fourth stage involved a random selection of 10 catfish entrepreneursthis gave a total of one hundred and twenty (120) respondents which constituted the sample size for the study.

Data for this study was collected with the use of structured questionnaire administered to the respondents. The questionnaire was designed to capture the relevant variables necessary for achieving the objectives of the study. The collected data were analyzed using both descriptive and inferential statistics. To analyze major determinants of investment, the Tobit model was estimated. This model was chosen because it has advantages over other models in that it reveals both probability of willingness and intensity of capital use which is tend to be censored at the lower limit of Zero. The Tobit model specification is given as follows:

$$Y^*_i = X_i\beta + \mu, \qquad i = 1,2,\ldots..n \quad - \quad - \quad - \quad - \qquad (1)$$

$$Y_i = Y_i^* \ if\ Y_i^* > 0$$

$$= 0, \quad \text{if } Y_i^* \leq 0 \quad - \quad - \quad - \qquad (2)$$

where,

Y_i: the observe annual investment

Y_i^* = is the latent variable which is not observed

β = vector of unknown parameters
µ = error term that are assumed to be independently and normally distributed with mean zero and constant variance ∂^2 (i = 1,2…n)

X_i= vector of independent variable affecting investment

The explanatory variables specified as factors influencing the level of investment were defined as follows: X1 = Age (years), X2 = Sex (male =1, female = 0), X3 = Education (years), X4 = Farming experience (number of years), X5 = Cooperative society (number), X6 = Household size (number), X7 = Transportation Cost (₦), Extension service (number), Credit use (₦) and Income(₦).

The threshold value in the above model is zero. The model parameters are estimated by maximizing the tobit likelihood function to the following form:

$$L = \prod_{Y_i^*} \frac{I}{\partial} f\left(\left(\frac{Y_i - \beta_i X_i}{\partial}\right) \prod_{Y_i^*, \leq 0} F\left(\left(\frac{\beta_i X_i}{\partial}\right) \quad (3)$$

where,
f and F are density probability function and cumulative distribution function of Y_i^*, respectively, $\prod_{Y_i^*}$ means the product over j for which $\prod_{Y_i^*, \leq 0}$ and $\prod_{Y_i^*, \leq 0}$ means the product over those 1 for which Y_i^*> 0,

Decomposition techniques will be used to analyze the effect of explanatory variables

1. Change in the probability of gain in independent variable X_i change is

$$\frac{\partial F(z)}{\partial X_i} = f(z) \frac{\beta_i}{\partial} \quad (4)$$

2. The marginal effect of an explanatory variable on the expected value of the dependent variable is:

$$\frac{\partial E(Y_i)}{\partial X_i} = f(z)\beta_i \quad (5)$$

where,

$$Z = \frac{\beta_i X_i}{\partial} \quad (6)$$

The change in intensity of dependent variable with respect to a change in an explanatory variable among the investors category:

$$\frac{\partial E\left(\frac{Y_i}{Y_i^*} > 0\right)}{\partial X_i} = \beta_i \left[1 - Z\frac{f(z)}{f(z)} - \left(\frac{f(z)}{f(z)}\right)^2\right] \quad (7)$$

F(z) is a cumulative normal distribution of z, F(z) is the value of the derivative of the normal curve at a given point (i.e. unit normal density). Z is the zero score for the area under the normal curve, β is a vector of the Tobit maximum likelihood estimate and ∂ is the standard deviation of the error term. Prior to running the above specified models, all dependent variables will be checked for the existence of data problems mainly multicollinearity problem, heteroscedasticity problem and endogeneity problem.

3. RESULTS AND DISCUSSION

3.1 Socio-economic and Demographic Characteristics of the Catfish Entrepreneurs

The distribution of the catfish entrepreneurs which is based on their socio-economic and demographic characteristics is presented in Table 1. The result in Table 1 showed that majority (64.29%) of the respondents were males while 35.71% were females. This shows that males dominates fish farming activities in the study area. This could be due to the fact that fish farming requires acquisition of fixed assets/high level of investment, constant supervision and monitoring, adoption of new technology as opined by Brummett *et al.* (2010), Olaoye *et al.* (2013) and Kumar *et al.* (2018). Furthermore, women's role in aquaculture is not widely acknowledged due to the fact of being at home most of the time, which eventually made their involvement in fish farming to be viewed as an extension of domestic activities and as such are not recognized and rewarded as opined by Ndanga *et al.* (2013). However, this result proves positive as women are faced with socially conditioned inequalities in the access, use and control of resources although they form big portion of the population undertaken farming activities. Removing these barriers will increase their involvement as well as enhance their performance in catfish farming.

The age distribution showed that 41.96% of the catfish entrepreneurs were within the age range of 21 – 30 years. Those between 31 and 40 were 26.79 %. The mean age of the entrepreneurs is 36 years. This implies that the entrepreneurs involved in fish farming activities in the study area were in their economically active and productive age. This conforms to the findings of Maina *et al*. (2014). It is obvious that people within a certain age range would have acquired some good level of experience; other people belonging to different age group might not have the experience but instead enough strength or energy which could be gainfully employed in the farm. However, according to Bassey (2017), age is considered to have a remarkable influence on the ability to invest in agriculture.

Table 1 showed that 51.79% of the respondents were married, while 48.21% were single. This result corroborates the findings of earlier studies of Adelaja *et al*. (2018) who reported that being married is a highly cherished value among farming households in Nigeria, not only because of the need for children and the continuation of the family, but due to the fact that the spouses and children form a vital source of unpaid family labour which can improve and boost fish production. This is typical of Nigeria rural setting because family members often serve as a source of additional labour together with cultural value attached to marriage.

About 68.75% of the respondents had spent 1 – 5 years of experience in catfish production, 25% had spent 6 – 10 years of experience while 3.57% had spent 16 - 20 years of experience in catfish production, respectively. The mean farming experience was approximately 5 years. This suggests that a considerable portion of the farmers have average experience in the business. Nwaru (2004) noted that the number of years spent in the farming business may give an indication of the practical knowledge he has acquired. This implies that the experience gained enables the entrepreneurs to use their resources prudently and consequently enhance their production status.

Table 1. Distribution of the respondents based on Sex

Sex	**Frequency (n= 112)**	**Percentage (%)**
Male	72	64.29
Female	40	35.71
Age (years)		
21 – 30	47	41.96
31 - 40	30	26.79
41 – 50	13	11.61
51 – 60	18	16.07
61 – 70	4	3.57
Mean	36.4	
Marital status		
Married	58	51.79

Single	54	48.21
Experience		
1 – 5	77	68.75
6 – 10	28	25.00
11 – 15	3	2.68
16 – 20	4	3.57
Total	112	100.00
Mean	5.1	
Level of education		
Primary	7	6.25
Secondary	58	51.79
Tertiary	47	41.96
Household size		
1 – 3	7	6.25
4 – 6	56	50.00
7 – 9	42	37.50
10 – 12	7	6.25
Mean	6	
Cooperative		
No	96	85.71
Yes	16	14.29
Extension contact		
No	94	83.93
Yes	18	16.07
Training		
No	72	64.29
Yes	40	31.71
Total	112	100.00
Location of business		
Rural area	61	54.46
Semi urban	29	25.89
Urban area	22	19.64

Source: Field survey, 2024

The distribution based on the level of education showed that literacy level was high among the catfish entrepreneurs with majority (51.79 %) having secondary form of education whereas 41.96% and 6.25% had secondary and primary education, respectively. High educational status of the entrepreneurs will also enable them acquire knowledge and skills for budgeting, saving, adoption of innovations and resources usage. Education plays a vital role in agricultural production as it promotes better exposure and access to vital information This means that they can be easily convinced to accept better practices of their farming operations. It is in conformity with Okezie *et al.* (2021) that a greater deal of change has occurred within the rural communities in recent times due to the introduction of education. This has implications on their involvement in agricultural development activities, since they can access information through print, electronic and professional associations meeting and workshop. Their high literacy level is an asset as the farmers would be exposed to many information sources, embrace innovations and analyze farm situations objectively. Undoubtedly, the high level of literacy predisposes some level of managerial ability in the farm business.

The distribution of the respondents according to household size showed that the mean household size of entrepreneurs was 6 persons. This corresponds with the findings of Nnamerenwa *et al*. (2017) as they noted that household size between 6 and 10 persons could likely participate in farming in order to improve sustainability of food production. Furthermore, according to Onwumere *et al*. (2017), this is desirable, consistence and of great importance as entrepreneurs may rely more on their family members than hired workers for labour on their farm. The economic implication is that it will provide the catfish entrepreneurs with family labour at reduce cost of farming.

From Table 1, 85.71% indicated that do not belong to cooperative society or farmers association. However, on the contrary, 14.29% indicated that they belong to an association. Membership of association satisfies the social needs of entrepreneurs in additions to serving as an avenue for access to information on agricultural technology. This corroborates with the findings of Okezie e*t al*. (2021). They noted that farmers by virtue of their membership has obvious advantages in terms of agricultural technology adoption and their doubts and misconceptions of technology and its adoption are clarified.

Majority of the catfish entrepreneurs (83.93%) did not encounter extension visitors. This suggests that greater numbers of the sampled fish farmers were not exposed to technical services and innovations in catfish production. According to Belton *et al*. (2017), extension services enhance farmers knowledge on agricultural technology and improved farm practices which would lead to increase productivity.

Majority of the catfish entrepreneurs (64.29%) did not have training in catfish production. The interpretation of 64.29% of catfish farmers reporting that they do not have any training in catfish production indicates that a significant majority of these farmers lack professional training specific to catfish aquaculture. This suggests that they might be relying on traditional knowledge, informal learning, or trial-and-error methods to manage their farming operations. Without proper training, entrepreneurs may not be using the most efficient or productive methods to raise catfish, which can lead to lower yields and higher costs. Lack of training can affect the quality of the catfish produced, as farmers might not be aware of the best practices for feeding, breeding, and disease management. Therefore, untrained farmers may inadvertently engage in practices that are unsustainable or harmful to the environment, such as overfeeding, improper use of chemicals, or poor waste management.

The result in Table 1 showed that majority (54.46%) of the catfish enterprises were located in rural areas, this was followed by semi-urban area (25.89%), and urban area (19.64%). The interpretation indicates that a significant majority of catfish farming takes place outside of urban centres. This could be due to various factors such as the availability of land, water resources, and the traditional location of agriculture in less densely populated areas. Rural areas often provide the space and water resources necessary for aquaculture, which may not be as readily available or affordable in urban settings. Catfish farming in rural areas can contribute to the local economy by creating jobs and supporting ancillary businesses such as feed suppliers, equipment retailers, and processing facilities. The concentration of catfish farms in rural areas may highlight the need for improved infrastructure, such as roads for transportation, electricity for farm operations, and access to markets.

3.2 Operating Cost in Catfish Business

The summary statistics of operating costs in catfish business is summarized and presented in Table 2.

Table 2. Summary statistics of operating costs in catfish business

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Fingerling	335,479.50	692,883.30	2,400.00	3,300,000.00
Fertilizer	4,808.04	15,005.20	0	60,000.00
Liming	2,675.89	5,022.14	0	20,000.00
Feed	765,205.40	758,519.40	72,000.00	2,600,000.00
Drugs	3,068.75	2,974.25	0	10,000.00
Labour	6,616.07	8,503.57	0	40,000.00
Energy	16,588.39	13,212.67	0	45,000.00

Source: Field Survey, 2024

The result in Table 2 shows that the cost of feed accounted for the highest proportion (₦765,205.40k) this was followed by fingerlings (₦335,479.50k). Others include energy (₦16,588.39k), labour (₦6,616.07k), drugs (₦3,068.75k), fertilizer (₦4,808.04k) and liming (₦2,675.89k). This reveals that feed constitutes the most significant operational cost, followed by fingerlings and then various other inputs like energy, labour, drugs, fertilizer, and liming. This reveals that large amount of money was spent by fish farmers for the purchase of feed (₦765,205.40k). This can be attributed to the high cost of imported feed by farmers. Feed has the dominant cost factor, accounting for over 60% of the total. This suggests a significant investment in fish feed, likely for intensive production systems or high-value fish species. Fingerlings (₦335,479.50k) the second-highest cost, serves as one of the most important inputs in catfish production. Farmers should ensure that fingerlings are purchased from reliable sources. Olasunkanmi and Yusuf (2014) reported that an average catfish farmer spent majority of the operational costs on feed. The cost breakdown can be used to justify further investments in feed production and storage facilities to improve efficiency and reduce reliance on external suppliers.

3.3 Pattern of Investment in Catfish Enterprises

The pattern of investment in catfish enterprises in the study area is summarized and presented in Table 3. Result in Table 3 reveal that catfish entrepreneurs in the study area invested majorly on land (₦592,946.40k). This was followed by borehole (₦249,830.40k), pond expansion (₦242,714.30k), generator (₦161,785.70k) and pumping machine (₦64,160.71k).

Table 3. Pattern of investment in catfish enterprises in the study area

Variable	Mean	Std. Dev.	Min	Max
Borehole	249,830.40	272,975.00	0	830,000.00
Pumping machine	64,160.71	10,780.90	0	123,500.00
Generator	161,785.70	93,478.47	0	350,000.00
Pond expansion	242,714.30	112,390.80	75,000.00	600,000.00
Land	592,946.40	680,130.70	0	3,000,000.00

Source: Field Survey, 2024

Land (₦592,946.40k): The highest average investment by catfish entrepreneurs is in land acquisition. This indicates that securing a physical and permanent location for their operations is the primary cost concern for these entrepreneurs. Borehole (₦249,830.40k): The second highest investment is in boreholes. This suggests that a reliable and clean water supply is crucial for maintaining the health and growth of the catfish. Pond Expansion (₦242,714.30k): The third largest investment is in pond expansion. This indicates that farmers are looking to increase their production capacity by enlarging their existing pond systems. Generator (₦161,785.70k): The fourth investment priority is in generators. Reliable power sources are essential for operations such as aeration, lighting, and running water pumps, especially in areas with unstable electricity supply. Pumping machine (₦64,160.71k): The smallest average investment among the listed items is in pumping machines. These are necessary for water circulation and management within the ponds.

This investment pattern suggests that catfish entrepreneurs prioritize the foundational elements of their operations, such as securing the land for ponds and ensuring a steady supply of both water and young fish to grow. The investments in boreholes and generators also indicate that these farmers may be operating in areas with limited infrastructure, necessitating self-sufficiency in water and power supply. The data reflects the capital-intensive nature of catfish farming, with significant upfront costs required for land and infrastructure before production can begin. It also highlights the areas where entrepreneurs may need financial support or loans to cover these substantial initial investments. According to Szyman´ska *et al.* (2021), investment is needed to reproduce and develop production capacity and improve the profitability and competitiveness of Nigeria agriculture. Productive investment decides the development opportunities of aquatic enterprise. It indicates the expansion of fixed asset inventory or an increase in its quality, which contribute to the growth of the enterprise's potential in the future.

3.4 Determinants of Investment in Catfish Enterprises in the Study Area

Tobit regression model result on determinants of investment in catfish enterprises is presented in Table 4.

The result in Table 4 showed that Chi-square value, capturing the goodness-of-fit, indicates that the model is significant at 1 percent (1%) probability level. Seven, out of the ten explanatory variables that were hypothesized to affect potential investors‟ decision to invest were statistically significant. Age, sex, education, experience, cooperative, extension visit and income were found to significantly affect the level of investment. Among the seven variables that were found to significantly affect the level of investment, the coefficients of sex, education, experience, cooperative, extension visit and income were positive, implying that these variables had a significant investment-enhancing impact. Whereas the coefficient of age had negative sign, implying that this variable had a significant investment deterring impact.

Table 4. Determinants of investment in catfish enterprises

Variables	Coefficients	Std. Error	z-value	Marginal effect dy/dx
X_1 = Age	-0.013	0.003	-4.02***	-0.003
X_2 = Sex	0.269	0.053	5.07***	0.269
X_3 = Education	0.034	0.008	3.96***	0.034
X_4 = Household size	0.003	0.014	0.18	0.003
X_5 = Experience	0.052	0.009	5.89***	0.052
X_6 = Cooperative	0.065	0.021	3.14***	-2.111
X_7 = Transport	0.075	0.049	1.51	0.075
X_8 = Extension visit	0.163	0.077	2.11**	-0.163
X_9 = Credit use	2.05e-08	1.16e-07	0.18	-2.05e-08
X_{10} = Income	3.339	0.462	7.23***	-4.65e06
Constant	.39266	0.075	5.20***	
LR chi^2 (10)	108.95			
Prob> chi^2	0.0000			
Pseudo R^2	0.8510			
log likelihood	-9.5368			
Number of observation	112			

*, **, *** denotes 10%, 5% and 1% significant respectively

Source: Field Survey, 2024

The coefficient of age was negative and significantly ($p<0.01$) affect the propensity to invest. The marginal effect of age on the level of investment was -0.003. The negative coefficient for age suggests that as catfish entrepreneurs get older, their propensity to invest decreases. The significance level ($p<0.01$) indicates that this is a statistically robust finding. Marginal effect of -0.003 implies that for each additional year of age, the level of investment decreases by 0.003 units on the scale used in the study. This marginal effect quantifies the change in the expected level of investment associated with a one-unit change in age. The implication is that older farmers may be less likely to invest due to factors such as approaching retirement, aversion to change, or satisfaction with the status quo. This could have implications for the transfer of knowledge to younger farmers and the adoption of new technologies or practices in the industry. Awoyemi (2011) obtained a negative relationship between age and level of investment.

The coefficient of sex was positive and significantly ($p<0.01$) affect the propensity to invest. The marginal effect of sex on the level of investment was 0.269. The positive coefficient for sex indicates that being of a particular sex (usually coded as male = 1, female = 0 in models) is associated with a higher propensity to invest in respect to male catfish farmers. The marginal effect of 0.269 suggests that the sex associated with the value of 1 (likely male) has a higher level of investment by 0.269 units compared to the female sex. The Implications is gender-related differences in access to resources, risk-taking behavior, or opportunities that influence investment decisions.

Accordingly, as expected, the coefficient of years of education was positively and significantly ($p<0.01$) related to the likelihood that the investor chooses to proceed with the investment. The marginal effect of education level of the sample investor on the level of investment was 0.034 and education increased the probability of investment. A higher education level among catfish entrepreneurs is positively associated with the likelihood of investing. The statistical significance indicates a strong relationship between education and investment behavior. The marginal effect of 0.034 means that for each additional level of education (however it is measured in the study), the level of investment increases by 0.034 units. Education also increases the probability of making an investment. The implications is that catfish entrepreneurs may have better access to information, be more aware of the benefits of investment, or be more capable of implementing sophisticated farming techniques. This finding is in agreement with the study of Uvaneswaran and Wollo (2019). This suggests that increasing educational opportunities for farmers could lead to higher levels of investment in the industry.

The coefficient of years of experience was positively and significantly ($p<0.01$) related to the likelihood that the investor chooses to proceed with the investment. The marginal effect of experience of the sample investor on the level of investment was 0.052. The positive coefficient for experience indicates that as the experience of the sample investor increases, the likelihood of proceeding with the investment also increases. The significance level ($p<0.01$) suggests a strong statistical relationship. The marginal effect of 0.052 implies that each additional unit of experience, the level of investment increases by 0.052 units. Uvaneswaran and Wollo (2019) noted that experienced farmers are more likely to invest and may do so at a higher level. The implications is that experienced farmers may have a better understanding of the industry, improved risk assessment skills, and more confidence in making investment decisions.

The coefficient of membership of cooperative society was positive and significantly ($p<0.01$) affect the propensity to invest. The marginal effect of cooperative on the level of investment was -2.111. The positive coefficient for cooperative suggests that entrepreneurs who are part of a cooperative are more likely to invest. The significance level ($p<0.01$) indicates a robust relationship. The implications is that catfish entrepreneurs who were part of a cooperative may provide access to shared resources, collective decision-making, or support networks that encourage investment.

However, the negative marginal is not in line with *a prior* expectation. In the study undertaken by Kareem *et al.* (2013), they noted that there is a positive interaction between cooperative membership and level of investment.

The coefficient of extension visit was positive and significantly ($p<0.05$) affect the propensity to invest. The marginal effect of extension on the level of investment was -4.65e06. The positive coefficient for extension visits suggest that entrepreneurs who receive extension services are more likely to invest. The significance level ($p<0.01$) indicates a strong relationship. The extremely large negative marginal effect here is unusual. Extension services can provide valuable information, training, and technical support to entrepreneurs, which can positively influence their investment decisions. This agrees with the findings of Aphunu and Nwabueze (2013) that showed that farmers who had contact with extension agent will investment more in production.

The coefficient of income was positive and significantly ($p<0.01$) affect the propensity to invest. The marginal effect of income on the level of investment was -1.163. The positive coefficient for income indicates that higher income is associated with a greater propensity to invest. The significance level ($p<0.01$) suggests a strong relationship. The marginal effect of-1.163 means that for each unit increase in income, the level of investment decreases by 1.163 units. The implication is that the higher income level may provide entrepreneurs with the financial capacity to invest, expand their operations, or take on new ventures. The volume of investment has been found to depend on income, cost of procuring investible fund and entrepreneurs' expectations on the trend of the industry in future (Shitu, 2012).

4. CONCLUSION AND RECOMMENDATIONS

Based on the results, it could be concluded that the major operating cost is the cost of feed and the major investments by catfish entrepreneurs were on land, borehole, pond expansion, generator and pumping machine. The significant determinants of investment in catfish business were age, sex, education, experience, cooperative, extension visit and income. It was recommended that since feed cost constitute a major operating cost in production, there is the need to formulate feed locally in order to reduce costs associated with the business as this would enhance commercial catfish production in the study area and Nigeria in general. Variables such as age, sex, education, experience, cooperative, extension visit and income should be taken into consideration in policy formulation.

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ASSESSMENT OF PARAMETERS AFFECTING THE OPERATIONS OF SELECTED STRATEGIC GRAIN RESERVE CENTERS IN NIGERIA

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ABSTRACT

Neglecting agricultural productivity, particularly in staple food crops, can drive a nation to rely on imports for sustenance. To address these challenges, the Federal Government established Strategic Grain Reserves to reduce post-harvest losses, ensure food storage for the population, provide relief during disasters, and support other countries in need. This study assessed factors affecting selected grain reserves using primary and secondary data. Primary data were collected through questionnaires administered at six Strategic Grain Reserves in Ondo, Kwara, Oyo, Osun, Ogun, and Ekiti States.The findings revealed that 50% of the facilities were operational, 40% were under construction, and 10% awaited commissioning. The reserves had stored grains for a maximum of 36 months and a minimum of 24 months. Despite their current status, grain losses were minimal, at less than or equal to 5%. However, at the time of the study, the reserves had no stock in storage.Secondary data, covering population growth, grain production, export, import, and demand from 2006 to 2015, were analyzed using correlation coefficients. The results indicated weak and negative relationships between most parameters: -0.3 for population and grain production, -0.4 for exports, -0.2 for imports, and -0.02 for demand, showing no significant correlation. The exception was a positive but moderate correlation (0.5) between grain imports and population growth, highlighting a growing dependence on imports.Although the reserves are equipped to function effectively, they are underutilized due to low grain productivity and insufficient supply from catchment areas. Ideally, domestic grain production should meet the needs for export, import, demand, and storage. However, the analysis shows that production levels are inadequate. Consequently, the reserves remain largely unused, with minimal grain stored to fulfill their intended purpose.

Key words: Strategic grain reserves, Silo storage structures, Storage stature, grain production, import.

1. INTRODUCTION

The strategic grain reserve is stocks of grain held in reserve intentionally by government programs for the purpose of meeting future, domestic and international needs. The strategic Grain Reserves Department is the apex of the three tier of the National Agricultural Food Storage Programme (NAFSP) of the Federal Government launched in 1987 to prevent post- harvest losses, and to provide the first line of food relief internally and to friendly countries in times of disaster, natural or man - caused disaster and to make food available at all times at affordable prices. (FMARD, 2013).

The postharvest policy of the Nigeria food security programme is centered on three tier grain storage; Strategic Grain Reserve being handled by the Federal Government, Buffer Stock to be coordinated by the State Government and the On – Farm Storage handled at the local level. The on - farm Storage Programme is to hold 85% of the grains required for food security (Olumeko, 1998). The "Buffer Stock Storage Programme "being operated by the states to reduce inter- seasonal variation in food supply, thus guaranteeing price stabilization to both the consumer and the producer. And the "On-Farm Adaptive Storage Programme" which is to promote adequate prevent Local post – harvest losses at farm level. (FMARD, 2013).

Strategic Grain Reserves, also called emergency food reserves or food security reserves have received considerable attention following the global food crisis of 2007-08. Various models for holding reserves have been discussed at such high – level forums as the G-8 summit and have been studied by the New Economic Partnership for African Development (NEPAD) and other regional economic organizations. (Ahmed, 2011).

Following the global food crisis of 2007/2008, Nigeria Government had merged the Strategic Grain Reserve (SRG) with other projects / departments like the Projects Coordinating Unit (PCU), Fertilizer Department, Cooperatives Department and Federal Department of Agriculture's (FDA's) Engineering / Mechanization and Post – Harvest Technology Divisions to form what is presently known as National Food Reserve Agency (NFRA). The NFRA is a parastatal of the Ministry of Agriculture to oversee Nigeria's Food Security Strategy. The agency has regional offices in each of the country's six geo- political zones.

The main objective of NFRA to significantly improve Nigeria's agricultural productivity;improve large scale production, storage/processing capacity as well as required infrastructure to achieve food stability; to achieve national food sufficiency and derive over 50% of the nation's foreign exchange through agricultural export strategy designed to promote self – sufficiency in rice production, processing and packaging even though the country still imports some.

The total completed Silo Complexes meant for Strategic Reserves are 18 and 15 are still under various level of construction and 45 community Warehouses with a total capacity of 94,000mt were as well constructed. (Delaporte et al, 2015). Strategic Grain reserves are being embraced in Nigeria also, to lessen the country's dependence on external assistance, particularly on food aid but also on food imports and reduction in capital wastage. For instance, Nigeria, a country which is considered as a major food exporter, now found itself in the crisis of food importation (Agriculture in Nigeria, 2011; Abdulrahaman, 2013; Abu, 2012; Adebayo, 2010; Adebayo et al., 2009).

Lawal (2009) reported that the National Food Reserves Agency (NFRA) in her effort to cater for strategic grain reserves has commenced additional twenty (20) silo complexes nationwide during the year, while Okunola et al. (2007) reported, that the Strategic Grain Reserve in Akure has silos with storage capacity of up to 2,500metric tonnes and Ware house of up to 5,000metric tonnes and the major problems identified during the study include leakages, inadequate ventilation and poor drainage as a result of the adaptation of existing structures, which were not originally warehouse, but eventually converted to warehouse after some modifications were effected by artisans. According to Oni (2014), the Federal Government has taken measures to address some issues responsible for food crop losses. For instance, "As at 2011, 12 silos were distributed across the geo-political zones with a combined storage capacity of 300,000tonnes for assorted grains, beans, and gari, while twenty additional silos have been built by the Federal Government.

Adewumi and Oduwole (1995) gave the report that silos in Nigeria have performed below expectation. Since, most of them are mostly used for short term storage with age ranged between 3-37 years and size range of 5-2500 tons. A lot still need to be done in the area of storage, processing, rendering of extension services, promotion and ensuring compliance to the standard and grades of agricultural produce. While twenty additional silos have been built by the Federal Government to further raise the joint storage capacity of the nation's silo to 1,336 million tonnes. These have been completed by the present administration to bring the total to thirty – three (Olukayode, 2014).

2. METHODOLOGY

The purposive sampling method was used to select the strategic grain reserve to be used. Six states in Nigeria including five in the Southwest and one in the North Central geo – political zones. The Strategic Grain Reserves Locations in Ondo, Kwara, Oyo, Osun, Ogun and Ekiti State. Two sets of data obtained for this research included the primary and the secondary data. The primary data was obtained using questionnaires administered to the selected SGR locations. The questionnaire was designed to ascertain the functionality and the level of usefulness of these reserves in terms of types of grain stored, handling and technical equipment available, maximum and minimum months of storage, level of grain loses experienced during storage, period at which their stored produce meets market demand in their zones and their present status.

The secondary data used was obtained from FAO publications, world – Bank publications, FAOSTAT Trade Statistics, National Bureau of statistics Journal, World – Grain and USDA – Annual Reports. Essential parameters affecting Strategic Grain Reserves required for the evaluation were firstly, studied for ten years (2006 – 2015). They include: Nigeria population growth as seen in (Table 1), grain output production (Table 2), grain export (Table 3), grain import (Table 4) and quantity in demand (Table 5). Correlation coefficient method was used to analysed and evaluate the relationship between these identified parameters.

3. RESULTS AND DISCUSSION

3.1 Results

Figure 1 shows the percentage of functional and non – functional visited Strategic Grain Reserves. 50% of the SGRs were in use and operational, the remaining 50% were yet to be in operation in which one had been completed but is awaiting commissioning, while the ones under construction are at 50% and 90% construction level respectively.

The assessment report indicates that 50% were functioning while the remaining 50% were yet to be in operation. All the three functioning locations visited stored the same grain crops which were maize, millet, sorghum, soyabeans in Silo Structures and gari, while location B (Kwara) include rice. They all stored these grain crops in silo storage structures but stored gari in warehouse for a maximum of 36 months except location B (Kwara) which had only been storing for 24 months (Figure 2). Also, the following handling and evaluating equipment were available for carrying out standard test and evaluation: moisture meter, hectoliter machine, scale and scoop; they were functioning and operating to expectation (Figures 3 and 4).

The highest percentage grain loss experienced during storage by these functioning locations was less than or equal to 5% with a least percentage loss of 1%. (Figure 5) using grain percentage damage factor method (Ajisegiri, 1991). Correlating identified parameters affecting grain security as conversant to Strategic Grain Reserves shows a negative and weak correlation. The relationship between the total grain output production and Nigeria population growth is – 0.3, that of total grain import and output production is – 0.4, total grain export and total output production is – 0.2, while the relationship that existed between the total grain output production and grain demand is – 0.02 which is negative, weak and even established no correlation. (All the values used were obtained for 2006 -2015).

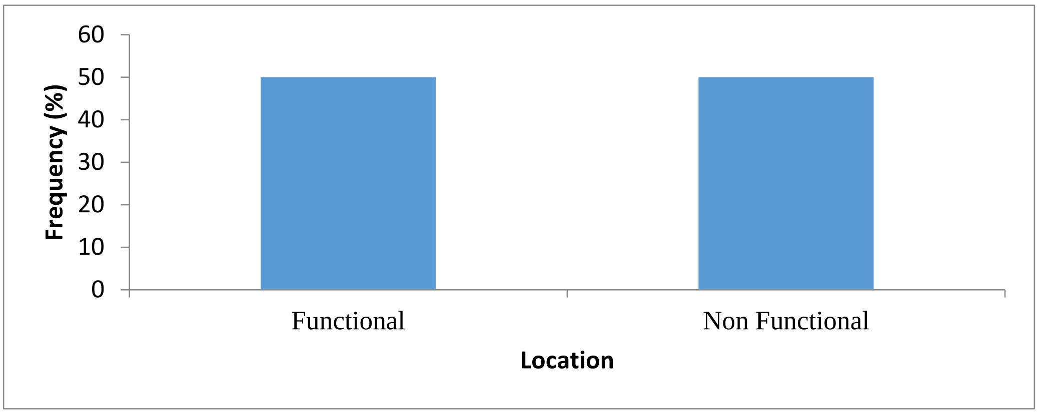

Figure 1. Functional and Non – functional Strategic grain reserves location

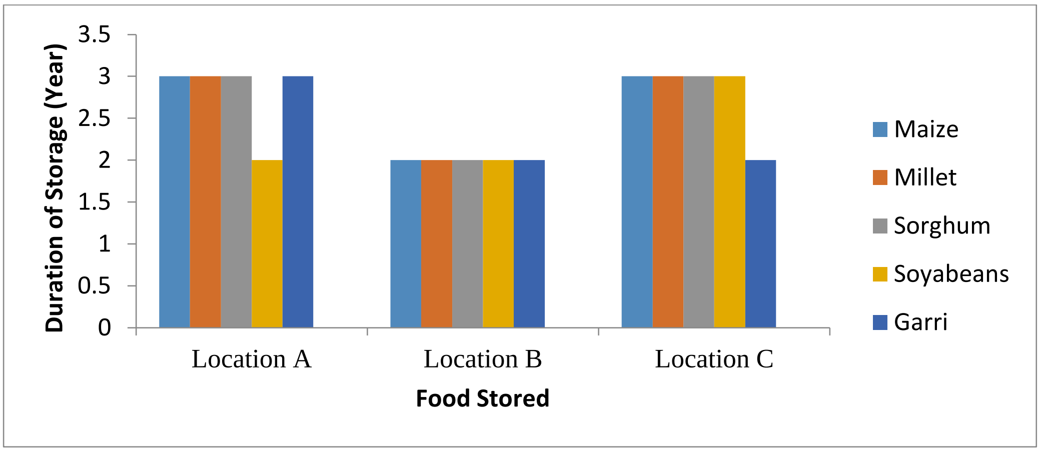

Figure 2. Duration of storage versus food stored

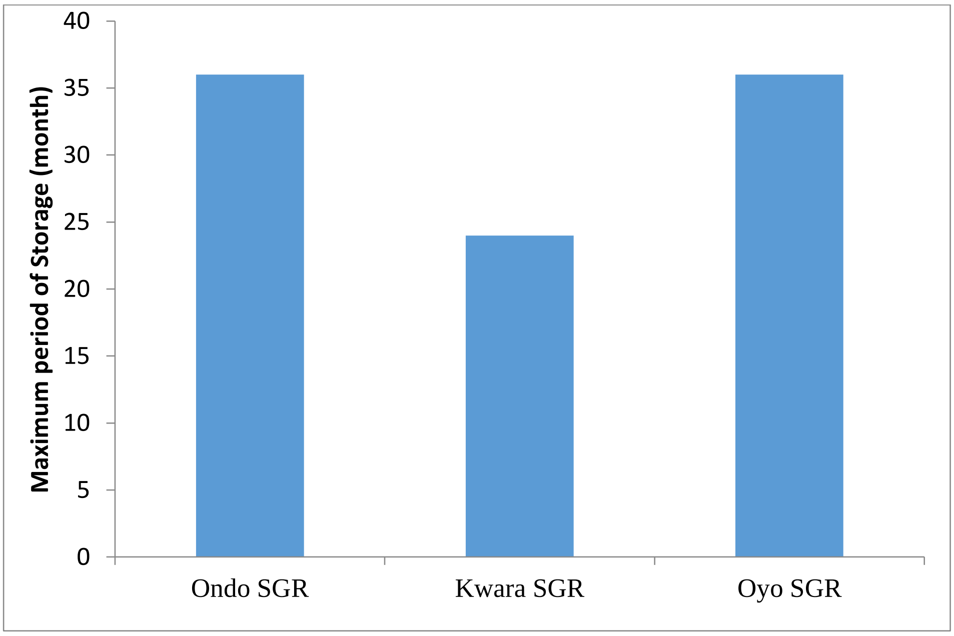

Figure 3. Maximum period of storage for Operational location

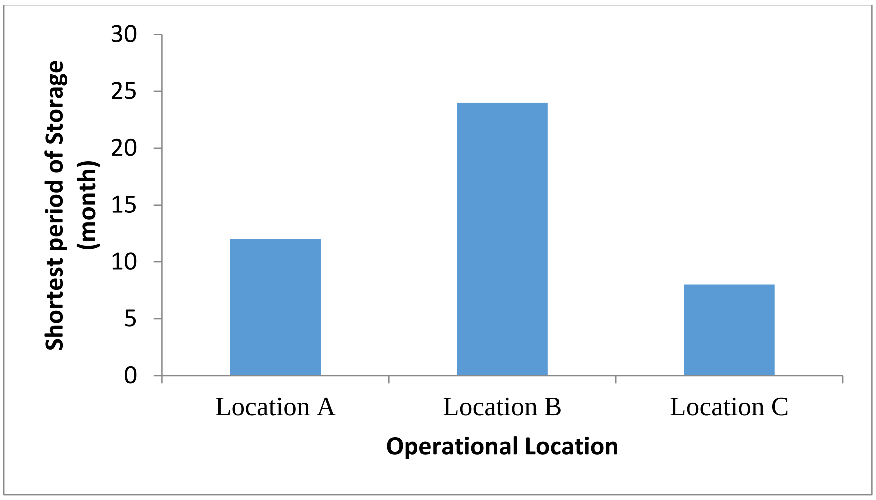

Figure 4. Shortest period of storage of Operational location

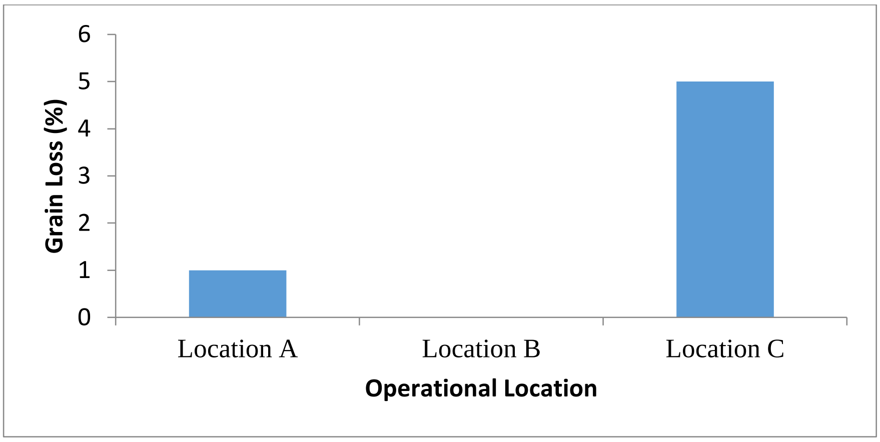

Figure 5. Level of grain loss in Operational locations

In contrast, the relationship established between the total grain import and population growth is 0.5 which showed positive correlation and established great dependence on grain import for the populations' survival.

Table 1. Nigeria Estimated Population for 2006 – 2015

Year	Population (Millions)
2006	143.00
2007	147.15
2008	151.00
2009	155.21
2010	159.42
2011	164. 77
2012	168.24
2013	172.82
2014	177.48
2015	188.20

Source: World Development Indicator (2016)

Table 2. Nigeria Estimated Agricultural Grain Crops Production for 2006 - 2015

GRAIN CROP /PRODUCTION (OUTPUT) Tonnes (T)							
Year	**Rice (Milled)**	**Wheat**	**Maize**	**Soyabeans**	**Sorghum**	**Millet**	**Total**
2006	2,873,420	______	7,023,000	1,650,090	6,474,000	5,940,000	23,960,510
2007	3,186,000	44,000	5,796,670	580,000	5,429,000	4,388,000	19,423,790
2008	4,179,000	53,000	9,113,710	591,000	5,218,400	4,327,610	23,482,720
2009	3,546,250	37,000	7,338,840	610,000	5,271,000	4,884,890	21,687,980
2010	4,472,520	34,200	7,669,180	460,000	7,133,820	5,167,090	24,936,810
2011	4,700,000	100,000	8,800,000	500,000	6,500,000	1,000,000	21,600,000
2012	2,709,000	100,000	9,250,000	510,000	6,900,000	5,000,000	24,469,000
2013	2,370,000	70,000	7,630,000	650,000	6,493,000	5,000,000	22,213,000
2014	2,772,000	70,000	7,700,000	650,000	6,592,000	5,200,000	22,984,000
2015	2,900,000	100,000	10,800,000	______	7,000,000	______	20,800,000

Sources:FAOSTAT 2011, 2014; USDA, 2011 – 2015; World – Grain.com, 2011

Table 3. Estimated Nigeria Agricultural Grain Crops Export for 2006 – 2015

	Grain Crop Export in Tonnes (T)					
Year	**Rice (Milled)**	**Wheat**	**Maize**	**Soyabeans**	**Sorghum**	**Total**
2006	2,497	15	3,666	11,500	699	18,377
2007	251	82	10,416	15,300	378	24,427
2008	46	12	1,023	15,000	17	16,098
2009	-----	12	------	14,400	30	14,488
2010	0	200,000	35	0	100,000	300,035
2011	0	570,000	100,000	0	60,000	730,000
2012	0	480,000	100,000	0	70,000	650,000
2013	0	450,000	50,000	0	0	500,000
2014	0	500,000	100,000	0	30,000	630,000
2015	0	500,000	200,000		100,000	800,000

Sources: FAOSTAT, 2012; FAOSTAT Trade statistics; Food Security Portal; Grain and Feed Annual Report, 2011-2015: FAO Food Outlook, 2011

Table 4. Estimated Nigeria Agricultural Grain Crops Import for 2006 - 2015

	Grain Import in Tonnes (T)					
Year	**Rice (Milled)**	**Wheat**	**Maize**	**Soyabeans**	**Sorghum**	**Total**
2006	1,000,000	3,244,000	9,612	23,124	0	4,276,736
2007	1,216,962	7,795,100	687	23,124	24	9,035,897
2008	971,815	1,132,180	49	83	12,601	2,116,728
2009	1,056,000	1,134,000	29	------	12,000	2,202,029
2010	2,100,000	3,400,000	400,000	4,000	------	5,904,000
2011	2,400,000	4,051,000	100,000	4,000	13,000	6,568,000
2012	2,890,000	3,800,000	100,000	10,000	0	6,800,080
2013	2,500,000	4,140,000	100,000	--------	0	6,740,000
2014	3,000,000	4,215,000	100,000	--------	0	7,315,000
2015	3,500,000	4,350,000	100,000	-------	0	7,950,000

Sources: Food Security portal; World – Grain.com, 2015; FAOSTAT, 2012; USDA, 2011 – 2015; FAO, Food Outlook, 2010

Table 5. Estimated Nigeria Agricultural Grain Crops Demand for 2006 - 2015

Grain Crops/ Food Demand in Tonnes (T)						
Year	**Rice (Milled)**	**Wheat**	**Maize**	**Soyabeans**	**Sorghum**	**Total**
2006	5,200,000	3,243,985	7,028,985	1,667,174	5,216,871	23,351,516
2007	3,100,000	7,839,018	5,786,944	587,824	5,428,766	22,742,552
2008	3,000,000	1,185,168	9,112,736	586,083	5,205,782	19,089,769
2009	2,800,000	1,170,988	7,338,869	595,600	5,282,970	17,188,247
2010	5,000,000	3,581,000	8,069,145	454,000	7,146,803	24,250,948
2011	5,030,000	3,490,000	8,825,000	484,000	6,690,000	24,519,000
2012	5,200,000	3,970,000	9,250,000	520,000	6,790,000	25,730,000
2013	5,000,000	3,970,000	7,800,000	650,000	6,850,000	24,270,000
2014	6,000,000	3,835,000	7,700,000	650,000	6,830,000	25,015,000
2015	6,000,000	3,920,000	7,511,000	----------	6,600,000	24,031,000

Sources: Agricultural Transformation Agenda, 2011; USDA, 2011 - 2015

3.2 Discussion

The major problem with these SGR is low farm output which invariably affects the quantity available for storage. For effective grain storage and functionality of structures, productivity and supplies from catchment areas and maintenance of the existing structures are paramount. The study has been able to reveal that 50% of grain reserves visited were functioning which according to Olumeko (1998) and FMARD (2013) were to be supplied grains from buffer stock, which are used to stabilize commodity prices and also aim to protect producers from price drop and or consumers (Annelies, 2014). Despite the aim of buffer stock which is to give room for grain storage for at least 2-3 years, the SGRs visited are not performing to expectation since its being alone compared with India Reserves where the government implements its price stabilization and food security policies through the Food Corporation of India (FCI) aiming at providing farmers' ruminative prices, to make food available at reasonable prices particularly to vulnerable section of the society and intervene in market for price stabilization. While McCreary, 2012 examined the performance of this programme a success-story. The non – functioning reserves would be due to lack of their supplies or technical failures of reserves as observed in Akure by Okunola et al (2007).

However, considering the estimated national population growth rate and other factors, the level of productivity of grain could only meet with local demand but insufficient to supply. The level of impact of the grain reserves indicates the needs to step up productions and increase the number of reserves adequacy. Notwithstanding the crops covered by grain reserves have excluded most crops prone to rapid spoilage and maximum percentage losses such as horticulture crops like fruits and tubers of different types.

Moreover, the merging of various parastatals to provide efficiency and combat food crisis has not yielded any positive improvement in performance of the reserves. Hence a major food exporting country is now importing food to augment food supply in the country. their point to the Federal

Government to step up efforts in funding, staffing and enhancing adequacy in quantity or structure and in their maintenance

4. CONCLUSION AND RECOMMENDATIONS

The evaluation carried out on the visited and functioning Strategic Grain Reserves showed that they have the potential to perform and operate adequately. Even though, they have handling, technical and mechanical facilities, they all require upgrade for adequate performance with minimal grain losses but were yet to satisfy the aims of their establishment judiciously as they were under – utilized due to low grain production. In view of this, the facilities were not stored to expectation as their present status indicated.

Nevertheless, the analysis obtained from secondary data clearly shows that Nigeria is low in grain production, having little or nothing to export, greatly depends on import to meet the population growth demand therefore, nothing is left for storage.

To optimize the performance of the Strategic Grain Reserves in Nigeria, the following recommendations are made for improved performance.

1. Establishment of farms by the government majorly for those strategic grain reserves within their locations to at least cater for half of their stored produce. This is to add those obtained from the contractor outside to keep up to the stock required.
2. Employment of more extension and marketing officers to link the grain producing farmers with the reserve centers directly to enhance adequate deposition of their produce and to offer the best agricultural practices required for improved production.
3. Training of officers and implementation of the outcome of their training on how to use facilities provided for improvement.
4. Employment of relevant personnel such as Agricultural Engineers and Technologist who are more experienced in the field of storage than the use of non – professionals as witnessed in the SGRs visited during the conduct of the research.
5. The Federal Government of Nigeria through the National Agricultural Technology Innovation Policy (NATIP) should employ the use of Information Technology (IT) in the management of the SGRs to enhance effective grain storage as there is no report of the use of software in the management of stored grain in the SGRs visited.

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DEVELOPMENT OF A MOTORIZED TWO-ROW MULTISEED GRAIN WALKING PLANTER

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ABSTRACT
Addressing the challenges of low crop yields and labour intensive planting processes, a motorized two-row multiseed grain walking planter was designed and fabricated. This innovative equipment enables small and medium-scale farms to enhance their productivity efficiently. Key features of the motorized two-row multiseed grain planter include a robust design suitable for small and medium-scale farms, adjustable settings for optimal seed-soil contact, efficient planting mechanism for increased productivity, and suitable for planting multiple types of grains. The motorized two-row multiseed grain planter was designed to operate effectively under various field conditions in order to ensure improved crop yields and reduced labour requirements for farmers. Laboratory and field tests were both conducted on the planter to evaluate the planter's performance. Test results revealed significant improvements in planting efficiency, crop yields, and reduced labour requirements. This innovation has the potential to transform the agricultural sector, particularly for small and medium-scale farmers, by increasing productivity, efficiency, and profitability.

Keywords: Planter, Productivity, Efficiency, Grain, Farming, Crop, Yields, Labour, Mechanization

1. INTRODUCTION
Cereal crops, often known as grain crops, are members of the grass family (Gramineae) and are primarily produced for their starchy, edible seeds. Examples of cereal crops are barley, rye, oats, soybeans, millet, wheat, rice, and maize (corn). Cereals are used for various purposes in Nigeria, which includes the making of akamu, agidi, nrioka, tuwo shinkafa, and then tuwo masara. They are also used for livestock feed and fodder. Cereal stems are used in some regions of Nigeria to make traditional shelters using structural designs. Protein content in cereal grains is comparatively low, particularly for the important amino acids. Legumes and proteins are necessary supplements for them (Adesoye and Mary, 2015). Grains planting operation in Nigeria are quite low because a large number of farmers still plant their crops with their hands or make use of hand tools as shown in Figures 1 and 2.

Nevertheless, the manual method of seed sowing causes the farmer to experience unbearable back discomfort, inadequate spacing, and poor seed placement, thereby restricting the amount of land that can be cultivated. Furthermore, it requires a lot of time and labour to plant by hand; eight persons are required to cultivate one hectare of land (Dela Cruz and Bobier, 2016). Majority of Nigerian farmers roughly 95% of them have small land holdings whereby they often struggle to escape poverty. The seed planters that are available in the market are expensive, made especially for large-scale farms, imported, and unsuited to the local environment. Purchasing expensive imported farming supplies and equipment can be difficult for a peasant farmer (Wahid and Khadatkar, 2023) The promptness of activities is a critical aspect that can be attained solely through the recommended utilization of agricultural machinery (Salokhe and Oida, 2003). Nonetheless, the diminished operational efficiency and elevated labour intensity of this planter render it unattractive in contemporary contexts. The manual nature of the technique renders it labourious.

Figure 1. Conventional Agricultural Method
Source: Ahmed (2022)

Figure 2. Women planting manually
Source: FAO/CIMMYT (2018)

With a history dated back to centuries, the evolution of agricultural machinery such as grain planters has been marked by ongoing innovation aimed at boosting efficiency and productivity in farming practices. The advent of mechanized agriculture revolutionized the industry, enabling farmers to cover larger areas in less time while achieving greater planting accuracy. Early motorized grain planters were rudimentary, often consisting of simple seed dispensers attached to horse-drawn carts or tractor. The initial designs established a foundation for future innovations, facilitating the creation of more advanced and efficient planting machinery. Manual and animal traction grain planters are often compact in design, lightweight, and easy to operate. These planters are primarily designed for limited plots of land, mountainous terraces, or inclined terrains (Chapagain and Raizada, 2017).

The development of a motorized two-row multiseed grain walking planter is a pivotal advancement in agricultural machinery, transforming the methods of grain planting and cultivation. This advanced equipment embodies a synthesis of state-of-the-art technology and conventional agricultural methods, providing farmers with a flexible and effective means to improve their planting processes. The motorized two-row multiseed grain walking planter exemplifies a new era of agricultural efficiency and sustainability through the integration of precision planting mechanisms and multifunctionality. This development aims to optimize planting operations while enhancing productivity and resource efficiency. The two-row arrangement facilitates the concurrent planting of two rows of grains, practically doubling the planting capacity relative to conventional single-row planters. This expedites the planting process while guaranteeing consistent spacing and depth, resulting in enhanced crop emergence and overall production potential. The agriculture sector has adopted mechanical processes to varying degrees, reflecting the variable conditions throughout different regions of the country. A prevalent characteristic of mechanization is planting. It is the procedure of sowing seeds in the soil to optimize germination outcomes. Planting commenced with manual techniques and evolved to incorporate stones, hand tools, and machines (Yasir et al., 2012). Adejuyitan *et al.* (2012) assert that the essential criteria for small-scale cultivation technology are suitability for small farms, a user-friendly design, enhanced planting efficiency, and reduced labour compared to manual planting methods. A row planter was engineered to achieve 88% field efficiency and a planting rate of 0.20 hectares per hour.

The cultivable field is constrained by the manual seed planting technique, which results in suboptimal seed placement and spacing efficiencies, leading to significant back pain for the farmer. It is essential to create an economical planter that reduces monotony and labour, enabling smallholder farmers to enhance food output sustainably and environmentally beneficially. Various design types have emerged historically, each employing distinct methodologies with specific advantages, disadvantages, and constraints.

2. MATERIALS AND METHODS

2.1 The Concept of The Machine and Working Principle

The principal design considerations for the development of the motorized two-row multiseed grain walking planter include power requirement, types of grains to be sown, farm's dimensions, scale of the operation, and selection of seeds.

2.1.1 Power requirement

Human assistance is necessary to direct the planter during its movement over the land.

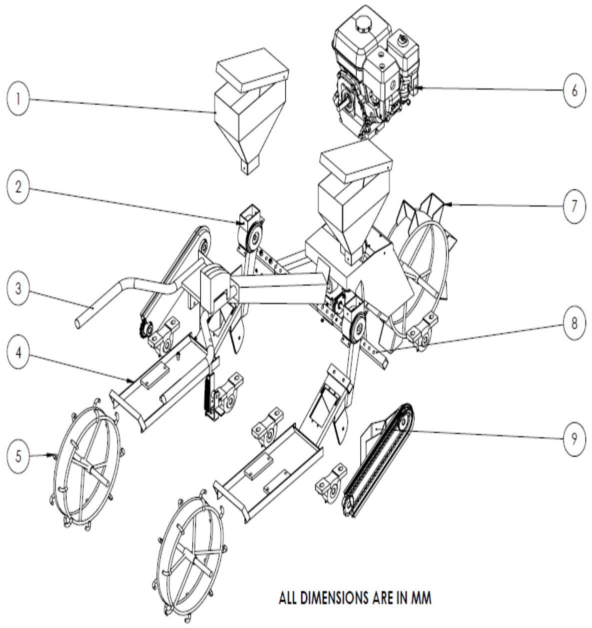
2.1.2 Crop varieties

This aim at obtaining an average plant spacing distance as specified by the planter as shown in Table 1.

Table 1. Grains with different planting inter-row and intra row spacing distances

S/No.	Grain	Inter-row spacing (cm)	Intra-row spacing (cm)
1.	Maize	75	30
2.	Soya bean	75	30
3.	Wheat	30	25
4.	Groundnut	25	25
5.	Guinea corn	90	40

The motorized two-row multiseed grain walking planter consists of fundamental components which include the primary frame, seed metering system, seed hoppers, ground wheels, furrow openers, and furrow coverer. The principal parameters of this two-row multiseed grain walking planter encompass the dimensions of length, width and height measuring 1,845 mm, 1,015 mm, and 1,495 mm, respectively; plant-to-furrow spacing within rows varying from 25 to 40 cm and between rows from 20 to 90 cm; and an integrated handle for maneuvering the planter during operation. The planter's seed metering system is placed vertically which was incorporated with few holes designed for the specified seed sowing distance. A transmission system has been developed to regulate seed placement and minimize movement between the 39 cm diameter planter's wheel and the feeding mechanism, controlling the number of seed drops per revolution using metering seed plates at a sprocket ratio of 1:1. The front column features a stationary furrow opener that enables the adjustment and modification of the furrow's depth. The closing mechanism consists of two cage wheels that compress the seeds into the soil as the planter advances. Presented in Figure 3 is the seed planter's exploded view which presents the part list. Presented in Figure 4 is the seed planter's 3D view.



Item number	Part number
1	Hopper
2	Metering device
3	Handle
4	Rear wheel frame
5	Back cage wheel roller
6	Prime mover
7	Front cage wheel
8	Adjustable frame
9	Chain and sprocket drive

Figure 3. Seed planter's exploded view containing the part list

Figure 4. Seed planter's 3D view

2.2 Design Calculations

2.2.1 Assessment of the mass of the hopper material

Presented in Figure 5 is the sectional view of the seed planter's hopper in its inverted orientation.

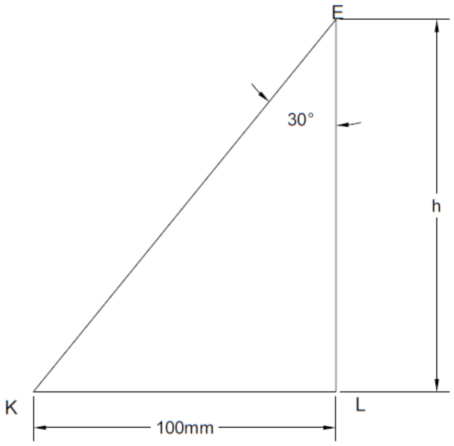


Figure 5. Illustrating the seed planter's hopper in its inverted orientation

The length EK was determined using the Pythagoras theorem as follows:

$$EK^2 = EL^2 + LK^2 \quad (1)$$

Recall from Fig. 5, that LK = 100 mm (0.1 m) and EL = h

Substituting these values into Equ. (1), we have

$$EK^2 = h^2 + (0.1)^2 \quad (2)$$

$$EK^2 = h^2 + 0.01 \quad (3)$$

$$EK = \sqrt{h^2 + 0.01} \quad (4)$$

$$\text{Area EKL} = \frac{1}{2} \times EL \times LK \quad (5)$$

By substitution method from Figure 5, this implies

$$\text{Area EKL} = \frac{1}{2} \times h \times 0.1 \quad (6)$$

$$\text{Area EKL} = 0.05h \text{ m}^2 \quad (7)$$

where h, could be expressed from Fig. 5 as:

$$h = \frac{0.1}{Tan\ 30^o} \quad (8)$$

h = 0.17322 m

Area EKL = 0.17322 x 0.05

Area = 0.008661 m^2

2.2.2 Determination of the weight of grain

From Figure 6, using Pythagoras theorem, the lengths EG and AC are determined as follows:

It can be deduced from Fig. 6, that EG is twice the distance of EQ and likewise AC is twice the distance of RA.

In determining the length of EG, there is need to consider triangle PEQ. From Pythagoras theorem,

$$PC^2 = PQ^2 + QE^2 \quad (9)$$
$$QE^2 = PE^2 - PQ^2 \quad (10)$$
$$QE = \sqrt{PE^2 - PQ^2} \quad (11)$$

Since EG is twice the distance of QE, therefore

$$EG = 2(\sqrt{PE^2 - PQ^2}) \quad (12)$$

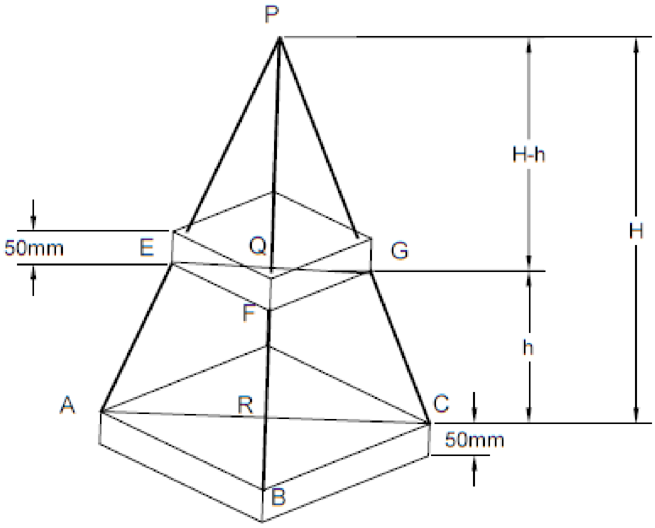


Figure 6. Schematic representation of the planter's hopper in its inverted orientation

In determining the length of AC, there is need to consider triangle PAR. From Pythagoras theorem,

$$PA^2 = PR^2 + RA^2 \quad (13)$$
$$RA^2 = PA^2 - PR^2 \quad (14)$$
$$RA = \sqrt{PA^2 - PR^2} \quad (15)$$

Since AC is twice the distance of RA, therefore

$$AC = 2(\sqrt{PA^2 - PR^2}) \quad (16)$$

Utilizing the principle of similar triangles, one can ascertain the overall height of the frustum as follows:

$$\frac{PQ}{PR} = \frac{QG}{RC} \quad (17)$$
$$PQ = PR \times \frac{QG}{RC} \quad (18)$$
$$H - h = H \times \frac{QG}{RC} \quad (19)$$
$$H - \frac{QG}{RC} H = h \quad (20)$$
$$H\left(1 - \frac{QG}{RC}\right) = h \quad (21)$$

$$H = \frac{h}{\left(1 - \frac{QG}{RC}\right)} \quad (22)$$

The hopper's volume can be derived from the subsequent expression.

$$V_H = \frac{1}{3}[(\text{area of frustrum base}) \times \text{overall height of frustrum}]$$

$$V_H = \frac{1}{3}[(\text{area of truncated frustrum base}) \times \text{height of trucated frustrum}] + \text{volume of the square extension at the top and bottom of hopper} \quad (23)$$

$$M_G = V_H \times P_G \quad (24)$$

$$W_G = M_G \times \text{Acceleration due to gravity} \quad (25)$$

where,

$V_{H=}$ Volume of hopper
M_G = Mass of grain
P_G = Density of grain
W_G = Weight of grain

2.2.3 Determining the shaft diameter

The primary aim of shaft design is to determine the ideal shaft diameter to provide successful power transmission under various operating and loading conditions while preserving adequate strength and rigidity. The strength-based design of ductile material shafts is governed by the maximum shear theory. The shaft consists of a mild steel rod. The diameter of a shaft under minimal axial loading can be calculated using the ASME code equation as given by Natarajan (2000) as:

$$d^3 = \frac{16}{\pi S_a}\sqrt{(K_b\, M_b)^2 + (K_t\, K_t)^2} \quad (26)$$

where,

d = Diameter of the shaft (mm)
M_b = Bending moment (KN − m)
M_t = Torsional moment (Nm)
K_b = Combined shock and fatigue factors applied to bending moments (Km)
K_t = Combined shock and fatigue factor applied to torsional moment (Kt)
S_a = Allowable stress (N/m2)

According to Natarajan (2000), when a load is abruptly imparted to rotating shafts under minor shock, the following terms applies:

$K_{b=}$ 1.5 *to* 2.0

$K_{t=}$ 1.0 *to* 1.5

For shaft without key way, allowable stress $S_a = 55MN/m^2$
For shaft with key way, allowable stress $S_a = 40MN/m^2$

For computations, the diameter of shaft $d = 14.87$ mm

2.2.4 Determining the maximum draught of the planter

The soil resistance faced by the machine and the contact area between the furrow opener and the soil determines the planter's maximum draught. The maximum draught of the planter can be calculated using the expression in Equation (27).

$$D_{FM=} R_S \times A_{FO} \times \text{Acceleration due to gravity} \quad (27)$$

where,

D_{FM} = Maximum draught (N)

A_{FO} = Surface area of furrow opener in contact with the soil (cm^2)

Rs = soil resistance (kg/cm^2)

$$A_{FM} = \text{Recommended depth of cut} \times \text{Thickness of furrow opener} \quad (28)$$

2.2.5 Determining the capacity of the planter

The area of land cultivated or the number of seeds sown during a planting session can be utilized to determine a planter's capability. This expression as expressed in Equation (29) can be utilized to ascertain the planter's capacity.

$$C_{PA} = \frac{\text{Area covered by planter}}{10000\ m^2} (\text{hectare/time}) \quad (29)$$

where,

C_{PA} = Capacity of planter in hectare per time

$$\text{Area covered by planter} = (\text{inter} - \text{row spacing}) \times (\text{Distance covered by planter}) \text{in } m^2 \text{ per time} \quad (30)$$

$$\text{Distance covered by planter} = (\text{speed of planter}) \times (\text{Time of planting}) \text{in m/time} \quad (31)$$

The planter's speed can be determined through empirical experimentation. The planter's capacity is so determined as follows:

$$C_{PN} = \frac{\text{Distance covered by planter per time}}{\text{Intra−row spacing}} \times \text{Number of seeds per hole (seeds/time)} \quad (32)$$

where,

C_{PN} = capacity of planter in terms of seed per time

2.2.6 Depth of sowing

Each grain has specific planting requirements regarding seed depth, spacing, and soil conditions, necessitating careful consideration and management during the planting process. Successful grain planting contributes to robust crop establishment, healthy growth, and ultimately, a bountiful harvest essential for sustaining global food systems (Technology *et al.*, 2021).

Table 2. Grains with different planting depths

S/No.	**Grain**	**Planting depth (cm)**	**Reference**
1.	Maize	5 to 10	Molatudi and Mariga (2009)
2.	Soya bean	5.08	Purcell *et al.* (2014)
3.	Wheat	4 to 8	Alwan *et al.* (2022)
4.	Groundnut	5 to 7	Howlader *et al.* (2009)
5.	Sorghum/Guinea corn	5 to 10	Reddy *et al.* (2012)

2.2.7 Determination of planter's driving wheel diameter of the ground wheel

This was calculated by using the expression given in Equation (34).

$$\text{From } V = \frac{\pi D_w N}{60} \quad (33)$$

Therefore, the driving wheel diameter, D_w can be expressed as follows:

$$D_w = \frac{V \times 60}{\pi N} \quad (34)$$

where,

V = speed of operation (m/s)
N = Number of revolutions per min by the ground wheel (rev/mins)
Dw = Diameter of the ground wheel (m)

2.2.8 Determination of the numbers of seed cell on the metering device

The seed cells were manufactured in accordance with specifications about the quantity of seeds needed to sow a given crop. The diameter of the ground wheel determines the rotation of the metering device, rendering this information crucial for determining the quantity of seed cells on the metering device. The standard plant spacing is determined. Dw = 600 mm as calculated, S = 600 mm plant spacing (Umar, 2022) and N = Number of seed cell on the metering device. Hence,

$$\text{Circumfrerence of the metering device (mm)} = \pi d \quad (35)$$

2.2.9 Measurement of the diameter of the metering apparatus

Considering the availability of the materials used in constructing the metering device. This has provided 3 holes or seed cells on it with 300 mm spacing due to the small size of the metering device which result to the approximately half of the standard spacing of planting maize, which is 600 mm. Hence, calculating the diameter of the metering device.

Given values:
Circumference of the metering device (mm)
Total planting space = 3 cells x 600 = 1,800 (mm)
Standard diameter = 572.88 mm (for a full planting space)
Half of the planting space = 3 x 300 = 900 mm

The maximum height of the seed must be known in designing the seed cells with dimensions exceeding the maximum height of the seed. The dimension of ten samples of maize was analyzed by Umogbaia and Shehu (2009). The planter's metering device was designed with a seed cell depth of 16.5 mm, which corresponds to the average height of the seeds being planted.

2.2.10 Design of handle

The planter's handles were designed to accommodate different heights of people either being a male or a female operator so that each operator could adjust the handle to suit his/her own height. To ensure operator comfort, the adjustable handle was designed with a length corresponding to the standard standing elbow height. The handle was fabricated by welding a mild steel square sheet and circular pipe to the frame. The adjustable handle assists the operator in maneuvering the planter during operation.

2.3 Material Selection and Fabrication of Machine Components

The motorized two-row multiseed grain walking planter was designed and fabricated using various materials. The pictorial view of the seed planter is presented in Figure 7. The hopper of the seed planter was formed using a 2 mm thick mild steel sheet. The shafts, with a diameter of 14.87 mm for both base diameters, were fabricated from a mild steel rod of 20 mm diameter and length size of 304.8 mm. A mild metal plate of 10 mm and 2 by 2 feet was cut, machined, and used to form the seating of the prime mover and the gear reduction unit. The frame was fabricated using flat bars of

50 mm. All the fabrication processes, including marking out, machining, cutting, joining, drilling, and fitting, were performed at the Centre's wokshop located at the TEFEDEC building.

The planter's components, including the metering mechanism, were constructed from mild steel, while the seed metering plate was composed of Teflon. The selection of Teflon for the seed plate was due to its lower coefficient of restitution, which significantly reduces seed bouncing and safeguards the seeds from impact-related harm. The primary structure of the seed planter was constructed from 3 mm mild steel sheet and 5 mm mild steel flat bar. The planter's adjustable handle was constructed from a 1.5-inch mild steel circular pipe measuring 1219.20 mm in length, while the adjustable furrow opener was made from a 60 mm x 5 mm mild steel flat bar. The planter's ground wheels were constructed from a combination of 3 mm mild steel sheets and 12 mm rods.

The specification of the materials used for constructing the motorized two-row multiseed grain walking planter is presented in Table 3.

Table 3. Specification of the construction material

S/No.	Component	Material
1.	Primary frame work	MS square tubing
2.	Seed chamber	Galvanized sheet
3.	Bearings	Steel
4.	Chain and sprocket	Steel
5.	Ground wheel	MS sheet
6.	Cage wheel traction	Mild steel bar
7.	Seed plate roller	Teflon
8.	Handle	Galvanized pipe
9.	Furrow opener	MS sheet

Figure 7. Pictorial view of the seed planter

3. CONCLUSİON

The requirements of underprivileged smallholder farmers have been met by developing a motorized multiseed grain walking planter at the National Centre for Agricultural Mechanization (NCAM), Ilorin. This planter will enable farmers to efficiently and successfully sow their seeds in the field. However, many crops possess different requirements for seed planting in the field. This project concentrated on the design and construction of an economically viable motorized operated two-row multi-crop walking planter that is affordable, easy to maintain, and requires minimal labour to operate. The planter will significantly enhance the appeal of farming and augment agricultural productivity. All components of the planter were constructed from mild steel, with the exception of the metering mechanism which was manufactured from high-quality Teflon material. The seed metering mechanism employed in this study was the nylon wheel type including peripheral cells. The design feature involving a drive shaft which directly operates the seed metering mechanism, helps to eliminate the need for a power transmission system, reduce complexities and costs, and enhance efficiency at a significantly lower expense.

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SOCIO-ECONOMIC ASSESSMENT OF WOMEN PRACTICING MECHANIZED AGRO-PROCESSING IN NIGERIA

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ABSTRACT
The socio-economic status of women practicing mechanized agro processing in Nigeria was assessed. Women agro-processors were identified and selected through their various State's ADPs across the six geo-political zones in Nigeria. The data generated were basically primary and obtained through personal interview schedule with a well-structured questionnaire. Data were collected based on the socio-economic variables such as age, marital status, educational status, main occupation and household size. The data generated were subjected to descriptive statistics involving frequency count and percentage computation. From the results gathered, it was observed that majority of the respondents (42.1%) were within the age group of 41 to 50 years, while 71.1% of them were married. Result further revealed that 86.8% were educated up to tertiary level, 68.4% were operators in the agro-processing centres, while 73.68% were maintaining a household size of 5 to 10. It was concluded in this study that majority of the educated women in the study area are educated andin their active age with high level of financial burdens, which influenced their decision towards embracing the practice of agro-processing technologies as a source of livelihood.

Keywords: Socio-economic characteristics, Agro-processing, Women

1. INTRODUCTION
Worldwide, food waste represents an important global challenge, with approximately one-third of all food produced for human consumption are lost or wasted annually thereby leading to severe environmental, economic, and social consequences. The issue not only exacerbates food insecurity but also contributes to greenhouse gas emissions, waste of resources, and economic losses estimated at over $1 trillion each year (Arowosegbe, 2024)**.** Jeremić *et al.* (2024) reported that one-third of the total amount of food produced every year that are lost or wasted is an indication that there exist an extremely high level of inefficiency in the food supply chain.

This is the tragic reality confronting Nigeria and the human race in general. Fogel (2004) asserted a high level of food wastage by British consumers and American retailers, food services and householders. He opined that the 1.5 billion people that are hungry could be alleviated by conserving the food including the arable crops such as wheat, maize and soy fed to animals to produce the wasted meat and dairy products.

High post-harvest losses observed during production and processing of food which is due to limited food processing and preservation capacity constitute part of the major factors hindering food and nutrition security in Nigeria. Ineffective or inappropriate food processing technologies, careless harvesting and inefficient post-harvest handling practices, bad roads, bad market practices and inadequate or complete lack of storage facilities, packing houses and market infrastructures, among others, are factors responsible for high post-harvest food losses in Nigeria (Uzoejinwa1 *et al*., 2016). The use of appropriate processing technologies and storage facilities would guarantee food security. Gernah *et al.* (2013) stated that the value of agricultural raw materials could be improved by using appropriate food processing technologies in removing unwanted materials and transforming these raw materials into high quality finished products. When appropriate processing methods are employed, the transformed finished product has extended shelf life, higher nutritional and economic value, thus contributing to the food security concern of the populace.

FAO (1997) describes agro-processing as the transformation of products originating from agriculture, forestry, and fisheries. It encompasses global-to-local patterns (processing of imported agricultural commodities to be sold on the local market) and local-to-global patterns (processing of locally-produced commodities for export. It vary from simple preservation operations such as drying products in the sun to more complex, capital-intensive processes. www.agriculturenigeria.com/agro-processing simply defines it traditionally as the transformation of raw materials and intermediate goods derived from the agricultural sector into finished products.

Agro-processing industries are typically comprised of upstream and downstream industries. The Upstream sector of agro-processing refer to the initial processing of agricultural commodities such as rice milling, leather tanning, cotton ginning, fish canning, among others. The downstream sector of agro processing are involved in more complex processing of intermediate products made from agricultural materials and include the making of bread, biscuits, textiles, paper, clothing, footwear, etc. (FAO, 1997).

Agro-processing plays a crucial role in converting raw agricultural products into value-added goods, extends their shelf life and improves their marketability. By adding value through processing, Africa can unlock its agricultural potential, generate employment opportunities, and enhance economic development. Martorano and Gonnelli (2022) stated that agro-processing encompasses a range of activities which include sorting, grading, packaging, preserving, and transforming raw materials into finished products.The development of agro-processing centres, equipped with mills and other processing equipment, can enhance the economic feasibility of processing activities in rural areas.

Agro-processing and agro processors face significant challenges like limited value addition, administrative barriers, and inadequate linkages with marketing and financial services. The development of the sector has been hindered by technological limitations and the need for new agricultural solutions to improve productivity and quality (Thembinkosi, 2022).Agro-processing also holds significant promise for economic and social development, however, it is also confronted with some challenges that require strategic interventions. The integration of new technologies, interdisciplinary research, and supportive policies can help overcome these obstacles and unlock the full potential of agro-processing industries. This approach can lead to sustainable growth and improved livelihoods, most especially in the rural communities.

Socio-economic characteristics refers to the position of an individual or family in the society, which is central to understanding the socio-economic characteristics of farmers (Kadian and Kumar, 2002). Demographic factors such as age, gender, education level, and family size significantly influence the socio-economic characteristics of farmers. Understanding these factors helps in assessing the labour force and the potential for agricultural productivity in a region (Niemets and Lohvynova, 2017).

Women's contributions to agricultural production in Nigeria have been noted in several literatures. Among different factors, the socio-economic characteristics of the farmers influence their production-decision in agribusiness (Oyinbo *et al.,* 2019). Akinbami *et al.* (2012) asserted that the socio-economic conditions of women who participate actively in the economy of the country, particularly at the grass-roots level, have remained challenging despite implementation of economic reforms in Nigeria.

Amanze *et al.* (2023) stressed that women farmers are the most involved in off-farm agro-processing activities. They are highly involved in cassava processing into gari, tapioca, odourless fufu, into pancake and cassava flour, maize processing into pap, corn meal, processing and utilization of soybean into soya flour, soya milk etc, Others are into maize processing for the making of maize flour and malted maize-milk drink, cocoyam processing for the making of cocoyam chips and cocoyam flour. Further processing activities include plantain processing for the making of plantain chips and plantain flour.

Agro-processing, according to Quartey and Darkwa (2015), is grouped into factory agro-processing and domestic agro-processing. Domestic agro-processing is dominated by females with the characteristics of illiteracy, informal training, use of family labour, variability in the quality of processed output (Owoo and Lambon-Quayefio, 2017). Notwithstanding these, domestic agro-processing is highly important in the country as it provides livelihood support to women in rural areas (Mabe, 2022).

1.1 Emperical Review

According to Huyer (2016), agriculture is the largest employment sector for 60% of women in Oceania, Southern Asia and sub-Saharan Africa as these women makes up two-third of the world's 600 million small livestock managers. Despite this, women's activities in agriculture are characterized by a global gender gap in vulnerabilities, access to resources, and productivity. Fanelli (2022) observed at the EU level (EU-28), around 30% of agricultural farms are operated by women whereby we have one farm in five. In rural areas of EU, women represent over 50% of the rural population. In the EU's agricultural sector, women accounts for about 45% of the total working population and for about 35% of their workers. The work of female farmers accounts for 31% of the total working hours (Franić and Kovačićek, 2019).

According to Abdisa *et al.* (2024), women makes up to more than 50% of the agricultural labour force but contribute less than 30% to agricultural productivity. Agriculture is the main source of livelihood in Ethiopia which contributes more than 35% to GDP, 90% to forex earnings, and 70% to employment sources. For improving economic well-being, ensuring sustainable development, and reducing poverty will become impossible if the role of women are ignored. Mukasa and Salami (2016) posited that empowering women has become a much-discussed subject among many political leaders, civil rights activists, and women's associations. In agriculture, women particularly face daunting constraints that significantly limit their potential and enmesh them into a gender productivity trap.

The study which emphasis on the socio-economic assessment of women practicing mechanised agro-processing in Nigeria is imperative due to the important role played by women over the years in the agricultural value chain of the country and beyond, in spite of the socio-economic challenges they face as noted in several studies carried out over the years. For instance, Anderson *et al.* (2021) reported that gender inequality in agriculture has been recorded to have cost Africa several billion annually. Furthermore, women in agriculture according to Huyer (2016), lack access to essential resources which limits their productivity to a very large extent. Therefore; empowering women through the practise of mechanized agro-processing serves as an important tool for poverty reduction as observed in EU and some sub-Saharan countries (Fanelli, 2022; Mukasa and Salami, 2016). It is based on these facts that it has become necessary to access the socio-economic characteristic of women involved in agro-processing in Nigeria as a means of identifying challenges and strategies to enable women contribute fully to the agro-processing industry in Nigeria.

2. METHODOLOGY

2.1 Study Area

The study area comprises of women agro-processors from the six geo-political zones of Nigeria. A sample size comprising of 76 women into agro-processing activities were randomly selected across the six geo-political zones using the already established Agricultural Development Centres available in the country. Upon selection, these women were assembled at the National Centre for Agricultural Mechanization (NCAM), Ilorin for a focus group discussion and filling of a structured designed questionnaire in generating data to be used for the study.

2.2 Method of Data Collection and Sampling Procedure.

The primary source of generating data which involved the use of structured questionnaire was used for this study. Data were collected based on the socio-economic variables such as age, marital status, educational status, main occupation and household size. The response of these processors forms the primary data used.

2.3 Statistical Tool

The data obtained from the 76 respondents who were into agro-processing activities in the six geo-political zone of Nigeria were subjected to descriptive statistical analysis involving frequency count and percentage computation. The SPSS statistical package of version 25.0.0.0 was used for the data computation

3. RESULTS AND DISCUSSION

3.1 Summary of Data Collated for Socio-Economic Characteristic of the Study Area

The selected related characteristics of the women practicing mechanized agro-processing in Nigeria include the use of age, marital status, level of education, occupation, household size and type of business engaged. The socio-economic characteristics of women practicing mechanized agro-processing in Nigeria is presented in Table 1. From Table 1, it was observed that 71.1% of the women under study were married, 86.8% were educated up to tertiary level, 68.4% were agro processors (machine operators) while 73.68% were maintaining a household size of 5 to 10. Table 1 further revealed that majority of the women (42.1%) were within the age group of 41 to 50 years.

Table1. Socio-Economic Characteristics of women practicing mechanized agro-processing in Nigeria

Socio-economic variable	Grouping of variable	Frequency	Percentage
Age of Respondent (Year)	21 – 30	18	23.7
	31 – 40	8	10.5
	41 – 50	32	42.1
	Above 50	18	23.7
Marital status	Single	14	18.4
	Married	54	71.1
	Widowed	8	10.5
	Divorced	0	0.0
Educational status	Quranic education	2	2.6
	Adult education	2	2.6
	Primary education	2	2.6
	Secondary education	4	5.3
	Tertiary education	66	86.8
Main Occupation	Civil Servant	2	2.6
	Agro-Processing centre operator	52	68.4

	Student	6	7.9
	Farmer	8	10.5
	Trading	8	10.5
	Others	0	0.0
Household size	1 – 4	16	21.05
	5 – 10	56	73.68
	Above 10	4	5.26

3.1.1 Age of respondents

Age is an important factor of the social-economic status of a given population. Figure 1 show that the least involved in mechanized agro-processing among women in Nigeria fell within the age group of 31 to 40 years, which represents 10.5%; while the most involved were women within the age group of 41 to 50 years.

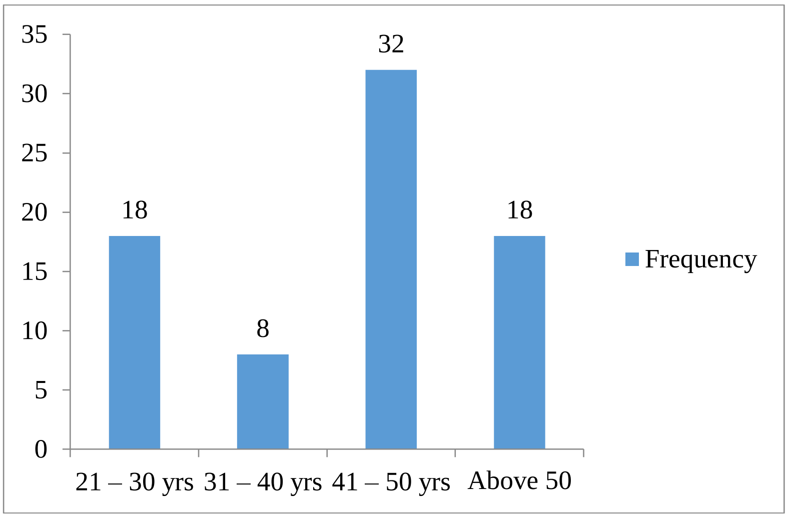

Figure 1. Age of respondents

This low level of involvement of women within the age group of 31 to 40 years may have been attributed to several factors such as economic, cultural and religious factors. However, most women within the age group of 31 to 40 years in Nigeria are still in their child bearing state and thus may have been constrained by pregnancy or nursing infants. Cultural perception of young and newly married women engaging in such physically tasking occupations as ignoble may have contributed as well as peer influence. However, the ever-increasing socio-economic crisis such as family welfare as noted by Yahaya (2002) and Adepoju *et al.* (2007) may have forced women within the age group of 41 to 50 years into agro processing activities, as most families experience higher financial burdens with higher number of children, higher children welfare and educational demand. Age may also be a contributing factor for their choice of mechanized agro-processing. This is similar to the findings of Akinbami *et al.* (2012) while studying technology adoption and women entrepreneurial behaviour. According to the findings of Eze *et al.* (2017) and Adenugba and John (2014), respondents within the age group of 41 to 50 years had the highest level of agro-technological adoption in their study area. Figure 1 further showed that respondents within the age group of 21 to 30 years were also actively involved in mechanized agro-processing activities. It appears that most of the respondents at this age group are students of secondary and tertiary institutions who either inherited the processing centres which they operate or are part time employees in the agro-processing centres in order to assist their parents in easing the financial burden of the family.

3.1.2 Educational status

Education level is a major determinant to women agro-processors. It was observed from the study that 66 of the respondents representing 86.8% attended tertiary institution as shown in Figure 2.

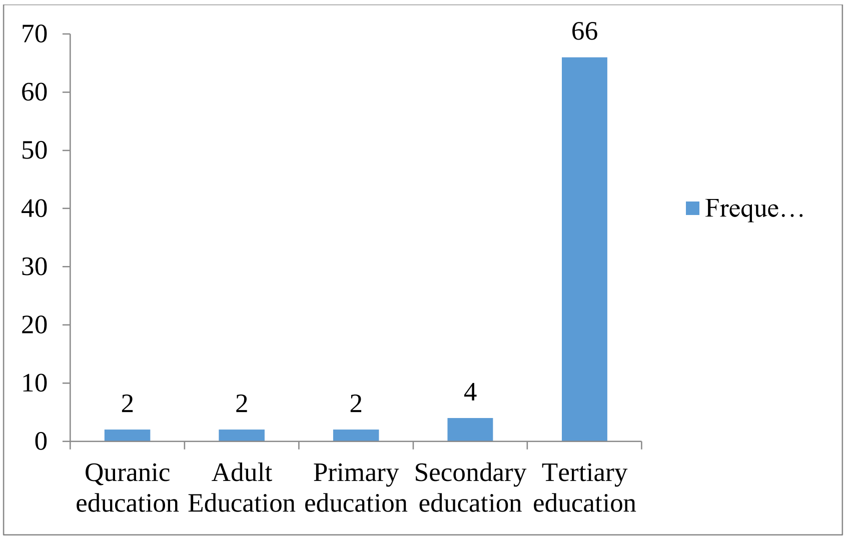

Figure 2. Educational status of the respondents

This suggests that majority of the respondents were educated, thus, understanding and adoption of mechanization technologies would not be a problem to them. Most of the respondents may have been acquainted to the limitations of traditional processing method and the merits of agro-processing technologies. This view is supported by the finding of (Eze *et al.*, 2017; Opaluwa, 2014; Audu, 2012; Adepoju et al., 2007) which revealed that education is not only an important determinant in the involvement and adoption of agricultural innovation but also a tool for agricultural productivity. The rising level of graduate unemployment may have also contributed to the dominance of educated women in agro-processing; perhaps as a lucrative means of earning money for themselves.

3.1.3 Main occupation

This study revealed that majority of the respondents (52) were agro-processing centre operators, while 8 are traders and farmers each as shown in Figure 3. Respondents on government payroll (civil servants) were only 2 out of the total respondents.

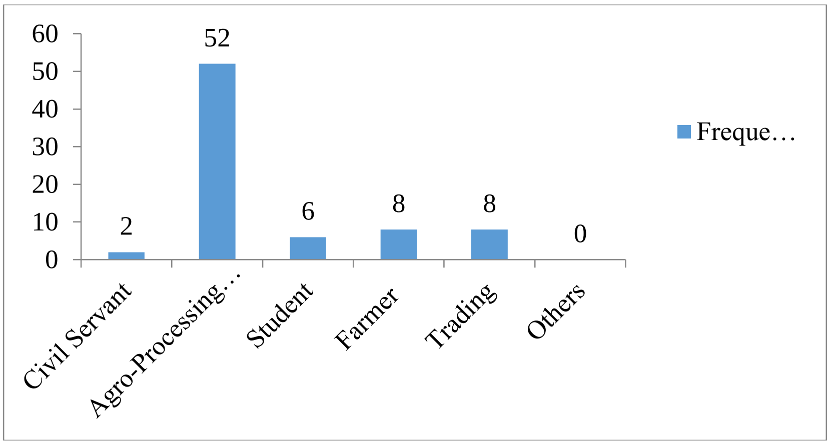

Figure 3. Main occupation of the respondents

This implies that most of the respondents' main occupation involves processing of the farmer's farm produce who have no access to mechanized processing technologies. The result also implies that some of the respondents (8) who are predominantly farmers process mainly their own crops as well as commercially processing for other farmers. However, some of the respondents (especially the traders) seem to be engaged in the buying of the unprocessed farm produce from these farmers thereby processing themselves for selling in the market. This was observed during oral interview with some of the respondents. This was in agreement with the findings of Eze *et al.* (2017 while assessing the socio-economic characteristics of melon processors who are into the use of motorized melon shellers in Edu Local Government Area of Kwara State, Nigeria. Majority of the processors who were traders buy unshelled melon from farmers who by this process shell them for sale.

3.1.4 Household size

This study shows that 56 of the respondents had a house hold size of 5 to 10 persons while 16 of the respondents has a household size of 1 to 4 persons as shown in Figure 4.

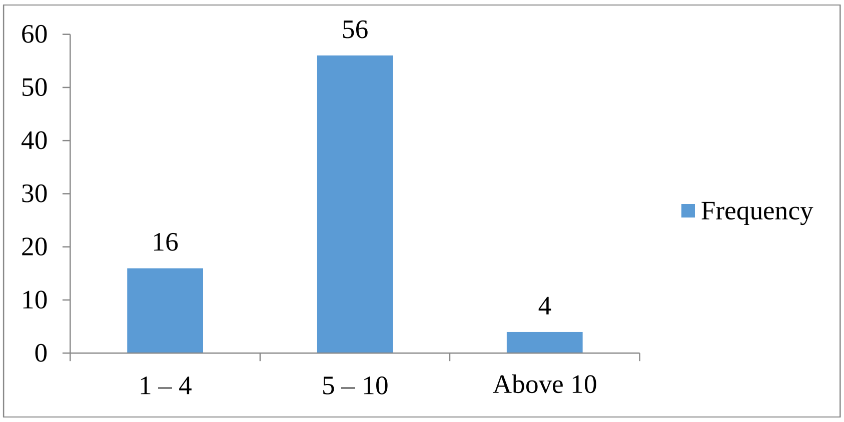

Figure 4. Household size of the respondents

This implies that majority of the respondents maintain a very large family size. Having a serious economic burden, they therefore find the need to empower the family members through agro-processing business venture. Other researchers such as (Eze *et al.*, 2017; Ajani, 2011; Enwelu, 2011; Emodi, 2009**?**) in their respective findings, observed that households in Nigeria are characterized by large family size with high dependency ratio.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The study showcased the impact of the socio-economic characteristics of women practicing mechanized agro-processing. Majority of the participating women in the agro processing centres were married, educated and within the age group of 41 to 50 years.

The study highlights that the participation of women in agro-processing activities proves their economic importance in income generation to the agricultural value chain. However, younger women face lots of barriers stemming from cultural and economic constraints, as well as the demands of childbearing and childcare.

Priority should be placed on younger women who wish to venture into agro-processing value chain system, so as to effectively harness their young and vibrant energy into the sector. This is because agricultural mechanization has the capacity for women empowerment, providing opportunities for income diversification and self-employment. Doing so will act as a catalyst for enhancing women's livelihoods and driving sustainable agricultural development in Nigeria.

4.2 Recommendations

Following the findings in this study, it is recommended that:

1. Strategic policies aimed at encouraging younger women within the age group of 31-40 years to participate in mechanized agro-processing should be enacted and promoted.
2. Further studies should be conducted to evaluate the awareness and gender friendliness of conventional agro-processing technologies in Nigeria.

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PERFORMANCE EVALUATION OF A MOTORIZED TWO-ROW MULTISEED GRAIN WALKING PLANTER

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ABSTRACT

This study details the performance evaluation of a motorized two-row multiseed grain walking planter intended for small-scale farmers. The planter maximizes crop yields, minimizes labour demands, and improves field efficiency. Results obtained from field test revealed that the seed planter recorded mean theoretical field capacity value of 0.2683 ha/h, mean effective field capacity value of 0.2447 ha/h, mean field efficiency value of 90.80%, mean intra-row spacing distance of 334.04 mm and fuel consumption value of 2.43 l/ha. More so, the theoretica fied capacity values obtained ranged from 0.1949 to 0.3228 ha/h , effective field capacity values obtained ranged from 0.1727 to 0.3024 ha/h; field efficiency values obained ranged from 88.62 to 93.67%; intra-row spacing distance values obtained ranged from 333 mm to 334.91 mm; and fuel consumption values obtained ranged from 1.95 l/ha to 2.98 l/ha. The planter's forward speed have posıtıve correlatıon wıth theoretical field capacity, effective field capacity, field efficiency, inter-row spacing and fuel consumption, hence improving agricultural productivity and efficiency. This study advances the creation of efficient agricultural technology, catering for small-scale farmers' requirements and enhancing food security. İt was recommended that future research should focus on improving the seed planter's mobility and integrating advanced technologies.

Keywords: Agricultural Machinery, Labour Efficiency,Mechanized Grain Planter,Smallholder Agriculture, Cropyeild

1. INTRODUCTION

The development of agricultural machinery has revolutionized farming practices, transforming the way grains are planted and cultivated. The motorized two-row multiseed grain walking planter represents a significant advancement in this field, combining cutting edge technology with traditional agricultural methods. This innovative equipment offers farmers a flexible and effective solution to enhance their planting processes, exemplifying a new era of agricultural efficiency and sustainability. The integration of precision planting mechanisms and multifunctionality in the motorized two-row multiseed grain walking planter optimizes planting operations, enhances productivity, and promotes resource efficiency. By facilitating the concurrent planting of two rows of grains, this planter doubles the planting capacity of the conventional single-row planters, expediting the planting process while ensuring consistent spacing and depth of planting. This results in improved crop emergence and overall production potential. The multiseed planter has the capability of delivering the seeds precisely with uniform depth in the furrow, and also with uniform spacing between the seeds.

Ikechukwu *et al.* (2014) developed a planter that functioned properly as expected with a planting capacity of 0.0486 ha/h. The planter was not motorized and the seed metering mechanism was made from wood. Adesoye and Mary (2015) developed a planter that had field efficiency and field capacity of 76.3% and 0.39 ha/h, respectively, with seed rate of 0.25 kg/ha, 0.18 kg/ha and 0.21kg/ha at different conditions. Ani *et al.* (2016) designed a planter which recorded a metering efficiency of 88.94%, effective field capacity of 0.27 ha/h and field efficiency of 71.86% during the planter's evaluation.

Mechanization has transformed the agricultural sector, with varying degrees of adoption across different regions. Planting, a critical process in farming, involves sowing seeds in the soil to optimize germination outcomes. Over time, planting techniques have evolved from manual methods to incorporate tools and machines. Research highlights the importance of developing small-scale cultivation technologies that cater for the needs of small farms, prioritize user-friendly design, and enhance planting efficiency while reducing labour requirements. The development of a tmotorized wo-row multiseed grain walking planter addresses the challenges faced by smallholder farmers, providing a mechanized planting solution that is adaptable to small-scale farming systems, enhances planting efficiency, and promotes sustainable agriculture practices.

2. MATERİALS AND METHODS

2.1 Description of the Planter

The two-row multiseed grain walking planter have some essential components such as the basic frame, seed metering system, seed hoppers, ground wheels, furrow openers, and furrow coverer. The primary specifications of this motorized two-row multiseed grain walking planter include dimensions measuring 1,845 mm, 1,015 mm and 1,495 mm for the planter's length, width and height, respectively; plant-to-furrow spacing within rows ranging from 25 to 40 cm and between rows from 20 to 90 cm; and a built-in handle for controlling the direction of the seed planter during planting operation. The seed metering system of the planter is vertically inclined with various holes inserted for providing the desired seed sowing distance. To ensure accurate seed placement and a reduce movement between the feeding mechanism and the planter's wheel having a diameter size of 39 cm, a transmission system was designed to control the number of seed drops per revolution using diverse metering seed plates at a sprocket ratio of 1:1. The front column has a fixed furrow opener that allows one to regulate and change the furrow's depth. Two cage wheels make up the closing mechanism, which presses the seeds into the ground while the planter is moving as shown in Figure 1. Presented in Figure 2 is the planter's orthographic projection and 3D view.

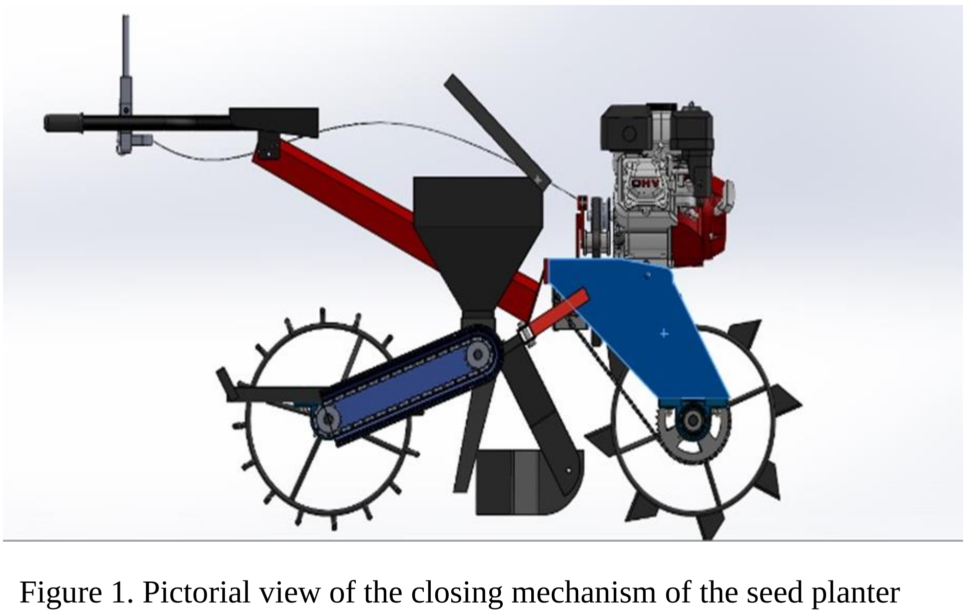

Figure 1. Pictorial view of the closing mechanism of the seed planter

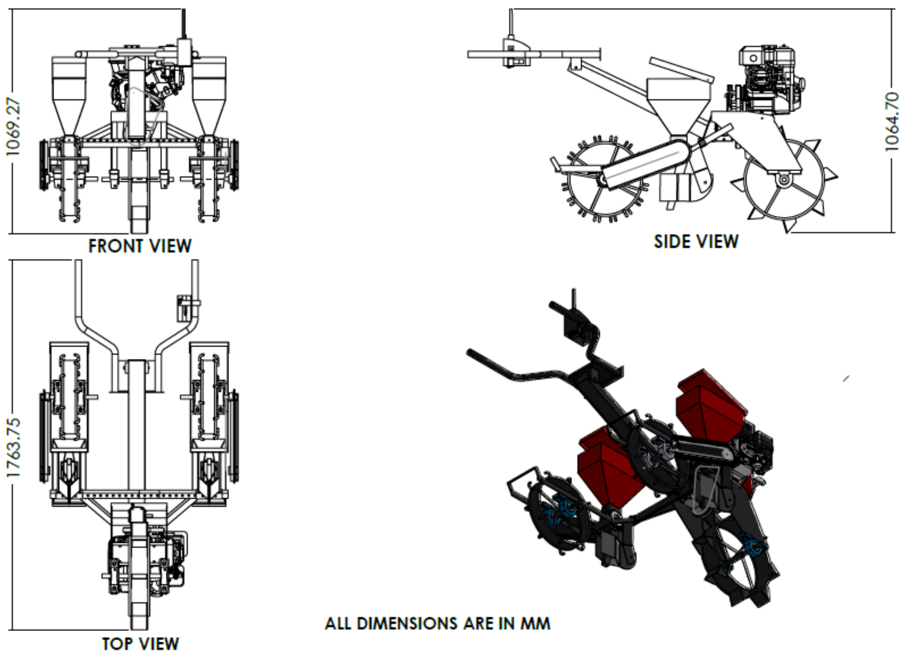

Figure 2. Orthographic projection and 3D view of the motorized two-row multiseed grain walking planter

2.2 Description of the Study Area

The study was carried out at the National Centre for Agricultural Mechanization (NCAM), Ilorin, Kwara State which is located at 370 m above sea level in the Southern Guinea Savanna ecological zone of Nigeria by Longitude 4^o 30′E and Latitude 8^o 26′N. The soil in the test location of the study area was classified as Alfisols (Soil Survey Staff, 1975) under the USDA soil order.

2.3 Particle Size Analysis

Particle size analysis was carried out using the hydrometer method described by Gee and Or (2002). Sodium hexametaphosphate (calgon) was used as the dispersant. The textural class of the soil was determined using the USDA Textural Triangle.

2.4 Experimental Field Layout

The experimental field used for the test was laid out in a Randomized Complete Block Design (RCBD). The field was ploughed and harrowed and later cleared of surface debris and impediments. Nine experimental plots with each measuring 30 meters by 10 meters, were created in the experimental field. The mean values of the three planting speeds used for evaluating the seed planter were used in assessing the performance of the seed planter.

2.5 Test Crop

Maize was used for testing the motorized two-row multiseed grain walking planter. The maize was purchased from Ganmo market in Ilorin, Kwara State.

2.5.1 Seed viability

Seed viability test was carried out on the maize seed purchased from Ganmo market. The seed viability test which involve placing 20 maize seeds at a time in water solution gave a viability value of 98.33%. This indicates almost all the seeds purchased from Ganmo market were viable.

2.6 Test Parameters

The parameters considered for use in assessing the performance of the motorized two-row multiseed grain walking planter include theoretical field capacity (TFC), effective field capacity (EFC), field efficiency (FE), intra-row spacing distance and fuel consumption. FC presented an area of land processed per unit time for a particular site operation, FE defined effective and theoretical site capacity as the ratio of expected and actual time required to complete the site operation (Dagnachew*et al.*, 2017).

2.6.1 Theoretical field capacity (TFC)

This is the maximum area that a grain planter can cover at a given time, under ideal conditions. Accurate theoretical field capacity determination is crucial for optimizing planter performance and productivity and is calculated using the expression given by Ram and Mishra (2020) and Science *et al.* (2021) as:

$$\text{TFC (ha/h)} = \frac{\text{Harvesting speed (km/h) x Harvesting width (m)}}{10{,}000} \quad (1)$$

2.6.2 Effective field capacity (EFC)

This describes the actual area that the planter can cover in a specific amount of time, accounting for variables like: planting speed, crop density and yield, field topography and soil conditions, machine efficiency and downtime. Effective field capacity is calculated using the expression given in Equation (2).

$$\text{Effective field capacity (ha/h)} = \frac{Area\ of\ land\ (ha)}{Time\ taken\ (h)} \quad (2)$$

2.6.3 Field efficiency

According to Andrew *et al.* (2024), this was computed using the proportion that exist between the effective and theoretical field capacities.

$$\text{FE} = \frac{EFC}{TFC}\ x\ 100\% \quad (3)$$

where,

FE = Field efficiency, (%)
EFC = Effective field capacity, (ha/h)
TFC = Theoretical field capacity, (ha/h)

2.6.4 Fuel consumption

The fuel required for each planting operation was determined by filling the tank to full capacity before and after the test. Amount of refueling after each test is the fuel consumption for the test. The filling of fuel tank before the operation and then refilling after completing the operation in determining the amount of fuel consumed during operation is a common method used in the field for determining fuel consumption in litres per hectare for any field machinery powered by an engine. This same method was as reported by (Ajav and Adewoyin, 2011; Ikpo and Ifem, 2005; Kudabo and Gbadamosi, 2012; Meshack-Hart, 1997; Sirelkatim et al., 2001; Udo and Akubuo, 2004) in determining tractor fuel consumption in litres per hectare.

Fuel consumption measured in either L/ha or L/h was expressed mathematically as:

$$Fuel\ consumption\ (\frac{l}{ha}) = \frac{Volume\ of\ fuel\ consumed\ (l)}{Area\ of\ field\ (ha)} \quad (4)$$

$$Fuel\ consumption\ \left(\frac{l}{h}\right) = Fuel\ consumption\left(\frac{l}{ha}\right) x\ Effective\ field\ capacity\ \left(\frac{ha}{h}\right) \quad (5)$$

2.7 Soil Parameter

2.7.1 Soil moisture

Klenin et al. (1985) defined soil moisture content as the amount of liquid, usually water that is present in the soil. It is expressed as a percentage of the mass of water in the soil to the mass of the dried soil (for dry weight classification). The soil moisture content (in dry basis) measured in%, can be expressed mathematically as:

$$M_c = \frac{W_w}{W_s}\ x\ 100\% \quad (6)$$

where,

Mc = Soil moisture content (%)
Ws = Mass of oven dried soil (g)
Ww = Mass of water present in soil (g)-

2.8 Laboratory Performance of the Grain Planter

Tests were carried out in the laboratory prior to subjecting the seed planter to field test. Analysis were carried out on the pattern of dropping, number of seeds per drop, spacing between seeds etc. Presented in Figure 3 is the pictorial view of the motorized two-row multiseed grain walking planter.

Figure 3. Pictorial view of the motorized two-row multiseed grain walking tractor

4. RESULTS AND DISCUSSION

4.1 Results

Table 1 displays the findings from the soil characterization utilized in the field used for testing the grain planter. Table 2 provides information concerning depth of planting, capacity of the seed and fertilizer hopper, number of seeds per drop, percentage of missing plants, percentage of double picking, height of the ridge, depth of fertilizer placement, and planter’s efficiency at three different working tractor speeds. Table 3 displays the performance of the motorized two-row multiseed grain walking planter. Table 4 displays the descriptive analysis of the results obtained during field evaluation of the planter.

Table 1. The Soil Characterizations used for the Field Evaluation

S/No.	Parameters	Result
1	Soil type	Loamy sandy
2	Soil moisture content	8.54% (db)
3	Method of sowing	center to center
4	Size of each plot	30 x 10 m
5	Number of plot	9

Table 2. Specific information obtained for the motorized two-row multiseed walking grain planter

Parameters	Result
Minimum number of seeds dropped	1
Maximum number of seeds dropped	3
Working speed of the planter (km/h)	1.92
Intra-row spacing obtained (mm)	380, 310, 300, 320, 360, 330, 320, 360, 350 and 300
Average intra-row spacing obtained (mm)	333
Standard deviation obtained for intra-row spacing using theoretical planting distance as mean (mm)	301.71 ± 43.21
Deviation in terms of percentage value	14.32
Standard deviation obtained for intra-row spacing using average intra-row spacing value as mean (mm):	333 ± 27.91
Deviation in terms of percentage value	8.38
Number of intra-row spacing readings obtained that fell above the theoretical planting distance of the planter	8
Number of intra-row spacing readings obtained that fell below the theoretical planting distance of the planter	2

Table 3. Performance evaluation of the motorized two-row multiseed walking grain planter

*Parameters	Speed of planter during operation (km/h)		
	1.92	2.60	2.92
Depth of planting (mm)	43.18	43.18	43.18
Intra-row distance (mm)	333	334.2	334.91
Uncovered seeds (%)	5.1	5.8	6.2
Missing hills (%)	3.7	4.3	4.98
Fuel consumption (l/h)	0.34	0.61	0.91
Fuel consumption (l/ha)	1.95	2.36	2.98
Sound level (dB)	62.21	62.83	63.51
Area of land (ha)	0.03	0.03	0.03
Time of operation (h/ha)	5.79	3.86	3.31
Theoretical field capacity (ha/h)	0.1949	0.2873	0.3228
Effective field capacity (ha/h)	0.1727	0.2589	0.3024
Field efficiency (%)	88.61	90.11	93.68

* mean values obtained for three replications

Table 4. Descriptive statistics of the results obtained during field performance of the grain planter

Test parameters	**N**	**Min.**	**Max.**	**Mean**	**STD**
Intra-row space distance (mm)	3	333.00	334.91	334.0367	.96542
Uncovered seed (%)	3	5.10	6.20	5.7000	0.55678
Missing hills	3	3.70	4.98	4.3267	0.64042
Fuel consumption (l/ha)	3	1.95	2.98	2.43	0.51856
Fuel consumption (l/h)	3	0.34	0.91	0.62	0.28513
Sound level (dB)	3	62.21	63.51	62.8500	0.65023
Time of operation (h/ha)	3	3.31	5.79	4.32	1.30242
Theoretical field capacity (ha/h)	3	0.1949	0.3228	0.2683	0.06603
Effective field capacity (ha/h)	3	0.1727	0.3024	0.244667	0.06601
Field Efficiency (%)	3	88.62	93.67	90.80	2.59474

4.2 Discussion

4.2.1 Determination of theoretical field capacity

The average values of the theoretical field capacity obtained considering the three different speeds used during the evaluation process of the planter in the field varied from 0.1949 to 0.3228 ha/h. The mean theoretical field capacity value obtained was 0.2683 ha/h with a standard deviation value of 0.06603 ha/h. The planter's theoretical field capacity demonstrates that the planter speed has a considerable impact. The outcome as shown in Figure 4 demonstrates that the planter's field efficiency increases as the planter’s speed increases.

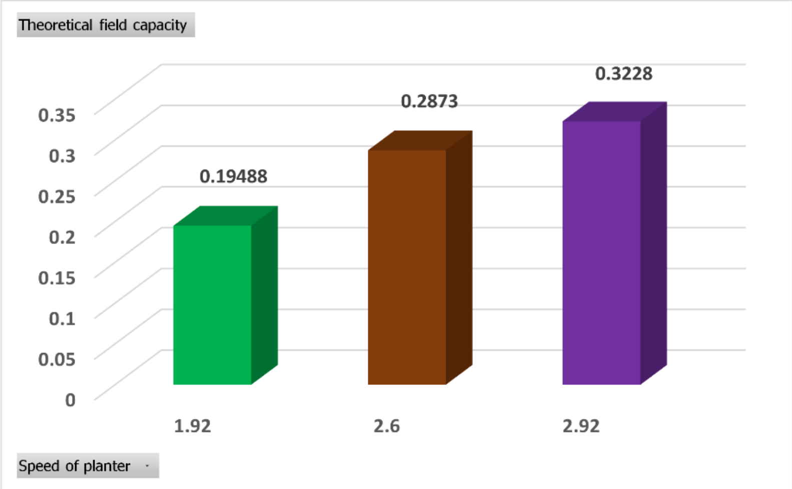

Figure 4. Bar chart showing the effect of planter's speed on theoretical field capacity

4.2.2 Determination of effective field capacity

The average values of the effective field capacity obtained considering the three different speeds used during the evaluation process of the planter in the field varied from 0.1727 to 0.3024 ha/h. The mean effective field capacity value obtained was 0.2447 ha/h with a standard deviation value of 0.06601 ha/h. The effective field capacity of the planter as shown in Figure 5 showed that the planter speed has effect on the effective field capacity.

The effective field capacity which contrasts with theoretical field capacity, accounted for real-world factors such as obstacles and turning time, offering a more realistic assessment of the planter's productivity.

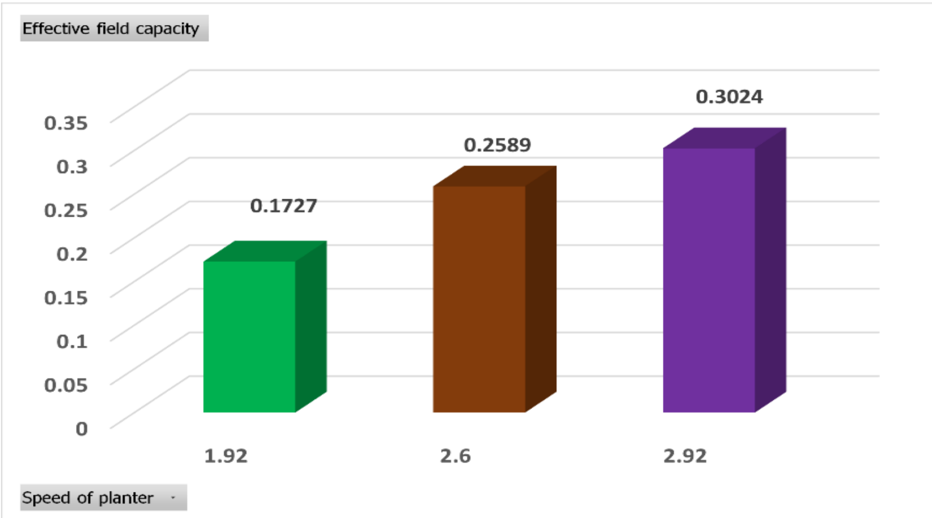

Figure 5. Bar chart showing the effect of planter speed on effective field capacity

4.2.3 Determination of intra-row spacing distance

The intra-row spacing distance obtained varied narrowly from 333 to 334.91 mm with a mean value of 334.04 mm. It also gave a low standard deviation value of 0.97 mm, suggesting consistent spacing along the row while planting. The intra-row spacing of the planter as shown in Figure 6 shows that the planter's speed has effect on the intra-row spacing distance of the planted maize.

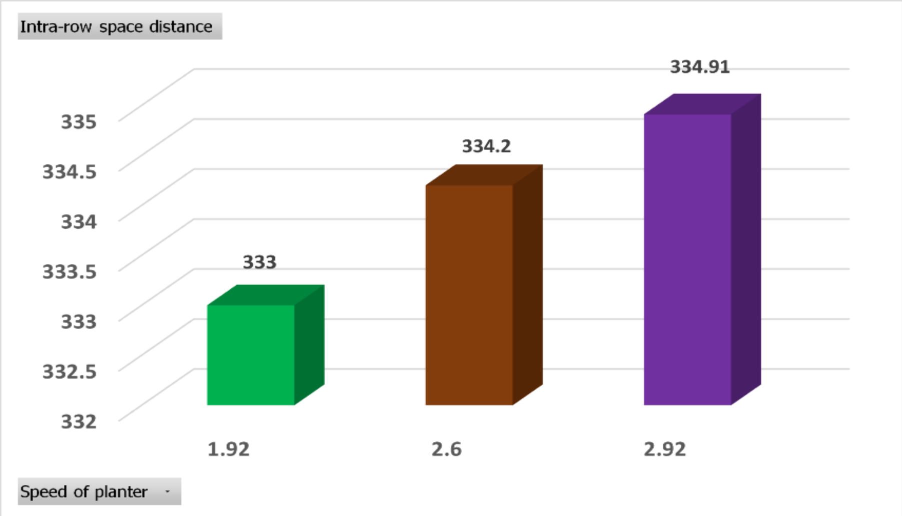

Figure 6. Bar chart showing the effect of the planter speed on intra-row spacing distance

4.2.4 Determination of field efficiency of the planter

The average values of the field efficiency obtained considering the three different speeds used during the evaluation process of the planter in the field varied from 88.62% to 93.67%. The mean field efficiency value obtained was 90.80% with a standard deviation value of 2.59%. It can be deduced from Figure 7 during planting operation that the planter's field efficiency increases as the planter's speed increases.

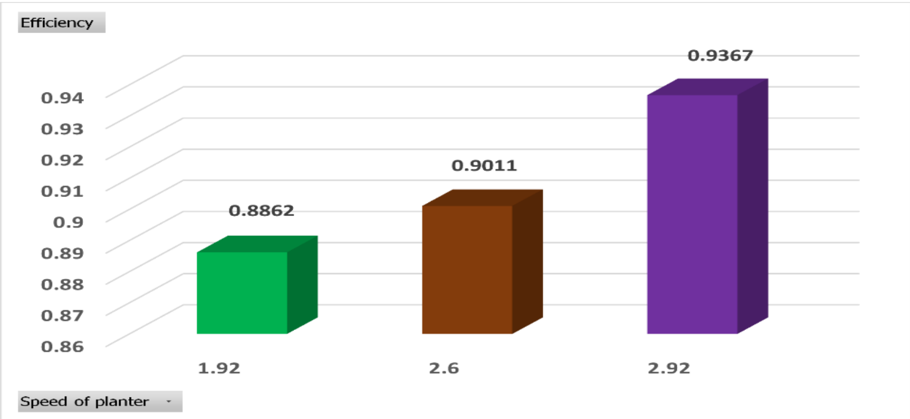

Figure 7. Bar chart showing the effect of planter's speed on field efficiency

4.2.5 Determination of fuel consumption

The seed planter's fuel consumption values obtained in the field ranged from 1.95 to 2.98 l/ha. The mean fuel consumption value obtained was 2.43 l/ha while the standard deviation value obtained was 0.52 l/ha. This demonstrates a moderate fuel usage. Figure 8 shows that the planter's fuel consumption value increases as the planter's speed increases during operation.

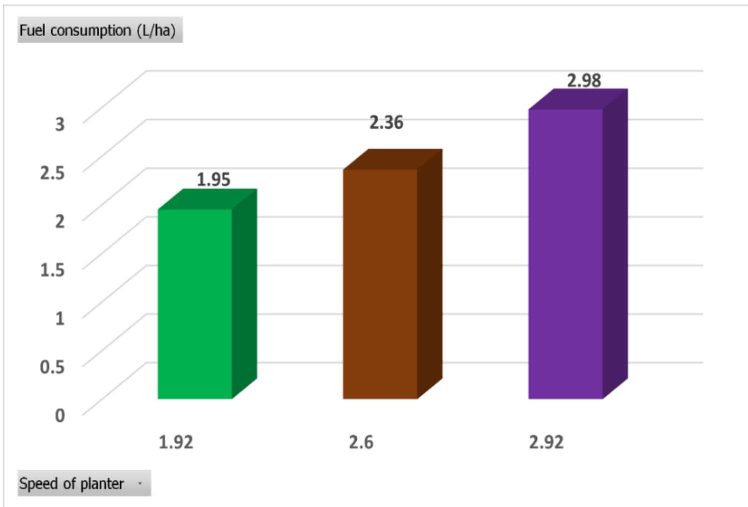

Figure 8. Bar chart showing the effect of planter's speed on fuel consumption

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Field performance evaluation was carried out on a motorized two-row multiseed grain walking planter which was developed by the National Centre for Agricultural Mechanization (NCAM), Ilorin. Results obtained from the field evaluation showed that there exist a positive correlation between the planter's speed and other measured parameters such as theoretical field capacity, effective field capacity, field efficiency, intra-row spacing distance and fuel consumption. The developed motorized two-row multiseed grain walking planter recorded effective field capacity values which ranged from 0.1727 ha/h to 0.3024 ha/h, theoretical field capacity values which ranged 0.1949 ha/h to 0.3228 ha/h, field efficiency values which ranged 88.62% to 93.67%, fuel consumption values which ranged from 1.95 l/ha to 2.98 l/ha and intra-row spacing distance values which ranged from 333 mm to 334.99 mm. The planter attained an average planting depth of 43.18 mm. The motorized two-row multiseed grain planter provides an effective means of maximizing crop yields, minimizing labour expenses, and improving food security.

5.2 Recommendations

Though, this study actually met its goals, however, additional research is required to improve on the planter's agility which will make the seed planter more user-friendly and suitable for use in the different terrains in Nigeria. Further research on the seed planter's should focus on:

1. Enhancing the planter's stability and equilibrium.
2. Incorporating sophisticated technologies, like precision agriculture and automation.
3. Executing field testing under varied environmental circumstances.
4. Assessing the planter's compatibility with alternative grain crops.

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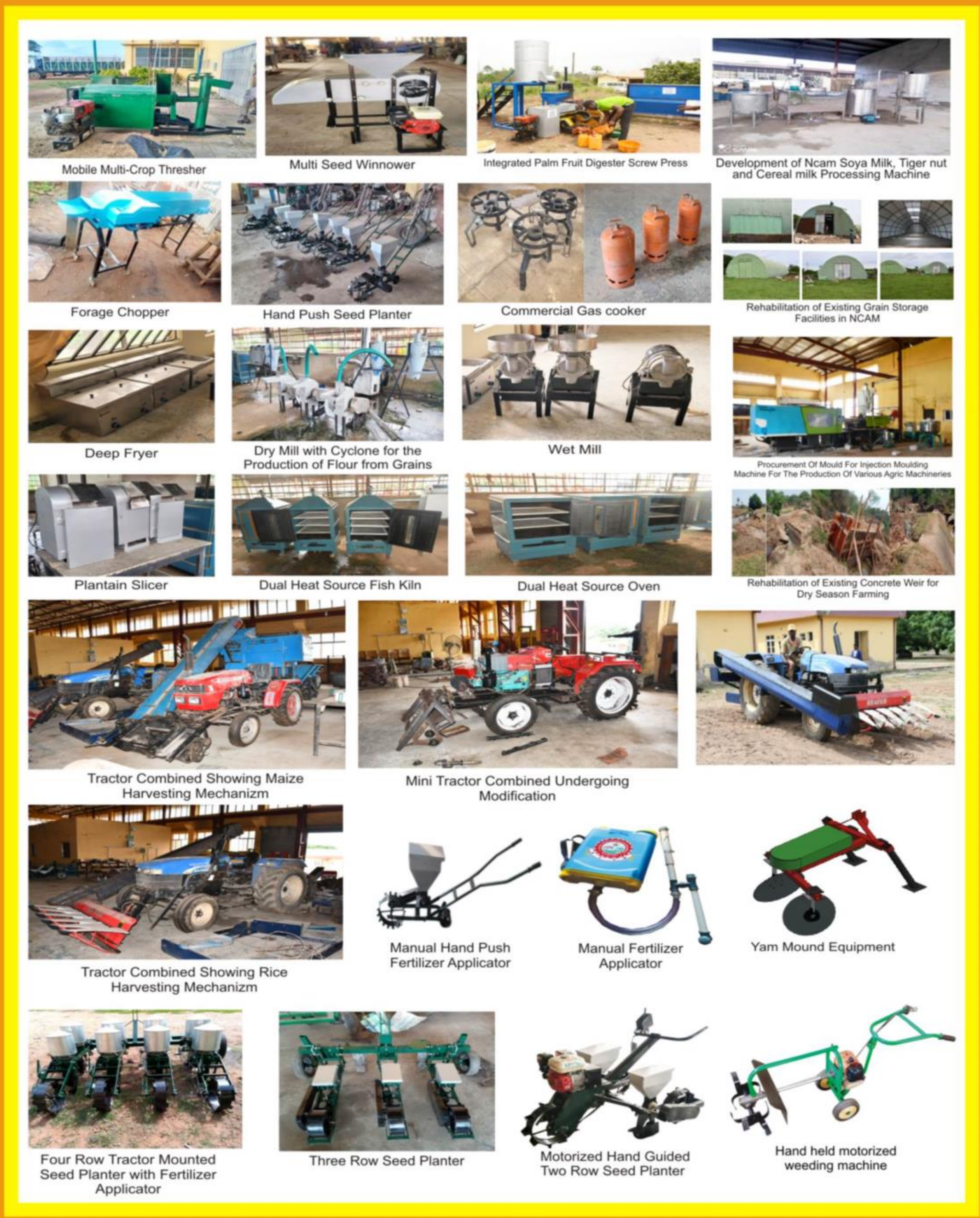

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