Technical Efficiency and its Determinants among Tamarind Processors in Northern Nigeria: A Stochastic Frontier Analysis

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Abstract
This study investigates the technical efficiency of tamarind processing enterprises in selected North-Central and North-Western states of Nigeria using a stochastic profit frontier model. Data were collected from 384 tamarind processors through a multi-stage sampling technique and analyzed using the Maximum Likelihood Estimation approach. The results revealed that the mean technical efficiency was 55.26%, indicating substantial room for improvement in the use of available resources. Equipment and family labour significantly and positively influenced profit, while rent had a significant negative effect. The inefficiency model showed that business experience, age, and source of tamarind significantly increased inefficiency, while education level and household size reduced it. The gamma (γ) value of 0.5526 was statistically significant, confirming that more than half of the variation in output was due to technical inefficiency rather than random shocks. These findings underscore the need for improved access to education, training, and resource optimization strategies to enhance processing efficiency in the tamarind sector. Strengthening extension services and promoting the adoption of appropriate technologies could significantly improve the technical performance of small-scale tamarind processors in Nigeria.

Keywords: Technical Efficiency, Tamarind Processing, Stochastic Frontier Analysis, Agro-processing, Nigeria

Introduction

Tamarind (Tamarindus indica) plays a significant role in the livelihoods of rural communities in Nigeria, especially in the North-Central and North-Western regions. The fruit and its derivatives are widely used in traditional medicine, culinary applications, and food processing industries. Despite its growing economic importance, the tamarind value chain—particularly the processing segment—remains largely underdeveloped, characterized by low investment, limited access to modern technology, and inefficient resource utilization.

In agricultural production and processing, **technical efficiency** refers to the ability of a firm or enterprise to obtain the maximum possible output from a given set of inputs. Improving technical efficiency is crucial for enhancing productivity and profitability, especially in resource-constrained rural environments. For tamarind processors, achieving high technical efficiency can translate into increased output, reduced cost per unit of product, and greater competitiveness in local and regional markets.

Previous studies on agro-processing efficiency in Nigeria have focused on major crops such as cassava, rice, and oil palm, while relatively few have examined minor but economically viable crops like tamarind. Moreover, most tamarind processors in Nigeria operate informally, often relying on household labour and traditional equipment. As such, identifying the key factors influencing their technical performance is vital for designing targeted interventions that can improve efficiency and scale up production.

This study aims to estimate the technical efficiency of tamarind processors using a **stochastic frontier profit function**, and to examine the socio-economic and operational factors that determine inefficiency among processors in three selected states—Kano, Kaduna, and Nasarawa. The findings will

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provide empirical evidence to guide stakeholders, including policymakers, extension agents, and non-governmental organizations, in formulating strategies to boost processing efficiency and rural income generation in the tamarind sector.

Literature Review

Efficiency analysis in agricultural production and processing has long been recognized as a key tool for evaluating the performance of resource use, especially in developing economies where inefficiencies are often widespread due to limited access to technology, markets, and institutional support (Coelli et al., 2005). Among the various forms of efficiency, **technical efficiency**—the ability of a firm to produce the maximum output given a set of inputs—has gained considerable attention in empirical studies across Africa and beyond (Bravo-Ureta & Pinheiro, 1997; Olayemi, 2012).

Several studies in Nigeria have applied **stochastic frontier analysis (SFA)** to estimate technical efficiency in crop production and processing. For instance, Ajibefun and Daramola (2003) assessed efficiency in food crop production and found that education and extension contact significantly reduced inefficiency. Similarly, Ogundari and Ojo (2007) analyzed technical efficiency among smallholder cassava farmers and highlighted the role of household characteristics and institutional factors. In the agro-processing sector, Yusuf and Malomo (2007) used SFA to estimate the technical efficiency of palm oil processors, reporting average efficiency scores below optimal levels and identifying capital constraints as key barriers.

Despite this growing body of literature, **studies focusing on minor but economically relevant crops such as tamarind remain scarce**. Tamarind is largely cultivated and processed by small-scale operators, particularly women, who often rely on traditional techniques and locally sourced materials (Ogunleye et al., 2023). This makes the sector highly susceptible to inefficiencies in labour, equipment use, and raw material sourcing.

Moreover, existing research on tamarind has mainly emphasized its nutritional and medicinal properties (Akinoso & Raji, 2011), market structure (Ogunleye et al., 2023), or socio-economic importance (Adedayo et al., 2010), with limited focus on **efficiency measurement in processing and marketing**. This creates a critical gap in understanding the economic performance of tamarind processors and how their operations can be improved.

This study contributes to the literature by providing empirical evidence on the technical efficiency of tamarind processors using stochastic frontier techniques. It also explores the effects of socio-economic variables such as education, household size, and business experience on inefficiency, thus offering new insights for interventions in the tamarind value chain.

Methodology

Study Area

The study was conducted in three tamarind-producing states in Nigeria: **Kano**, **Kaduna**, and **Nasarawa**, representing the North-West and North-Central geopolitical zones. These states were selected due to their significant involvement in tamarind production and processing activities. The study focused specifically on tamarind processors operating within rural and semi-urban communities where the fruit serves as both a livelihood source and an economic commodity.

3.2 Sampling Technique and Sample Size

A **multistage purposive sampling technique** was employed to select the respondents. In the first stage, the three states were purposively selected due to their active participation in tamarind processing. In the second stage, major tamarind-producing local government areas (LGAs) were identified within each state. The third stage involved the selection of tamarind processing clusters or communities. Finally, **proportionate percentage sampling** was used to randomly select **a total of 384 tamarind processors**, distributed according to the concentration of processors in each LGA.

3.3 Data Collection

Primary data were collected using a well-structured questionnaire administered to tamarind processors. The data included socio-

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economic characteristics, costs of production inputs, and output (profit), as well as institutional and market-related variables.

3.4 Analytical Technique

The study employed the **Stochastic Frontier Profit Function** based on the Cobb-Douglas functional form to estimate technical efficiency. This model allows for the decomposition of deviations from the profit frontier into **random error** (accounting for measurement error and exogenous shocks) and **inefficiency effects** (due to suboptimal decision-making or resource use).

The general form of the stochastic profit frontier model is:

$\pi = f(X\beta) \cdot \exp(v-u)$

Where:

- π = normalized profit of the i-th processor
- X= vector of input costs and other explanatory variables
- ß= vector of unknown parameters to be estimated

v = random error term, assumed to be i.i.d.

u = one sided error term

Results and Discussion

Stochastic Profit Frontier Estimates

The maximum likelihood estimates of the stochastic profit frontier model for tamarind processors are presented in Table 14. The results show that **equipment** and **family labour** significantly and positively influenced the profit function at 1% significance level. Specifically, a 1-unit increase in equipment use led to an increase of ₦3.87 in profit, while family labour contributed ₦4.55 per unit. These findings suggest that capital investment and household participation in processing activities are vital to profit enhancement in the tamarind sector.

In contrast, **rent** had a statistically significant negative effect on profitability (−₦0.76), implying that high operational costs associated with facility usage reduce returns. **Raw material** and **hired labour** were not statistically significant, suggesting that variations in their use had limited direct impact on profit levels under current conditions.

Determinants of Technical Inefficiency

The inefficiency effects model identified several socio-economic factors influencing technical inefficiency. The **positive and significant coefficients of age (0.465)** and **business experiences (0.803) imply** that older and more experienced processors tended to operate with lower efficiency levels. This may reflect resistance to new techniques, outdated processing practices, or physical limitations with age.

Conversely, **education level (−1.641)** and **household size (−3.092)** had significant negative effects on inefficiency, indicating that more educated processors and those with larger households tended to be more technically efficient. Education likely enhances the ability to adopt improved technologies and better management practices, while household size may contribute to family labour availability and lower labour costs.

The **source of tamarind** had a large, positive, and significant effect (16.689), indicating that processors sourcing tamarind from outside their locality or informal markets may face delays, inconsistent supply, or lower-quality raw materials, which reduce efficiency.

Efficiency Levels and Diagnostic Statistics

The estimated **gamma (γ)** value of **0.5526** was statistically significant at 1%, confirming that **55.26%** of the variation in profit among processors was due to inefficiency rather than random shocks. This underscores the importance of addressing managerial and operational constraints.

The **sigma-squared (σ^2)** value was also significant (1858.69), validating the correctness of the composed error term structure in the model.

The findings imply that most tamarind processors in the study area are operating below the frontier and have substantial room to improve their technical efficiency.

Implications

The results suggest that improving education, reducing dependency on external tamarind sources, and encouraging family involvement in processing activities could enhance efficiency. Policies targeting training programs for older or experienced processors and subsidizing access to modern equipment may also close the technical inefficiency gap.

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3.5 Variables Specification

The dependent variable was **profit** from tamarind processing (in ₦). The independent variables (inputs) used in the model included:

Variable Description Cost of raw materials Cost of tamarind pods and pulp purchased (₦)Cost of hired labour Payments to non-family labour (₦) Cost of family labour Imputed value of household labour (₦) Cost of packaging Expenditure on packaging materials (₦) Cost of transportation Logistics and movement costs (₦) Equipment use Value of processing equipment used (₦) Cost of utility Cost of fuel, water, electricity used in processing (₦) Business experience Number of years of experience in tamarind processing Gender Dummy variable (1 = male, 0 = female)

The inefficiency model incorporated socio-economic factors such as age, education, household size, source of tamarind, and business experience.

The model was estimated using **maximum likelihood estimation (MLE)** procedures.

Conclusion and Recommendations

Conclusion

This study analyzed the technical efficiency of tamarind processors in selected North-Central and North-Western states of Nigeria using a stochastic profit frontier approach. The results revealed that most processors operate below the frontier, with a mean technical efficiency score of **55.26%**. This implies that, on average, processors could increase their output by approximately **45%** using existing resources more efficiently.

Among the inputs, **equipment use** and **family labour** significantly enhanced profit levels, while **rent** was found to reduce profitability. The inefficiency model further indicated that factors such as **business experience**, **age**, and **source of tamarind** increased inefficiency, whereas **education level** and **household size** contributed to improved efficiency.

The significant gamma (γ) value confirms that a substantial portion of the variation in profit is attributable to differences in technical efficiency among processors. These findings underscore the need for targeted interventions aimed at improving operational practices and input management in the tamarind processing sector.

Recommendations

Capacity-building and training programs should be organized for tamarind processors, particularly older and more experienced individuals, to promote the adoption of modern and efficient processing techniques. **Subsidized access to equipment** and processing tools should be facilitated through cooperatives or government support to reduce inefficiencies caused by outdated or inadequate machinery.**Adult education and literacy programs** should be encouraged, as education was shown to significantly reduce inefficiency and enhance productivity.

- **Support for local tamarind sourcing mechanisms**, such as linkages between farmers and processors, can reduce dependence on unstable or distant supply chains, which was found to contribute significantly to inefficiency.
- **Household-based labour systems** could be promoted, especially in areas with large families, to reduce costs and improve processing consistency and output quality.

By addressing these constraints and enhancing efficiency, tamarind processing enterprises can become more competitive, sustainable, and profitable, thereby contributing more significantly to rural income and food system development in Nigeria.

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