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Enhancing the Cassava Processing Value Chain: Sustainable Production of Edible Starch and Cassava-Based Confectionery in Emerging Markets

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Abstract

Agriculture is critical to Nigeria's economic development and food security, yet its potential is constrained by limited value addition, particularly in cassava processing. This study examines the cassava value chain with a focus on transforming cassava into edible starch and local cassava cake (gari) in Isoko North, Delta State, Nigeria. A cross-sectional survey was conducted during the 2024 production season using a multistage sampling approach to select 100 cassava processors from ten randomly chosen communities. Data were collected via structured questionnaires and analyzed using descriptive statistics, gross margin analysis, and regression modeling. Results reveal that 80% of respondents were female, with 80% lacking formal education and 75% married, reflecting the socio-economic profile of processors in the area. 55% had over 16 years of experience in cassava processing, underscoring the sector's longstanding importance. Economic analysis indicated that processors generated an average revenue of ₦500,000 against total costs of ₦237,000, resulting in a gross margin of ₦263,000 and a return on investment of 111%. Regression analysis demonstrated that 77% of the variability in annual revenue was explained by production inputs, market dynamics, and socioeconomic factors. The study identifies several challenges, including outdated processing technologies, limited credit access, volatile market pricing, insufficient storage facilities, and high operational costs. Policy recommendations include developing local innovation hubs, integrated digital platform, alongside implementation of Blockchain-enabled Traceability and incentivization of renewable energy adoption. These interventions could facilitate a transition from subsistence to a modern cassava value chain, thereby enhancing food security and economic empowerment in Nigeria.

1. Introduction

Agriculture remains a cornerstone of Nigeria's economy, serving as a critical driver of employment, food security, and national Gross Domestic Product (GDP) [1,2,3,4,5]. Among the myriad of agricultural commodities, cassava (Manihot esculenta) stands out as a linchpin due to its remarkable adaptability to diverse agro-climatic conditions and its pivotal role as a staple food for millions of Nigerians [6]. Nigeria is the world's leading producer of cassava, contributing approximately 20% of global production, with an annual output exceeding 60 million metric tons [7]. Despite this impressive production capacity, the cassava industry is plagued by significant challenges in value addition, as the majority of harvested cassava is either consumed in its raw form or processed using traditional, inefficient methods, thereby constraining its economic potential and global competitiveness [8,9]. Recent studies underscore the imperative of fortifying cassava value chains to enhance profitability, bolster food security, and improve rural livelihoods [10]. Value addition through advanced agro-processing can substantially mitigate post-harvest losses, expand market opportunities, and foster sustainable economic prospects for smallholder farmers and processors [11]. Cassava derivatives such as edible starch and local cassava cake (commonly referred to as fufu or akpu) are widely consumed in Nigeria and hold significant potential for industrial and commercial applications. Edible starch, for instance, is extensively utilized in food production, pharmaceuticals, and the textile industry, while local cassava cake remains a staple food product with consistent consumer demand [12]. However, the full economic benefits of cassava processing remain largely untapped due to technological, financial, and infrastructural constraints. The widening chasm between food supply and the rapidly burgeoning population underscores the urgent need for a paradigm shift toward agro-processing to minimize post-harvest losses and amplify economic returns.

The Isoko North Local Government Area in Delta State is a prominent cassava-producing region where traditional processing methods predominate, often resulting in inefficiencies, suboptimal product quality, and financial losses for local processors [13]. The dearth of modern processing facilities, limited access to credit, and weak market linkages have further compounded the challenges faced by small-scale cassava processors. These impediments not only curtail profitability but also undermine the sector's contribution to rural economic development. Consequently, there is an exigent need to investigate and bolster the cassava processing value chain in the region to enhance its economic impact. To address these challenges, a multi-faceted approach is essential. This includes the adoption of innovative technologies, capacity building for local processors, and the establishment of robust market linkages. Additionally, policy interventions aimed at improving access to credit and infrastructure development are crucial for the sustainable growth of the cassava processing sector. By leveraging these strategies, the cassava industry in Isoko North can be transformed into a more efficient, profitable, and sustainable value chain, thereby contributing significantly to the broader goals of food security and economic development in Nigeria.

This study significantly enriches the burgeoning body of literature on cassava processing value chain development by offering actionable insights and practical recommendations for policymakers, agribusiness stakeholders, and rural farmers. With a specific focus on the localized context of cassava processing value chains, the research delves into the intricate socio-economic dynamics confronting small-scale processors in Nigeria. By integrating sustainability with profitability, the study examines the dual challenges of market accessibility and financial constraints, thereby bridging a critical gap in existing research. A distinguishing feature of this study is its micro-level socio-economic and profitability focus, which sheds light on pivotal factors such as the predominance of female labor, low levels of formal education, and extensive hands-on experience among processors. Utilizing a robust methodological framework that includes descriptive statistics, gross margin analysis, and regression modeling, the researchers elucidate how these socio-economic variables, in conjunction with inadequate infrastructure and limited access to credit, impede profitable cassava processing [44].

In contrast to broader studies that often overlook localized nuances, this paper not only quantifies the economic viability of cassava processing—revealing a profitability index of 52.6%—but also underscores the imperative for tailored policy interventions. The study advocates for targeted strategies such as microcredit schemes, local innovation hubs, and consumer education campaigns, which are designed to bridge the gap between technological advancements and the on-the-ground realities of small-scale processors [13]. This comprehensive approach underscores the necessity of both immediate financial interventions—such as credit access and mechanization—and long-term structural reforms—including market stability and infrastructure development. By adopting this holistic perspective, the study not only highlights the immediate financial barriers but also addresses the systemic issues that perpetuate inefficiencies in the cassava processing value chain.

Furthermore, the research contributes to the discourse on sustainable agricultural development by emphasizing the importance of gender inclusivity and educational empowerment in enhancing the productivity and profitability of small-scale processors. The findings advocate for a multi-dimensional strategy that combines economic support with social and infrastructural improvements, thereby fostering a more resilient and sustainable cassava processing sector. This study, therefore, serves as a critical resource for stakeholders aiming to enhance the economic impact of cassava processing in Nigeria, offering a nuanced understanding of the socio-economic factors at play and providing a roadmap for achieving sustainable and profitable value chain development.

In contrast to studies conducted in Brazil, Thailand, Ghana, and Indonesia, this research diverges significantly by shifting the focus from large-scale mechanization (Brazil), value-added exports (Thailand), macro-level policy reforms (Ghana), or technology adoption (Indonesia) to a granular examination of local-level barriers in Nigeria. Specifically, the study highlights critical issues such as small-scale credit constraints, unpredictable market pricing, and the socio-economic intricacies that define the cassava value chain in rural Nigerian communities. By integrating social, economic, and policy dimensions, the research addresses a critical yet often overlooked knowledge gap: how rural community dynamics, entrenched gender roles, and fragmented markets collectively influence the efficiency and profitability of cassava processing. This multi-dimensional approach not only enriches the academic discourse but also provides a nuanced understanding of the unique challenges faced by small-scale processors in Nigeria.

The study underscores the necessity of context-specific interventions that harmonize financial access, technology transfer, and targeted policy support to enhance the profitability and sustainability of cassava processing in local communities. These findings are particularly relevant for emerging markets grappling with similar structural challenges, offering a replicable model for sustainable agricultural development. By focusing on the interplay between local socio-economic factors and broader policy frameworks, the research provides a comprehensive roadmap for stakeholders aiming to optimize the cassava value chain. This holistic perspective not only bridges the gap between theory and practice but also highlights the importance of tailored interventions that address the specific needs and constraints of rural communities. Ultimately, this study serves as a pivotal contribution to the global discourse on agricultural value chain development, demonstrating that sustainable and profitable cassava processing is achievable through a combination of localized strategies and systemic reforms. The insights gleaned from this research are invaluable for policymakers, agribusiness stakeholders, and development practitioners seeking to foster inclusive and resilient agricultural systems in emerging markets. By emphasizing the critical role of context-specific solutions, the study advocates for a paradigm shift in how agricultural value chains are conceptualized and implemented, ensuring that they are both economically viable and socially equitable.
The study contributes to the growing body of literature on cassava value chain development and seeks to provide practical recommendations for policymakers, agribusiness stakeholders, and rural farmers. By addressing critical gaps in cassava processing and proposing evidence -based solutions, this study aims to facilitate a transition from subsistence cassava processing to a more structured, technology-driven value chain that enhances food security and economic resilience in Nigeria.
This study aims to analyze the cassava processing value chain in Isoko North local government Area with a particular focus on the current value chain of cassava processing into edible starch and local cassava cake, key challenges faced by cassava processors, including technological limitations, financial constraints, and market accessibility issues and propose strategic interventions for improving the efficiency, profitability, and sustainability of cassava processing, distribution in the study area.

Hypothesis
H_{01}: There is no significant relationship between the level proposed strategic interventions for improving the efficiency, profitability, sustainability of cassava processing, technology used in cassava processing and the quality of the final products (edible starch and local cassava cake) in Isoko North Local Government Area.

2. Related Works

Cassava (*Manihot esculenta*) plays a critical role in the agricultural economies of many tropical and subtropical regions, particularly in Africa, where it serves as a staple food and an essential source of income for millions of smallholder farmers [7]. The cassava processing value chain consists of multiple stages, including cultivation, harvesting, transportation, processing, and distribution, ultimately transforming raw cassava into various high-value products. Despite its economic significance, the sector faces significant challenges, including inadequate processing technologies, post-harvest losses, and market access constraints [14].
Two key products derived from cassava processing are edible starch and local cassava cake (commonly known as *gari* in Nigeria and other West African countries). Both products highlight cassava's economic versatility and potential for value addition, offering substantial opportunities for income generation, food security, and industrial applications [15].

2.1 Cassava Processing Value Chain

The Cassava processing value chain has three components to wit:

1. Production: The value chain begins with cassava cultivation, where farmers plant and manage cassava crops over a growth period ranging from 9 to 24 months, depending on the variety and environmental factors [16]. Due to its high perishability, freshly harvested cassava must be processed within 48–72 hours to prevent spoilage.

2. Transportation: Harvested cassava roots are transported to processing centers. Transportation efficiency plays a crucial role in minimizing post-harvest losses, as cassava roots begin to deteriorate rapidly after harvest [17].

3. Processing: The processing phase is where the most significant value addition occurs. Cassava roots undergo various transformation processes to yield products such as edible starch and *gari*. Efficient processing techniques improve product quality and market value, reducing waste and enhancing food security [9].

2.2 Edible Starch Production

Edible starch extracted from cassava is widely utilized in the food, pharmaceutical, and textile industries due to its functional properties as a thickener, binder, and stabilizer. Cassava starch is particularly valued for its gluten-free nature, making it a preferred alternative in the growing global gluten-free food market [12]. The processing phases for edible starch are:

a. Peeling and Washing: Cassava roots are peeled to remove cyanogenic compounds and washed thoroughly to eliminate soil and impurities.

b. Grinding and Extraction: The peeled cassava is grated or milled into a pulp, followed by water-based extraction to separate starch granules from fibrous material [40].

c. Filtration and Drying: The extracted starch is filtered, allowed to settle, and dried to a moisture content of approximately 12%, ensuring a stable shelf life.

d. Packaging and Storage: The dried starch is milled into a fine powder and packaged for commercial or industrial use.

The demand for cassava starch is rising due to its diverse applications, particularly in food processing, adhesives, paper production, and pharmaceuticals. However, Nigerian cassava starch processors face challenges such as inadequate mechanization, poor quality control, and low access to global markets [39]. Addressing these challenges through improved processing techniques and market linkages could significantly enhance the profitability of cassava starch production.

2.3 Local Cassava Cake (Garri) Production

Local cassava cake, known as *gari*, is one of the most widely consumed cassava products in West Africa. It is produced through fermentation, pressing, and roasting of grated cassava. Fermentation plays a crucial role in reducing cyanogenic content and improving the nutritional and sensory properties of *gari* [38]. The processing garri involves the following phases:

a. Peeling and Grating: Fresh cassava roots are peeled and grated using mechanical or manual graters.

b. Fermentation: The grated cassava is left to ferment for 2–3 days, allowing beneficial lactic acid bacteria to enhance flavor and extend shelf life [41].

c. Pressing and Roasting: After fermentation, the grated cassava is dewatered using hydraulic presses or manual squeezing methods. The semi-dry cassava mash is then roasted in shallow frying pans over controlled heat.

d. Cooling and Packaging: Once the desired texture and color are achieved, the *gari* is cooled and packaged for storage or sale.

As a staple food in Nigeria, *gari* provides a stable source of income for many rural households. Its production is relatively labor-intensive but can be scaled through mechanized processing [12]. However, the sector is hindered by challenges such as inadequate storage facilities, price volatility, and poor market integration [14].

2.4 Cassava Processing Equipment, and Resources

Efficient cassava processing requires various methods, equipment, and resources to optimize product quality and maximize economic returns. The processing approaches for edible starch and *garri* differ significantly, reflecting their distinct industrial and culinary applications. The key equipment required for edible starch are: mechanical peelers, chippers and grinders, centrifuges, drying racks or dryers, and milling machines. For Garri, the major equipment are manual or mechanical graters, fermentation sacks or containers, hydraulic presses, and frying pans or roasting machines.

2.5 Challenges in Cassava Processing and Value Chain Development

Despite its economic significance, cassava processing in Nigeria faces several challenges:

a. Technological Limitations: Many smallholder processors lack access to mechanized equipment, leading to inefficiencies and high labor costs [19, 20, 21, 22, 13].

b. Financial Constraints: Limited access to credit facilities prevents processors from scaling up operations [14].

c. Market Access Issues: Poor market infrastructure, price fluctuations, and supply chain inefficiencies hinder profitability [17].

d. Post-Harvest Losses: The high perishability of cassava contributes to significant postharvest losses, reducing overall production efficiency [9].

2.6 Socioeconomic Impact of Cassava Value Addition on Local Farmers and Processors

The impact of cassava value addition on the livelihoods of local farmers and processors has been profound, contributing to increased income, enhanced food security, and strengthened community resilience. As a drought-resistant crop with a high starch content, cassava (Manihot esculenta) is a crucial staple in many parts of Africa, particularly in Nigeria, where it serves as a primary source of carbohydrates [23]. However, the economic potential of cassava has historically been underutilized due to limited processing infrastructure, inadequate investment in value addition, and inefficient market linkages [16]. Value addition in cassava entails converting raw cassava into processed products such as gari, fufu, cassava flour, and industrial starch. These processes not only cater to diverse consumer demands but also significantly extend the shelf life of cassava, reducing post-harvest losses and improving profitability. A study by [24] found that engagement in cassava processing increases farmer incomes by as much as 40%, enabling reinvestment in farm productivity, improved household welfare, and expanded market participation.

Moreover, cassava value addition contributes substantially to employment generation, particularly in rural communities where agriculture is a dominant economic activity. Processing activities often necessitate additional labor, creating opportunities for both men and women. Notably, women play a significant role in cassava processing, particularly in the production of gari and fufu, thereby enhancing their economic independence and social status [7]. Studies by [18] indicate that women-led cassava processing enterprises have contributed to improved household incomes, better access to education for children, and enhanced community development.

Beyond economic benefits, cassava value addition plays a crucial role in food security by diversifying the range of available food products. Processed cassava derivatives provide year-round food availability, reducing seasonal food shortages and enhancing dietary diversity. The International Institute of Tropical Agriculture [25] highlights that the development of cassava value chains has significantly mitigated hunger and malnutrition in regions heavily dependent on the crop, particularly through fortified cassava flour, which offers enhanced nutritional value.

Despite these evident benefits, several challenges hinder the full realization of cassava's economic potential. Limited access to modern processing technologies, inadequate financial support, and weak market structures constrains the scalability and efficiency of cassava processing enterprises [26]. Many small-scale processors rely on traditional processing methods, which often result in lower yields and product quality inconsistencies. However, initiatives aimed at training farmers in advanced processing techniques, facilitating access to credit through microfinance institutions, and improving infrastructure for cassava processing are proving effective in overcoming these barriers [27].

3. Challenges in the Cassava Value Chain: Implications for Farmers and Processors

The cassava value chain offers significant economic opportunities for local farmers and processors, particularly in regions where cassava serves as both a staple food and a key agricultural commodity. However, several challenges impede the efficiency of value addition processes, ultimately affecting the livelihoods of those involved in cassava production and processing. These barriers, which range from technological limitations to financial constraints and market access issues, must be addressed to maximize the sector's potential for income generation and food security [14].

3.1 Key Challenges in Cassava Value Addition

One of the primary challenges in cassava value addition is the lack of access to modern processing technologies and integrated digital platforms. Many small-scale processors continue to rely on rudimentary tools that limit their production capacity, efficiency, and competitiveness in larger markets [42]. Without mechanized peeling, grating, or drying systems, cassava processing remains labor-intensive and inefficient, reducing the quality and scalability of processed cassava products such as flour, chips, and starch. This technological gap not only affects profitability but also restricts access to premium markets that demand high-quality, standardized products [28].

Another significant barrier is **poor infrastructure**, particularly in rural areas where cassava farming is most prevalent. Limited road networks, inadequate transportation facilities, and unreliable electricity supplies hinder cassava processing operations. Efficient transportation is crucial to reducing post-harvest losses since cassava is highly perishable and must be processed within a short timeframe after harvesting [29]. Furthermore, inconsistent electricity access disrupts cassava processing activities that require a stable power supply, such as dehydration, fermentation, and milling.

Market access and price volatility also present considerable challenges for cassava farmers and processors. Many local cassava producers struggle to find stable markets for their products due to poor distribution networks, weak value chain linkages, and fluctuating demand [43]. Farmers often face price instability, which discourages investment in cassava value addition and leads to reliance on traditional subsistence farming rather than commercial-scale production. Additionally, inadequate access to real-time market information makes it difficult for farmers to make informed decisions about when and where to sell their products for maximum profitability [30].

Furthermore, **post-harvest handling and quality control** remain pressing concerns. Poor storage techniques, inefficient drying methods, and contamination risks can result in significant losses in both quantity and quality, negatively affecting the marketability of processed cassava products [16]. Many smallholder farmers lack the technical knowledge and training required to implement best practices in cassava processing, leading to inconsistencies in product quality that limit their ability to compete in national and international markets [31].

3.2 Socioeconomic and Gender Dynamics in Cassava Processing

Social factors, particularly gender disparities, also affect cassava value addition. Women constitute a significant proportion of cassava processors, yet they often face limited access to resources, credit, and training compared to their male counterparts [36]. These gender-based inequalities restrict their ability to scale up production, invest in mechanized processing equipment, or access larger markets. Addressing these disparities through targeted policies and support programs can enhance women's economic participation and drive inclusive growth in the cassava sector.

3.3 Impact of Technological, Financial, and Marketing Challenges on Cassava Value Addition

The cassava value chain presents vast opportunities for improving rural livelihoods, but its success is constrained by persistent challenges in technology, finance, and marketing. Each of these barriers affects the efficiency and sustainability of cassava processing enterprises, ultimately influencing the sector's ability to contribute to food security and economic development.

3.3.1 Technological Challenges

The lack of access to modern cassava processing technologies remains a major hindrance to value addition. Traditional methods of cassava processing, including manual peeling, grating, and roasting, are not only labor-intensive but also yield lower productivity and inconsistent product quality [16]. This limits the potential for commercial-scale production and reduces the competitiveness of locally processed cassava products in broader markets. Additionally, limited knowledge of advanced processing techniques further constrains value addition efforts. Many local processors are unfamiliar with modern fermentation, dehydration, and preservation methods that could enhance product shelf life and nutritional quality [24]. Without sufficient training and access to research driven innovations, cassava processors may continue to experience inefficiencies and product wastage.

3.3.2 Financial Challenges

Financial constraints pose significant obstacles to smallholder farmers and processors in the cassava industry. Limited access to credit and investment capital makes it difficult for entrepreneurs to purchase modern equipment, upgrade facilities, and adopt improved processing techniques [37]. Many formal financial institutions perceive smallholder cassava processors as high-risk borrowers, which restricts their ability to secure loans for business expansion.
Furthermore, the high cost of mechanized processing equipment discourages small-scale farmers from adopting more efficient technologies. Government and private sector interventions, such as subsidized equipment leasing programs and microfinance schemes, could help bridge this financial gap and promote inclusive growth within the cassava value chain [26].

3.3.3 Marketing Challenges

Establishing sustainable market linkages remains a critical challenge for cassava farmers and processors. Many smallholder enterprises lack the resources and expertise to develop branding and marketing strategies that would allow them to differentiate their products in competitive markets [30]. In contrast, larger agribusinesses and imported cassava-based products dominate both domestic and export markets, making it difficult for small-scale processors to gain traction.
Moreover, inadequate market infrastructure and distribution networks often result in inefficiencies in getting cassava products to consumers. Many local processors depend on informal markets with volatile pricing structures, limiting their ability to plan for long-term business sustainability [16]. Strengthening value chain integration and improving access to formalized market platforms could significantly enhance profitability in the cassava sector.

4. Methodology

4.1 Area of study

This study was conducted in Isoko North Local Government Area (LGA) of Delta State, Nigeria (see Figure 1). Delta State, located in the southern region of Nigeria, was established in 1991 and comprises 25 Local Government Areas (LGAs), which are further categorized into three major agricultural zones: Delta North, Delta Central, and Delta South [48]. Delta State lies approximately between longitude 5°00' and 6°45' East and latitude 5°00' and 6°30' North. It covers a total land area of about 18,050 km², with an annual mean rainfall ranging between 2,000 mm and 2,300 mm, and an average temperature of 28°C to 30°C [33]. The climate is characterized by two distinct seasons: the rainy season, which typically lasts from late March to the end of October, and the dry season, which spans from November to early March. Isoko North LGA was selected for this study due to its high prevalence of cassava cultivation and processing activities. Cassava is a major staple crop in the region and serves as an essential component of the local agricultural economy. The area's favorable **agro-ecological conditions** make it highly suitable for food crop cultivation, tree crop farming, fishery, and livestock production [34]. Apart from cassava, other economically significant crops cultivated in the region include: Rubber (Hevea brasiliensis), Oil palm (Elaeis guineensis), Orange (Citrus sinensis). Isoko North is strategically located and shares boundaries with several LGAs in Delta State: Ndokwa West LGA to the north, Ndokwa East LGA to the east, Ughelli North LGA to the west, and Patani LGA to the south. The major occupation of the people in Isoko North is farming, with a significant portion of the population engaged in both subsistence and commercial agriculture. The region's rich agricultural potential makes it an ideal site for studying cassava value chain dynamics, particularly in cassava processing and value addition.

Figure 1: Location of the Study

3.2 Sampling Technique and Sample size

Data for this study were collected using a **structured questionnaire**, which was administered by a team of well-trained enumerators proficient in both **English and the local language** to ensure clarity and accuracy of responses. A **cross-sectional survey** was conducted using a **multistage sampling procedure** to select participants involved in cassava processing in **Isoko North Local Government Area (LGA), Delta State**. A Multistage sampling procedure was used in selecting 100 cassava processors in the study area, stage one involved the purposive selection of ten communities within the LGA. In stage two, 10 cassava processors were randomly selected from each community for interview, resulting to a total sample size of 100 processors. Equal number was selected because the distribution of cassava processors is almost of equal population across the world.

Each selected community serves as a site for data collection, allowing researchers to capture the unique aspects of cassava processing in those specific contexts. The selected communities are:

i. **Ozoro**
ii. **Owhelogbo**
iii. **Otor Owhe**
iv. **Iyede**
v. **Emevor**
vi. **Okpe-Isoko**
vii. **Ofagbe**
viii. **Oyede**
ix. **Otor-Igho**
x. **Ellu**

The 10 communities were selected based on their established prominence in cassava production and processing within Isoko North LGA. Preliminary data from local government records and consultations with agricultural extension officers indicated that these communities consistently demonstrate high cassava production volumes and active processing activities. This made them ideal sites to capture a comprehensive snapshot of the local cassava value chain. Additionally, the communities were chosen to reflect diverse socio-economic conditions and infrastructural setups across the LGA, thereby ensuring that the findings would be representative of the broader processing landscape in the region. This purposive selection was intended to enhance the reliability of the study by focusing on areas where cassava processing is a significant economic activity and where the impact of value addition—or lack thereof—could be most effectively observed and analyzed.

The ten (10) cassava processors from the chosen communities had significant engagement in small-scale *gari* processing and their contribution to cassava value addition. More so, the selection took note of their expertise, cassava production volume, levels of cassava processing activities in the area and involvement in cassava production in the study area, and the insights they can provide regarding value chain dynamics, technological limitations, financial constraints, and market accessibility issue [47]. The study chooses respondents (processors) who have been active in the cassava processing enterprise for a certain number of years, utilizing distinct processing techniques, processors engaged in producing specific products like edible starch or local cassava cakes.

3.3 Ethical Considerations

This study adhered to ethical research principles, ensuring informed consent, voluntary participation, confidentiality, and data protection. Participants were fully informed about the study's purpose and provided consent before data collection. Anonymity was maintained by presenting findings in aggregated form, and data security measures were implemented to prevent unauthorized access. To uphold non-maleficence and beneficence, the research minimized risks and aimed to benefit cassava processors and local farmers. Cultural sensitivity was observed, ensuring respectful engagement with participants. The study complied with institutional and national ethical guidelines, including Nigeria's National Research Ethics Framework and the Helsinki Declaration on Ethical Research. Additionally, data transparency and responsible sharing were prioritized to support policymaking and agricultural development while safeguarding participants' rights. These ethical measures ensured research integrity and contributed to sustainable improvements in the cassava value chain.

3.4 Analytical Techniques

A combination of descriptive statistics, gross margin analysis, and regression model was employed to analyze the collected data. Descriptive Statistics such as the frequency counts and percentages were used to describe and summarize the socioeconomic characteristics of respondents (Processors) including gender, age, education level, household size and years of experience, processing pattern and methods, versus constraints to processing. Analytical tools such as frequency distributions, means, and percentages were utilized to describe the collected data. Gross Margin Analysis was employed to determine the profitability of cassava processing enterprises by estimating the difference between total revenue and total variable costs. This technique provided insights into the economic viability and financial sustainability of cassava processing in the study area [34]. On the other hand, regression analysis was used to estimate the relationship between revenue (dependent variable) and key independent variables, including production inputs, labor costs, market accessibility, and access to processing technology. The regression model helped identify significant factors influencing the profitability of cassava processing enterprises.

The various models for Gross Margin and regression model are given in equation (1), (2), (3), (4) and (5)

$$GM = TR - TVC \quad (1)$$

$$TR = P \times Q \quad (2)$$

Where;

GM= Gross Margin

TR= Total Revenue accruable from the sales of cassava products

TVC = Total variable cost incurred in processing e.g. labour, firewood, water, cassava

P =Price per unit of processed cassava products

Q = Quantity of processed cassava products.

ROI = Rate of return on investment =TV/ TVC (3)

Regression Model

Multiple regression model was used in determining variables influencing quantity of cassava products or profit of cassava processors profit is implicitly expressed thus;

$$Y = f\,(b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6 + e) \quad (4)$$

or

Explicitly expressed as;

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_5 x_5 + \beta_6 x_{6} + \mu \qquad (5)$$

Where;

Y =Estimated revenue per annum; b_0 = Constant; $b_1 - b_6$ = Coefficients of multiple regression x_1 = Labour cost (₦)
x_2 = Processing cost, x_3 = Selling price, x_4 = Quantities of tubers processed or cost equivalent, x_6 = Packaging, x_5 =Miscellaneous cost,
e = error term and β_0 = Constant term, $\beta_{1} - \beta_5$ =parameters to be estimated

4. Results and Discussion

4.1 Socio-Economic Characteristics of Respondents

The results presented in Figure 2 highlight the socio-economic characteristics of cassava processors in the study area. Though this study did not focus only on female cassava processors within Isoko North LGA, however, preliminary findings and local agricultural data indicated that women overwhelmingly represent the processing workforce in this region. Consequently, findings indicated that 100% of respondents were female, reinforcing the notion that cassava processing is a female-dominated activity. This aligns with the findings of [46], who observed that cassava processing in Kwara State was predominantly carried out by women (88.1%) and that the sector was characterized by an aging workforce. The educational background of respondents revealed that 90% had no formal education, which may influence their ability to adopt improved cassava processing techniques and access formal markets. Regarding education, although 90% of respondents lack formal education, decades of hands-on experience in cassava processing play a crucial role. Many processors have honed their skills over years, learning through on-the-job experience and informal knowledge-sharing mechanisms such as community workshops, peer-to-peer mentoring, and locally organized training sessions. These informal educational avenues compensate for the absence of formal business training by imparting practical insights into effective processing techniques and market strategies. Finally, while some literature indicates male involvement in cassava processing, our study found that 100% of processors in Isoko North are female. This outcome is reflective of the local socio-cultural and economic dynamics where cassava processing is traditionally a female-dominated activity. Although gender roles may vary across Nigeria, evidence suggests that in regions like Isoko North, women overwhelmingly drive cassava processing, indicating a localized trend rather than a nationwide phenomenon.

Furthermore, most respondents had large household sizes (6–8 members), with 75% being married, suggesting a strong reliance on family labor for cassava processing. The age distribution of respondents showed that 48% were 51 years and above, indicating a workforce with significant experience but potential aging related productivity concerns. Additionally, 55% of respondents had over 16 years of cassava processing experience, confirming that cassava processing has been an established livelihood activity in the region for a long time. These findings underscore the importance of targeted interventions, such as capacity-building programs, access to credit, and improved processing technologies, to enhance productivity and sustainability in cassava processing enterprises.

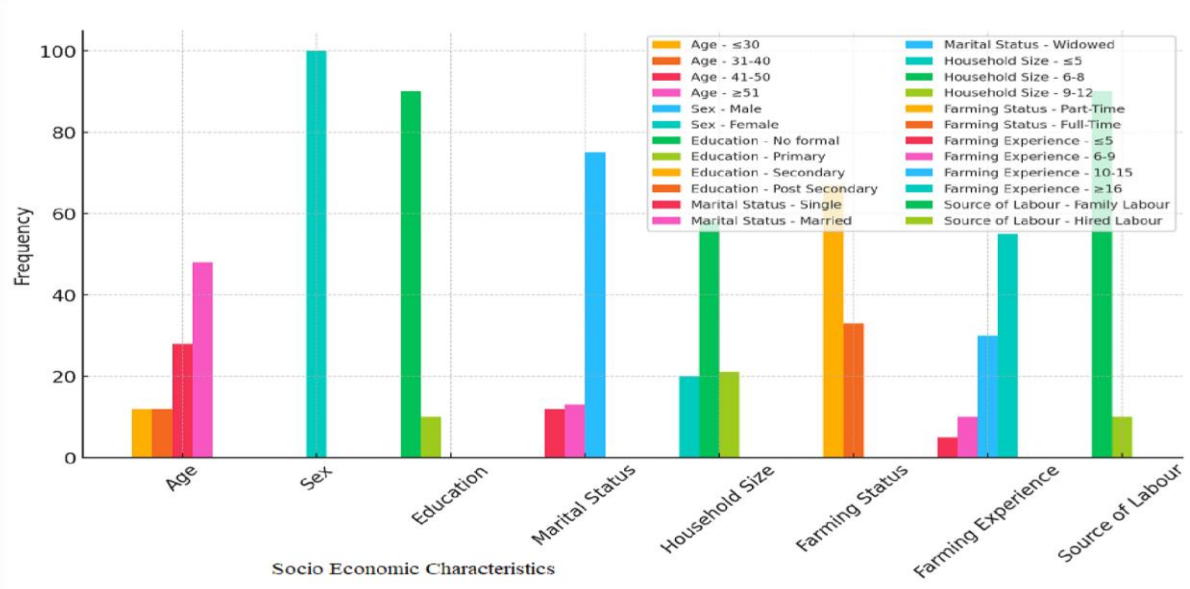

Figure 2: Socio Economic Characteristics of Cassava Processors

4.2 Estimated Annual Average Variable Cost per Respondent

The findings presented in Figure 3 reveal the estimated annual average variable cost incurred by cassava processors. The results indicate that the cost of purchasing fresh cassava tubers was ₦120,000, accounting for 50.6% of the total production cost per metric tonne of cassava. This confirms that raw cassava tubers represent the highest variable cost in cassava processing, emphasizing their significance in the production of edible starch and cassava cake. These findings align with [35], who also reported that the purchase cost of fresh cassava tubers constitutes the largest proportion of total variable costs among cassava processors.

Additionally, the study found that grating labor costs accounted for 19.8% of total variable costs, making it the second most significant cost component in cassava processing. This highlights the labor-intensive nature of cassava processing and underscores the potential benefits of mechanization and improved processing techniques in reducing production costs and enhancing profitability.

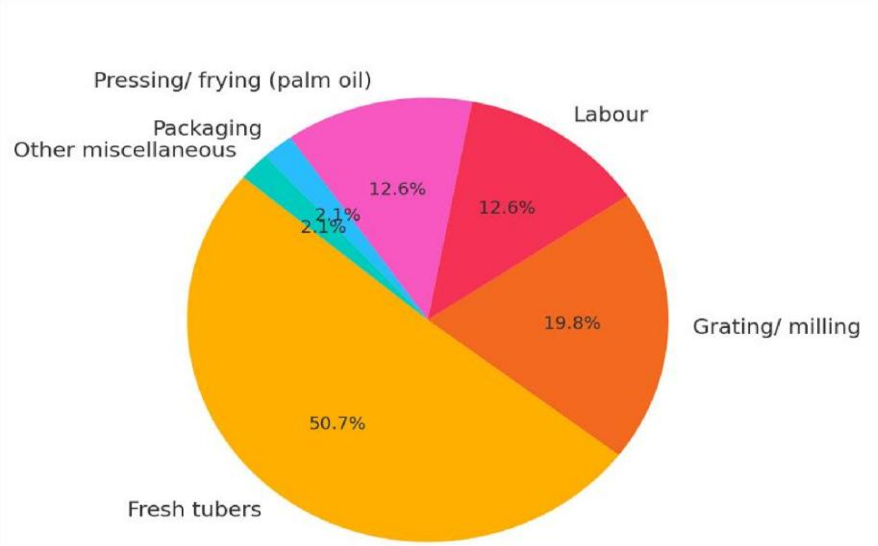

Figure 3: Estimated Average Annual Variable Cost per Cassava Processor

Gross Margin Analysis

The results presented in Figure 4 indicate that the estimated annual total revenue per cassava processor was ₦500,000, while total variable costs amounted to ₦237,000. The gross margin, which represents the difference between total revenue and total variable costs, was ₦263,000 per annum per processor. The computed Return on Investment (ROI) is ≈1.11 or 111%. That is, for every ₦1.00 invested (i.e., spent on variable costs), the enterprise earns an additional ₦1.11 in gross profit. Equivalently, the net gain (profit above the investment) is ₦1.11 per ₦1.00 invested demonstrating the profitability and economic viability of cassava processing enterprises in the study area. The computed net profit margin was 52.6% implying that for every ₦1.00 of sales revenue, approximately ₦0.526 is gross profit.

Processors remain profitable despite market volatility by leveraging strong informal market networks and, in some cases, cooperative arrangements. These networks enable them to negotiate collectively with buyers, secure more stable pricing, and reduce individual market risks. Even in a fluctuating market, pooled resources and long-standing relationships help buffer against sudden price drops, ensuring a relatively stable annual revenue.

The high level of experience in processing must have accounted for return in place of lack of formal education. The result is consistent with the findings of [44], who reported similar profit margins in their study on cassava processing profitability in Yewa South Local Government Area, Ogun State, Nigeria. These findings highlight the economic significance of cassava value addition and suggest that targeted interventions, such as access to improved processing technologies, credit facilities, and better market linkages, could further enhance profitability and sustainability in the cassava processing sector.

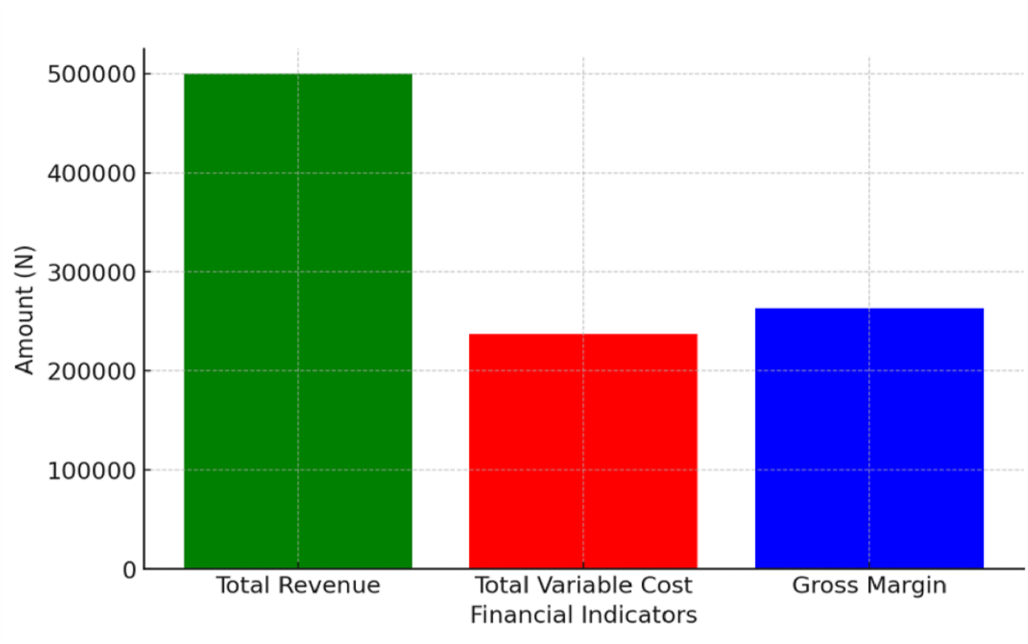

Figure 4: Estimated Annual Total Revenue and Gross Margin of Respondents

4.2 Regression Result of Returns to Cassava Processing

The results presented in Table 1 identify the key factors influencing the income of cassava processors in the study area. The coefficients of independent variables, including labor cost (0.717), processing costs (0.173), selling price (0.132), and quantity of cassava tubers processed (0.420), were all positive and statistically significant. This indicates that increases in these variables lead to corresponding increases in cassava processors' income. Conversely, packaging costs (0.024) and miscellaneous costs (0.162) did not exhibit a statistically significant relationship with income. This suggests that changes in these cost components do not consistently influence income levels, possibly due to their relatively minor contribution to overall production costs. The F-calculated value (5.711) was greater than the F-tabulated value (3.123), confirming that there is a significant relationship between processing input costs and income levels of cassava processors. Additionally, the adjusted R^2 value of 0.767 (77%) indicates that 77% of the variation in income levels can be attributed to the combined effect of the independent variables included in the model. These findings suggest that investment in labor, processing efficiency, and increasing the quantity of cassava tubers processed can significantly enhance profitability. Furthermore, the statistical significance at the 5% confidence level reinforces the reliability of these results in explaining the economic behavior of cassava processors in the study area. To enhance profitability, policymakers and stakeholders should focus on reducing labor costs through mechanization, improving processing efficiency, and stabilizing selling prices through better market linkages. Table 2 shows the computed variance inflation factors (VIF) for each predictor. All the independent variables (aside from the constant, which often shows a higher VIF) have VIF values well below the commonly used threshold of 10. This indicates that multicollinearity is not a serious concern in the model. In practical terms, the coefficients for labour cost, processing cost, selling price, and quantities processed (the variables that were found to be statistically significant) are unlikely to be distorted by high intercorrelations among the regressors. The result for the White's Test for heteroscedasticity are: white Test Statistic (14.82), p-value (≈ 0.112) and F-Test p-value (≈ 0.098). White's test was used to detect whether the variance of the error terms is constant (homoscedasticity). In our computation, both the standard and the F-test p-values are above the 0.05 significance level, implying that we do not have sufficient evidence to reject the null hypothesis of homoscedasticity. This suggests that the residual variance remains relatively stable across different levels of the independent variables, which is important for the reliability of standard errors and hypothesis tests. Similarly, we evaluated the Jarque–Bera test to ascertain whether the residuals of the regression are normally distributed. With a test statistic of approximately 2.54 and a p-value of 0.280, we fail to reject the null hypothesis of normality. The skewness (0.3) and kurtosis (3.45) values are close to those expected under a normal distribution. This confirms that the assumption of normally distributed errors is reasonably met, which supports the validity of inferential statistics (e.g., t-tests and confidence intervals) derived from the regression model. Together, these results provide strong evidence that the key assumptions for a valid regression model have been met. Therefore, the estimated coefficients (including the significant effects of labour cost, processing cost, selling price, and quantities processed) can be considered reliable for explaining the determinants of income among cassava processors.

Even though the regression model explains the variability in the estimated annual revenue, the authors admit the omission of some variables that could influence cassava processing income include: Government Policies(such as policy-driven microcredit schemes, subsidies, or regulatory frameworks may affect access to capital and overall profitability), climatic conditions that include variability in weather patterns (e.g., rainfall, temperature) which can influence cassava yield, processing efficiency, and raw material availability; and supply chain disruptions such as poor road infrastructure, transportation delays, or market instability can impact both input costs and revenue stability. These limitations will be addressed in a future work using an expanded model that includes additional variables to capture external influences such as government policy effects, climatic conditions, and supply chain factors. This would reduce omitted variable bias and potentially improve the explanatory power of the model.

Table 1: Determinants of Income of Cassava Processor

Variable	Coefficient B	Std Error T		Probability level
Constant	**2**8.465	2.727		0.013
Labour costs	0.717	1.672	0.173	0.081
Processing costs	2.403 0.132		2.538	0.023
Selling price/bag	0.420	4.667	0.024	0.001
Quantities of processed Tubers	0.234			0.000
Packaging costs	0.162	0.385		0.815
Miscellaneous	0.767			0.701
R^2	5.711			
F-				

** Significant at 5% level (P< 0.050)

Table 2: Computed Variance Inflation Factor for the Predictors

Predictor	VIF Value
Labour Cost	1.32
Processing Cost	1.28
Selling Price	1.45
Quantities of processes tubers	1.15
Packaging Cost	1.10
Constant	12.34

4.3 Challenges Encountered by Cassava Processors

The results presented in Figure 5 highlight the key challenges faced by cassava processors in the study area. Respondents were asked to identify and rank the major constraints encountered from the procurement of cassava tubers through processing to the final distribution stage. The study employed a Likert-type scale to measure the severity of these challenges, and five major constraints were identified:

1. Inadequate capital and funding
2. Poor markets characterized by low and unstable pricing of products
3. Lack of improved technology
4. Inadequate processing and storage facilities
5. Small-scale enterprises with low earnings

Ranking of Constraints

The results indicate that inadequate capital and funding (mean score: 2.50) was ranked as the most significant challenge, highlighting the financial constraints faced by cassava processors in acquiring necessary resources for production. The second major constraint was poor market conditions (mean score: 2.18), characterized by low and unstable pricing, which affects processors' profitability and discourages further investments in the cassava value chain. Lack of improved technology (mean score: 2.02) was the third-ranked constraint, suggesting that limited access to modern processing techniques and machinery reduces efficiency and increases processing costs. Inadequate processing and storage facilities (mean score: 1.94) ranked fourth, indicating that post-harvest losses and inefficiencies in storage and preservation remain significant barriers to cassava processing. Finally, small-scale enterprises with low earnings (mean score: 1.80) ranked as the least severe challenge, though still relevant. Many cassava processors operate at subsistence levels, limiting their ability to scale up and maximize profits.

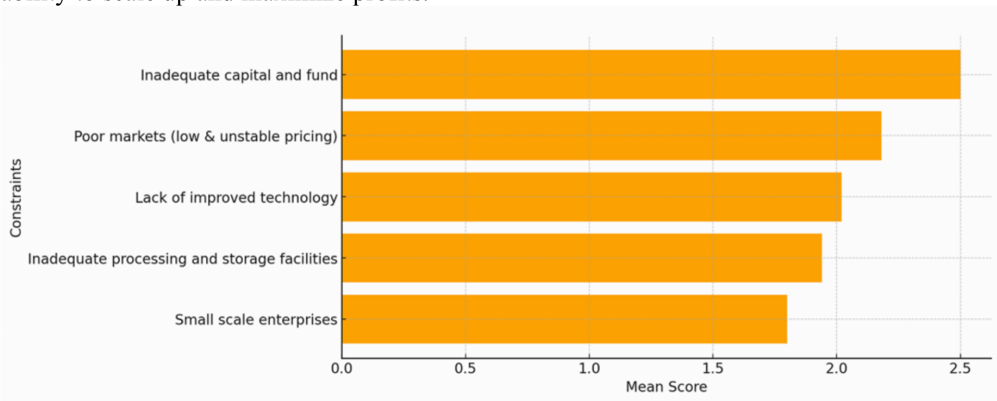

Figure 5: Challenges faced by Cassava Processors

5.0. Conclusion

The study revealed that cassava processing into edible starch, *fufu*, and cake is a profitable enterprise in the study area, with an estimated annual revenue of ₦500,000, total variable costs of ₦237,000, and a gross margin of ₦263,000 per processor. These findings confirm that cassava processing is not only a sustainable livelihood activity for processors but also a viable avenue for wealth creation if properly harnessed and adequately funded. To further enhance productivity and profitability in cassava processing, the study makes the following recommendations:

i. **Establishment of Cassava Innovation Clusters through** public–private partnerships that link local universities, research institutes, and cassava processors. These clusters could pilot next-generation processing technologies, diversify cassava-derived products (e.g., bio-based materials or renewable energy inputs), and encourage localized R&D. Evidence from innovation hubs in Nigeria's tech and agribusiness sectors suggests that such clusters boost productivity and drive sustainable growth.

ii. **Development of Integrated Digital Platforms which will l**everage Nigeria's strong mobile and fintech ecosystem to design digital platforms that combine real-time market data, digital payments, and tailored financial services. By integrating supply chain management with digital credit scoring and micro-insurance, processors could mitigate market volatility and improve access to finance. Studies in similar agricultural contexts have shown that digital integration can reduce transaction costs and enhance financial inclusion.

iii. **Implementation of Blockchain-enabled Traceability** to ensure transparency in product quality and supply chain transactions. Such systems, piloted in other Nigerian agricultural sectors like cocoa, can build consumer trust, stabilize pricing, and create data-driven insights for market planning.

iv. **Incentivization of Renewable Energy Adoption--**Offer targeted incentives for incorporating renewable energy solutions (e.g., solar-powered processing units) to reduce operational costs and environmental impacts. This strategy aligns with Nigeria's broader renewable energy policies and could improve the sustainability of cassava processing operations.

v. Access to Credit Facilities: Microfinance institutions and government-backed microcredit schemes should prioritize funding for cassava processors to enable them to acquire modern processing machines and essential inputs. Financial support should be structured with low-interest rates to encourage investment in mechanized processing.

vi. Government Support and Subsidies: Government agencies should subsidize essential cassava processing equipment, such as milling machines, graters, and storage facilities, to reduce production costs. Policies should be implemented to enhance the availability of high-quality cassava varieties and affordable raw materials.

vii. Capacity Building and Technology Adoption: Extension officers should be actively involved in training cassava processors on modern processing techniques to improve efficiency and product quality. Establishing technology demonstration centers where processors can gain hands-on experience with new technologies would be beneficial.

viii. Market Development and Value Chain Strengthening: Cassava processors should be linked to structured markets, including industrial buyers and export opportunities, to ensure better pricing and income stability. Cooperatives and producer associations should be strengthened to improve bargaining power and market access.

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