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Resource Use Efficiency and Profitability in Small Scale Palm Oil Production in Delta State Nigeria

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ABSTRACT
This study investigated the efficiency and profitability of palm oil processing in Delta State. A sample of 240 palm oil processors was used. Socio-economic findings revealed a male-dominated industry with an average age of 53 and an average household size of 7. Modern processing methods dominated (96.7%), with an average monthly processing of 869 litters. Profitability analysis showed a monthly gross margin of ₦930,852.48 and a return on investment of ₦3.14k, indicating a profitable venture. Stochastic frontier production estimates highlighted the significance of family and hired labour, emphasizing the role of well-maintained equipment. Marital status influenced inefficiency, and 66.7% of variability in efficiency was attributed to inefficiency. Technical efficiency ranged from 0.86 to 1.0, with a mean of 0.95, suggesting room for improvement among some processors. Production elasticity indicated increasing returns to scale. Resource-use efficiency revealed underutilization of fresh fruit bunches (ratio of 12.12) and excessive labour inputs (ratio of 2.2). Major constraints include high rent costs (82.1%) and expensive acquisition of fresh fruit bunches (67.1%). This study suggested the need for targeted interventions and technology adoption, to enhance efficiency and sustainability in the palm oil processing sector in Delta State.

Keywords: Palm Oil Processing, Efficiency Analysis, Profitability, Technical Efficiency, Delta State

1.0 Introduction

Palm oil has rapidly emerged as one of the most important global agricultural commodities. With over $50 billion in estimated annual market value, palm oil constitutes the leading vegetable oil worldwide (Naidu & Moorthy, 2021). When taking into account all downstream derivatives, few crop value chains can match palm oil's ubiquitous presence across the food, health, and commercial industries. On the production side, palm oil's exceptionally high oil yield extracted from the fruit and kernels of oil palm trees enables it to be the world's most efficient oilseed crop (Nwalieji & Ojike, 2018). This unparalleled production efficiency has driven extensive expansion of oil palm cultivation into tropical regions of Asia, Africa and Latin America (Pirker et al., 2016). As the technology and agronomy of palm oil continues advancing, some projections forecast production reaching 240 million tonnes by 2050 (Meijaard et al., 2018).

Nigeria has accelerated its engagement in the palm oil sector over the past decade, now ranking as the globe's 5th largest producer. In 2021, Nigeria generated approximately 1.4 million metric tonnes of crude palm oil and derivatives, primarily from smallholder farms and plantations clustered in the tropical southern regions (Food and Agriculture Organisation (FAO, 2022). While considerable growth has occurred in cultivation and harvesting capacities, domestic processing capabilities for converting raw palm fruit bunches into refined palm oil remain underdeveloped. An estimated 65-70% of Nigeria's total palm oil output is exported abroad semi-processed for further refining and additional value addition (Akpan, 2019).

Strengthening local processing infrastructure for crude, refined and derivative palm oil products would allow more sector revenue to be captured domestically. In addition to boosting Nigeria’s trade balance accounts through import substitution, growth in domestic refining can spur inclusive economic development through smallholder farmer income gains and employment generation in processing clusters (Egwu, Odoh & Eze, 2023).

Delta State, located in Nigeria’s oil-rich Niger Delta region, has emerged as one the country’s most significant palm oil production areas. The state contains numerous independent small- and medium-scale mills that process fresh fruit bunches sourced from local smallholder farms into crude palm oil (Imarhiagbe et al., 2021). These mills confront severe capital limitations relating to antiquated machinery, poor transport and storage infrastructure, and lack of quality control systems (Aliyu, 2022). Compounding matters, technical expertise gaps and sub-optimal management efficiency have also plagued processors for decades across Nigeria (Okoro et al., 2017).

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Addressing these systemic challenges is an imperative for the palm oil industry's development given processors' economically pivotal position between raw material supply bases and downstream distribution channels. Improving operational efficiency and financial sustainability of mills through technological upgrading and better practices unlocks greater prospects for smallholder farmer inclusion, food security, and broader sector industrialization (Ofem, Kefas & Garjila, 2022).
However, research rigorously evaluating efficiency and profitability dynamics of Nigerian mills using advanced statistical and econometric methods remains scant. Although some studies analyse financial ratios for small processing firms (Uchua, 2020; Adejuwon et al., 2020), analytical gaps persist regarding technical efficiency, costs, and multivariate statistical performance modelling. While determinants of profitability have also received slightly more focus (Ohimain et al., 2014; Agwu, Oteh & Amama, 2017; Anyanwu et al., 2020), the preponderance of studies rely largely on univariate financial ratio analysis. More sophisticated multivariate techniques incorporating efficiency, costs, pricing and revenue factors into predictive models is limited (Okoro et al., 2017). This study therefore investigates efficiency and profitability dynamics in Nigerian palm oil processing in Delta State. The specific objectives of the study are;

i. estimate the profitability of palm oil processing in the study area;
ii. examine the technical efficiency level of palm oil processors in the study area;
iii. examine the allocative efficiency of resources used among palm oil processors in the study area; and
iv. identify the constraint/factors affecting the margin of profit made by palm oil processors in the study area.

2.0 Methodology

Area and Scope of the Study

The study was carried out in Delta State. Delta State was created in 1991out of the defunct Bendel State. It lies roughly between Longitudes 05º 00´ and 6º4´ East and Latitudes 5º 00´ and 6º 30´ North. It is bounded in the north by Edo State, Ondo State to the South-West, Anambra State to the East and Bayelsa State to the South-West. The Atlantic Ocean forms its Southern boundary with a coastline of 160 Kilometres and a total land area of 18,050Km^2 (Ulu et al., 2022). The State is mainly agrarian, producing crops such as yam, cassava, cocoyam, maize, plantain, oil palm, rubber, timber etc. A large proportion of the population is engaged in farming, fishing, welding and fabrication, hair dressing, tailoring, etc.

Data Collection and Sampling Procedure

Primary data were used mainly for the study. They were obtained using well structured questionnaires. A 4-stage sampling technique was employed in selecting the samples for the study. Firstly, the study area was stratified based on the Delta Agricultural and Rural Development Authority (DARDA) delineation, that is, Delta South, Delta North and Delta Central agricultural zones, so as to get a state wide coverage. Each of the agricultural zones was used as a stratum. The second stage involved the random selection of four blocks from each of the stratum. In which case, every block had a chance of being selected. This amounted to twelve (12) blocks used for the study. The third stage involved a purposive selection of two (2) dominant palm oil producing communities from each of the twelve blocks. This implies that a total of 24 communities were used for the study. The fourth stage involved a random selection of ten (10) palm oil producers from each of the communities using simple random sampling technique. The result of the above selection process gave a total sample size of 240 palm oil processors.

Data Analysis Techniques

Data were analysed using the following techniques;

Objective I: Cost and Returns Analysis was used to determine the profitability of palm oil processors in the study area. This was expressed as follows;

$$NFI = GFI - TC \quad \ldots(1)$$

Where;
NFI = Net Farm Income
GFI = Gross Farm Income
TC = Total Cost

$$GFI = P_q Q - TR \quad \ldots(2)$$

Where:
P_q = Price Per Unit of Output
Q = Total Output

TR = Total Revenue

$TC = FC + VC(TVC + TFC)$……………………………..…………(3)
Where:
FC = Fixed Cost (Depreciation obtained using the straight line method)
VC = Variable Cost

$\Pi = TR - TC$…………………………………………………….……..(4)
Where:
Π = Farm Profit
GFI = Π

Objective II: The stochastic frontier production function was used to analyse the efficiency of inputs used in the production of palm oil in the study area.
The production function is specified as follows:
$LogY = \beta_0 + \beta_1 logX_1 + \beta_2 logX_2 + \beta_3 logX_3 + \beta_4 logX_4 + \beta_5 logX_5 + e_i$…………(5)
Where:
Log = Natural logarithm
Y = Net returns of palm oil producers (₦)
X_1 = Hired labour (₦)
X_2 = Family Labour (₦ value in man days)
X_3 = Depreciation on equipment (₦) (fixed inputs)
X_4 = Cost of fresh fruit bunches (FFB) (₦)
X_5 = Costs of transport and energy (₦)
β_0 = Intercept
$\beta_1 - \beta_5$ = Regression coefficients of the independent variables
e_i = error term

The Inefficiency of production, U_i was modelled in terms of the factors that are assumed to affect the efficiency of palm oil production. Such factors are related to the socio-economic characteristics of palm oil producers. The determinant of technical inefficiency is defined by:
$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + e_i$ … … … … … … … … … … … … …(6)
U_i = Technical inefficiency
Z_1 = Gender
Z_2 = Age
Z_3 = Marital status
Z_4 = Family size
Z_5 = Educational level
e_i = error term
δ_0 - δ_5 = Inefficiency parameters

Objective III: Marginal Analysis Concept was used to examine the efficiency of resources/input use and was determined by the ratio of the value of the Marginal Product (VMP) to Marginal Factor Cost (MFC). The relationship as indicated by Tambo and Gbemu (2010) is given as:
$r = \frac{VMP}{MFC}$ ……………………………….………… (7)
The decision rule is that:
If r =1, resources are efficiently used
r >1, resources are under utilized
r <1, resources are over utilized
Where:
r = Efficiency Coefficient
VMP = Value of Marginal Product, which is the additional revenue gained by using one more unit of input (e.g., additional revenue from adding one more worker or machine)
MFC = Marginal Factor Cost which is the additional cost of using one more unit of input (e.g. wage for one more worker or cost of one additional machine)
MFC = P_x
Px = Unit price of X_1
Efficiency is upheld when VMP = MFC
For this study, the value of Marginal Product (VMP) as used by Tambo and Gbemu (2010) was obtained as:

VMP = MPP * P_y …………………….……………..(8)
Where:
MPP = Marginal physical Product
P_y = Unit Price of Output
MPP = $E_P \frac{\bar{Y}}{\bar{X}}$
Where:
E_P = Elasticity of Production
$\bar{X}$ = Geometric Mean of Input X_i
$\bar{Y}$ = Geometric Mean of Output

The elasticity of production which is defined as the degree of responsiveness of the output to a unit change in input was computed using the Cobb Douglas function. This elasticity is represented as:

EP = $\frac{dy_i}{dx_i} * \frac{Xi}{Y}$, hence $\frac{dy_i}{dx_i}$ which is MPP = Eps $\frac{\bar{Y}}{\bar{X}}$
Where;
E_P = Elasticity of Processing
Y = Output
X_i = Inputs X_1 –X_9 as defined earlier
$\frac{dy}{dxi}$ = Marginal Physical Product (MPP_{X1}) (obtained from the production function)

Objective IV: Descriptive statistics Such as frequency counts and percentages were used to identify the constraint/factors affecting the margin of profit made by palm oil processors in the study area.

3.0 Results and Discussions

Socio-Economic Characteristics of Palm Oil producers in the study area

The result of socio-economic characteristics of Palm Oil producers in the study area are presented in Table 1.

Table 1: Socio-Economic Characteristics of Palm Oil producers in the study area

Variable	Frequency	Percent	Mean
Gender			
Male	220	91.7	
Female	20	8.3	
Age (years)			
21-30	4	1.7	
31-40	20	8.3	
41-50	68	28.3	
51-60	108	45	53 years
61-70	36	15	
71-80	4	1.7	
Above 61 years	33	26.2	
Marital Status			
Married	208	86.7	
Single	4	1.7	
Separated	28	11.7	
Household size			
< 4 persons	54	22.5	
4 – 6 persons	136	56.7	
7 – 9 persons	33	13.7	7 persons
Above 9 persons	17	7.1	
Level of Education			
No formal education	0	00	
Primary education	50	20.8	
Secondary education	182	75.8	
Tertiary	8	3.4	
Processing Experience (Years)			
1 – 5	132	55.1	
6 – 10	90	37.5	10 years
Above 10 years	18	7.4	

Gender: The gender of palm oil producers as shown in Table 1 showed that 220 respondents representing 91.7% of the total respondents in the study area were males while 20 respondents representing 8.3% of the total respondents were females. The finding corroborates the finding of Donkoh, Antwi and Sarfo (2020), who stated that males dominate the palm oil processing industry. Again, the finding is contrary to the established findings by Nwankwo (2016), who reported that in most societies, palm oil processing activities is the responsibility of women.

Age: The age of respondents as shown in Table 1 indicated that palm oil processors in the study area were aging but still active in palm oil processing business. With an average age of 53 years and an age range of 51-60 years accounting for the highest frequency of 108 (45%). The highest age of palm oil processors in the study area stood at 77 years, and this accounted for 1.7% of the total respondents. In the same vein, the lowest age bracket of palm oil producers stood at 21-30 years accounting for 1.7% of the total respondents.

Marital Status: The result of marital status of respondents showed much variation. Majority of respondents were married (86.7%) while others were either single (1.7%) or separated (11.7%). The findings are in agreement with that of Koyenikan and Anozie (2017), who found about 72% oil palm processors in Edo State were married. Also, Abazue, Choy and Lydon (2019) in their study reported that 189(70%) of sampled oil palm producers were married.

Household: From the result presented in Table 1, it showed that palm oil pro in the study area had household size of an average of Seven (7) persons with a range of 3-16 persons per family. The findings are closely supported by Adesiji et al. (2016) who submitted that palm oil processors in Kogi State, Nigeria had an average of seven (7) persons per family. Also, Oyibo et al. (2019), reported a relatively large household size of palm oil processor in Ankpa Local Government Area, Kogi state, Nigeria.

Educational Level: On the educational level of the respondents, majority of them had secondary School education (75%), 20.8% had primary school education while 3.4% had tertiary education. The finding implies that palm oil processors are fairly educated. The finding is in line with that of Owolarafe et al. (2022).

Processing Experience: The result showed that palm oil producers from the study area had an average processing experience of 6 years with a range of processing experience of between 1-16 years. From the findings, processing experience had positive influence in the performance of palm oil processors in the study area.

Sources of Raw Materials, Inputs, Techniques and Scale of Processing

The various sources of raw materials, inputs, techniques and scale of oil palm processing is shown in Table 2.

Table 2: Sources of Raw Materials, Inputs, Techniques and Scale of Processing in Delta State

Variable	Frequency	Percent	Mean
Source of processing materials			
Ownership of Plantation	190	79.2	
Purchase of FFB	50	20.8	
Sources of Labour			
Family	19	7.9	
Hired	60	25.0	
Both family & hired	161	67.1	
Processing methods			
Local	8.0	3.33	
Modern	232	96.7	
Scale of Processing (per 20 litres jerry can)			
< 20	40	16.6	
21-29	13	5.4	
30-39	36	15	
40-49	60	25	44 jerry cans
50-59	61	25.4	
60-69	17	7.2	
70-79	13	5.4	

Source of Processing Materials: The result in Table 2 revealed that majority of palm oil processors in the study area depend on the ownership of plantations as their primary source of processing materials, constituting a substantial 79.2%. This result aligns with that of Reeb et al. (2014) who reported that in palm oil production, where plantation ownership ensures a consistent and reliable supply of fresh fruit bunches (FFB). This finding is in line with previous studies emphasizing the significance of plantation ownership for sustained raw material supply (Osabuohien & Omoregbee, 2017). However, it is worth noting that 20.8% of processors still rely on purchasing FFB, suggesting potential variations in access to land or resources among the processing community.

Sources of Labour: From the results presented in Table 2, it showed that palm oil processors in the study area relied more on the combination of hired and family labour for their processing activity. The combination of hired and family labour accounted for 67.1% while hired labour accounted for 25% of total labour input. In the same vein, those respondents that use only family labour accounted for 7.9% while those that uses only hired labour in their palm oil processing activity accounted for just 25% of the total respondents from the study area. The result is in agreement with the study carried out by Dib et al, (2018) that showed that majority of oil palm producers in rural communities depended on a combination of family and hired labour for their farming activities. The result is also in agreement with that of Takele & Selassie (2018) who also showed that a large percentage of farmers in smallholder farmers depended on a combination of both family and hired labour for their farming activities.

Processing Method: From the result presented in Table 2, it showed that palm oil processors in the study area used two major processing methods in their palm oil production business. The processing methods are modern (hydraulic hand press, 96.7% and local method (traditional processing method) 3.3%. The result further showed that the level of education of palm oil producers in terms of their level of adaptation to innovations comes to bear here, as a more educated farmer will adapt to technological innovations faster than the uneducated farmer.

Scale of processing: Table 2 shows that palm oil processors in the study area process an average of 869 litters (44 Jerry can of 20 litters each) of palm oil on a monthly basis. From the findings, the lowest monthly processing stood at 400 litters (20 jerry can) and the highest monthly processing stood at 79 jerry cans of palm oil which is accounted for by one processor (0.4%).

Profitability analysis in palm oil production
Profitability analysis in palm oil production in the study area is shown in Table 3.

Table 3: Profitability Analysis in palm oil production

Category	Average monthly value output (₦) of palm oil at ₦23,565.54 per 20 litters	Percentage of total cost
Returns		
Palm oil (44 Jerry cans)	1,036,883.94	
Palm Kernel (By-Product)	131,977.00	
Total Revenue	1,168,860.94	
Variable Cost Components		
Fresh Fruit Bunches (FFB)	132,741.22	47.0
Hired Labour	16,260.00	5.8
Transport/Water/Firewood	36,173.08	12.8
Fuel Diesel, Electricity	52,834.16	18.7
Total Variable Cost	**238,008.46**	**84.2**
Fixed Cost Components		
Depreciation of Assets	18,054.02	6.4
Maintenance and Repairs	26,558.00	9.4
Total Fixed Cost	**44,612.02**	15.8
Total Cost	**282,620.48**	
Profitability Indices		
Gross Margin	930,852.48	
Net Farm Income	886,240.46	
Return/Naira	3.14	
Benefit/Cost Ratio	4.14	

The result presented in Table 3, showed the average monthly cost of Fresh Fruit Bunches (FFB) that can be processed into 44 numbers of 20 litters jerry cans of palm oil. An average total cost of ₦282,620.48 was incurred in producing 44 Jerrycans of palm oil. Of this cost, the total fixed cost accounted for 15.8% of the total cost of processing while the average variable cost accounted for 84.2% of the total cost of processing. Fresh Fruit Brunches (FFB) were the most important cost components in palm oil production accounting for about 47.0% while hired labour has the least cost in the production process, accounting for 5.8%. This finding is in line with a result of the earlier findings of Takele & Selassie (2018) on heavy dependence on family labour in combination with hired labour for palm oil processing activities which is seen to be responsible for the low labour cost in the entire production process. These findings corroborate the findings of Abdullah et al. (2019), that cost of fresh fruit bunches constitutes the highest cost components in palm oil processing.

The result further shows that processing of palm oil in the study area was a profitable business venture. This is evidenced by the monthly gross margin and net farm income (profit) of ₦930,852.48 and ₦886,240.46 respectively. The return on naira invested stood at ₦3.14k implying that, for every one naira invested in oil palm processing, ₦3.14k comes back to the processor as net return

Stochastic Frontier Production Estimate of Palm Oil Producers in the study area
The result in Table 4 presents the stochastic frontier production estimate of palm oil producers in the study area.

Table 4: Stochastic Frontier Production Estimate of Palm Oil Producers in the study area

Variables	Coefficient	T-Value	Sig.
Production function			
Constant	2.6001	9.24	0.000
Family labour	0.921***	20.42	0.000
Hired labour	0.158**	2.56	0.011
Depreciation (equipment)	0.095***	3.77	0.000
Cost of FFB	0.0007	0.70	0.481
Cost of transport and energy	-0.021	-0.87	0.385
Inefficiency function			
Constant	-1.434	-0.92	0.358
Gender	0.127	0.36	0.723
Age	-0.006	-0.44	0.658
Marital status	-1.311**	-2.55	0.011
Family size	-0.154	-1.47	0.141
Level of education	-0.143	-0.63	0.532
Variance parameters			
Sigma squared $a_s^2 a_5^2$	0.0067***	4.45	
Gamma γ	0.667***	8.144	

Where *** and ** are significant at 1% and 5% probability level respectively

Production Function:
Constant: The intercept, represented by the constant coefficient (2.6001, T=9.24) is highly significant ($p < 0.000$). The substantial positive coefficient suggests that there is a significant inherent capacity for palm oil production, even without the direct influence of explanatory variables like labour and equipment. This baseline level serves as a foundational aspect, indicating the minimum production output achievable in the absence of specific inputs. The statistical significance of the constant underscores its crucial role in shaping the overall production landscape, contributing to a comprehensive understanding of the palm oil production process in the study area.

Family Labour: The coefficient (0.921, T=20.42) demonstrates a highly significant impact on production ($p < 0.001$). This emerges as a pivotal factor influencing palm oil production, suggesting that an increase in family labour significantly contributes to enhanced production output. The magnitude of the coefficient underscores the substantial impact of family labour on the production process. This finding aligns with the previous study of Takele & Selassie (2018), emphasizing the intrinsic dedication and shared commitment within family labour, contributing significantly to overall production efficiency.

Hired Labour: With a coefficient of 0.158 and a T-value of 2.56, hired labour also shows significance in production ($p < 0.05$). The positive coefficient suggests that an increase in hired labour is associated with a 0.158 unit increase in the production output. While the magnitude of the coefficient is smaller compared to family labour, it still holds practical significance, implying that the engagement of additional, non-family labour positively influences palm oil production in the study area. The significance of hired labour in the production function highlights the diverse and dynamic nature of the labour inputs in the palm oil industry. The positive impact suggests that, even when family labour is predominant, supplementing the workforce with hired labour contributes to increased efficiency in the production process. According to Alwarritzi, Nanseki and Chomei (2015), this underscores the importance of a diverse labour force, where the unique skills brought in by hired labour complement the familial contributions, thereby enhancing the overall productivity of palm oil producers.

Depreciation (Equipment): The coefficient (0.095, T=3.77) indicates a highly significant influence on production ($p < 0.001$). This result indicates a robust impact of equipment depreciation on production. It underlines the importance of equipment maintenance, upgrade, or replacement strategies in sustaining or enhancing palm oil production efficiency. According to Tong (2017), the quality and performance of the equipment used in palm oil production are crucial for achieving optimal results. Well-maintained and upgraded equipment can reduce waste, increase efficiency, and enhance product quality. Therefore, investing in proper maintenance and upgrading of equipment is imperative for the sustainable and efficient production of palm oil.

Cost of FFB: The coefficient (0.0007, T=0.70) suggests a non-significant impact on production ($p > 0.05$). This implies that the cost of FFB does not exhibit a statistically significant impact on palm oil production in the studied context. The non-significant coefficient suggests that variations in the cost of FFB may not reliably predict changes in production output. While the coefficient is positive, indicating a potential positive relationship with production, the lack of statistical significance at the 5% level suggests that this relationship may be due to random chance rather than a true association. The T-value of 0.70 is relatively low, further supporting the idea that the Cost of FFB is not a strong predictor of production levels. Furthermore, the non-significant impact of the Cost of FFB on production may have practical implications for palm oil producers in Delta State. It suggests that, within the observed range of cost variations for FFB, changes in these costs do not play a substantial role in determining the overall output of palm oil. Producers may need to focus on other factors such as labour management, equipment maintenance, and efficiency improvements to enhance production levels.

Cost of Transport and Energy: The coefficient (-0.021, T=-0.87) and the significance level ($p > 0.05$) imply a non-significant impact on production. This implies that changes in the cost of transport and energy do not exert a statistically significant influence on palm oil production in Delta State at the 5% significance level. The non-significant result suggests that variations in the cost of transport and energy may not be crucial determinants affecting production output in the context of palm oil producers in the study area. The negative coefficient implies a small negative association, suggesting that an increase in the cost of transport and energy is associated with a slight decrease in production, but this relationship is not statistically robust.

Inefficiency function:
Constant: The constant coefficient (-1.434, T = -0.92), is not statistically significant (p> = 0.05). This implies that at the baseline level, inefficiency is not significantly different from zero, and the constant does not play a substantial role in explaining inefficiency. The non-significant constant implies that other explanatory variables, rather than a baseline inefficiency, may be more influential in understanding variations in inefficiency among palm oil producers.

Gender: The coefficient for gender (0.127, T = 0.36) is not statistically significant ($p > 0.05$), indicating that gender differences among palm oil producers do not significantly contribute to inefficiency in the production process. This result suggests that, in this context, gender-related factors may not be key drivers of inefficiency, and other variables should be explored to understand variations in inefficiency.

Age: Similarly, age (coefficient = -0.006, T = -0.44) does not have a statistically significant impact on inefficiency ($p > 0.05$). This implies that the age of palm oil producers does not reliably predict variations in inefficiency. This finding contradicts the findings of Iwala, Okunlola and Imoudu (2006) that age positively influenced efficiency, as experience and accumulated knowledge are often associated with improved productivity. However, in this specific study, age appears to play a minor role in explaining inefficiency differences among producers.

Marital Status: The coefficient (-1.311, T = -2.55) is a significant determinant of inefficiency ($p > 0.05$). This finding suggests that marital status plays a crucial role in influencing inefficiency among palm oil producers in Delta State. The negative coefficient implies that being married is associated with a decrease in inefficiency. Palm oil producers who are married, on average, exhibit lower levels of inefficiency compared to their unmarried counterparts. This result introduces a socio-demographic dimension to the efficiency dynamics, suggesting that the support structure and stability provided by marital status positively impact the efficiency of palm oil production. The magnitude of the coefficient (-1.311) signifies a meaningful effect. Palm oil producers who are married may benefit from shared responsibilities, mutual support, and potentially better resource allocation within the household. The statistical significance at the 5% level strengthens the confidence in this relationship, highlighting the robustness of the association between marital status and efficiency.

Family Size: With a coefficient of -0.154 and T value of -1.47, family size does not significantly impact inefficiency ($p > 0.05$), indicating that variations in family size among palm oil producers are not strongly associated with differences in inefficiency. The non-significant result suggests that family size may not be a critical factor influencing inefficiency in this particular agricultural context.

Level of Education: The coefficient for the level of education (-0.143, T = -0.63) is not statistically significant ($p > 0.05$), suggesting that the education level of palm oil producers does not reliably predict variations in inefficiency. While education is often considered a key factor in efficiency, this result implies that, in the specific context of palm oil production in the study area, education may not be a significant driver of inefficiency.

Variance Parameters:
Sigma Squared: The variance parameter for Sigma Squared (0.0067) is highly significant at the 1% level ($p < 0.001$), indicating substantial variability in the random component of the model. This suggests that unobserved factors not captured by the explanatory variables significantly contribute to the variability in production output. The significant variance parameter emphasises the importance of considering unobservable factors in understanding production variability.

Gamma γ (Proportion of Variability Due to Inefficiency): The gamma parameter (γ) is estimated at 0.667 (Table 4), indicating that approximately 66.7% of the total variability in palm oil production efficiency can be attributed to inefficiency. This parameter provides insights into the proportion of variability that is not explained by the observed input variables, emphasizing the importance of addressing inefficiency factors to enhance overall production efficiency.

Technical Efficiency of Palm Oil Processors in the Study Area.
The distribution of technical efficiency among palm oil producers in Delta State, as presented in Table 5, reflects a wide range of performance within the industry.

Table 5: Distribution of technical efficiency indices among palm oil producers in Delta State

Technical efficiency	Frequency	Percentage
0.84 - 0.86	10	4.2
0.87 - 0.89	13	5.4
0.90 - 0.92	27	11.3
0.93 - 0.95	71	29.6
0.96 - 0.98	90	37.5
0.99 - 1.00	29	12.1
Total	240	
Mean efficiency	0.95	
Maximum	1.0	
Minimum	0.86	

Majority of producers, constituting 37.5%, operate at the highest efficiency levels (0.96 - 1.0), showcasing a substantial cohort of producers effectively utilizing available resources. This top-performing group signifies the presence of successful practices and management strategies that contribute to optimal production outcomes. Additionally, a significant portion of producers (29.6%) falls within the 0.93 to 0.95 efficiency range, indicating a sizable group operating at high, albeit not maximum, efficiency. This distribution suggests that there is a range of efficiency levels within the industry, providing opportunities for targeted interventions to elevate overall performance.

The findings further underscore the favorable efficiency profile of the industry, revealing a mean efficiency of 0.95. This indicates that, on average, palm oil producers in Delta State are maintaining commendably high levels of operational efficiency. The mean technical efficiency index also signifies the potential for an average palm oil processor to enhance technical efficiency by 5% compared to the best practice farmer within the study area. This observation highlights existing efficiency gaps, signaling a need for ongoing improvements in palm oil processing practices among the processors in the study area. This outcome aligns with the conclusions drawn by Anyaoha and Zhang (2023) and Ahmad Hamidi et al. (2022), who similarly identified efficiency gaps from the optimum level and emphasized the potential for increased efficiency among palm oil processors.

However, the identified minimum efficiency of 0.86 suggests that there is still room for improvement among certain producers, underscoring the necessity for targeted support and capacity-building initiatives. This recognition emphasizes the importance of tailored interventions to elevate efficiency levels and promote sustainable practices within the palm oil processing sector in Delta State.

Production Elasticity and Return to Scale

The processing elasticity and return to scale in palm oil processing of respondents is presented in Table 6.

Table 6: Production elasticity and return to scale

Variable	Production elasticity
Family labour	0.921
Hired labour	0.158
Depreciation on equipment	0.095
Cost of fresh fruit bunches	0.0007
Transport/ Diesel/Electricity	-0.021
Return to scale	1.154

The processing elasticity with respect to family labour, hired labour depreciation on equipment and cost of fresh fruit bunches were 0.921, 0.158, 0.095 and 0.0007 respectively, while processing elasticity with respect to transport and energy was -0.021. The return to scale which is the sum of elasticity of the inputs used had a value of 1.153. For transport and energy, a unit percentage increase in these input quantities will decrease output by 0.021%. For family labour (0.921), hired labour (0.158), depreciation on equipment (0.095) and cost of fresh fruit bunches (FFB) (0.0007) which had elasticity that is greater than unity, indicative of an increasing returns to scale.

On return to scale, the addition of the elasticity of the inputs gave the returns to scale value of 1.154 for the entire study area. This is an indication that palm oil production in the study area was in stage one, implying that inputs were under-utilized by palm oil processors. At this stage, processors are advised to increase some of the inputs used in processing as further addition of some of the inputs may result to an increasing return to scale which is fit for processing (rational stage).

Resource-use Efficiency Levels of Inputs used in Palm Oil Processing

The allocative efficiency levels of inputs used in palm oil processing in the study area are presented in Table 7.

Table 7: Resource-use Efficiency Levels of Inputs used in Palm Oil Processing

Inputs	VMP	MFC	Ratio
Fresh fruit bunches (FFB)	53,914	4,449	12.12
Labour(N/manday)	3,000	1,375	2.2
Transport/ Water	6,674	6,674	1.0
Fuel/ Electricity	9,748	9,748	1.0

The result showed that the average efficiency ratio for fresh fruit bunches among palm oil processors in the study area was 12.12. This figure is greater than one signifying underutilization of fresh fruit bunches meant for processing in the study area. This implies that palm oil processors in the study area could increase their output and profit by increasing their palm oil output using improved mills with higher extraction capacity like the more advanced mini-improved processing unit such as those from NIFOR.

Similar result was obtained from labour input with ratio of 2.2 for the overall study area. Again, the value was more than unity confirming the existence of disequilibrium. In this case, the labour input is on the high side. Here, palm oil processors can increase their income by reducing the number of hired labour inputs in palm oil processing venture. This finding corroborates the findings of Takele & Selassie (2018), who reported the underutilization of hired labour among smallholder farmers. For transport and energy which stood at unity, it portends that these inputs are used when there is need to carry out palm oil processing activity. This conforms to a prior findings by Rivera-Méndez, Rodríguez and Romero (2017) that oil palm fruits/ bunches are the major raw materials input in the processing of palm oil and the number of oil palm fruits/ bunches that a farmer has access to will definitely determine the quantity of palm oil that would be processed from the extraction activities and by extension, other inputs that would be employed in the processing activities. When there is no processing, these other inputs would not be put to use thus conforming to determined equilibrium value.

Processing Constraints of Palm Oil Processors
The constraints confronting palm oil producers are presented in table 4.8.

Table 8: Processing Constraints of Palm Oil Processors

Constraints	Frequency	Percentage
High cost of rentage	197	82.1
High cost of FFB	161	67.1
High cost of improve small scale Mills	93	38.8
High cost of transport	78	32.7
Inadequate capital	52	21.7
Price fluctuation	52	21.7
Age of oil palm plantation	38	15.8
Unavailability of labour	21	8.8
Low return from production	12	5.0
High cost of labour	6	2.5

About 82.1% of processors highlighted the high cost of rentage as a major hurdle, reflecting the economic burden posed by rental expenses within the industry. This aligns with research by Anyaoha and Zhang (2023), emphasizing the significant impact of high rents on the financial viability of small-scale agricultural enterprises. Moreover, the substantial percentage (67.1%) attributing constraints to the high cost of acquiring Fresh Fruit Bunches (FFB) emphasises the financial strain associated with procuring raw materials for palm oil production. This resonates with the findings of Imarhiagbe et al. (2021), highlighting the economic challenges entailed in securing essential raw materials within the palm oil industry.

Infrastructure-related challenges are evident, with 38.8% of processors citing the high cost of improved small-scale mills as a constraint, highlighting the obstacles in adopting upgraded processing technologies. This aligns with observations by Khatun et al (2017), emphasising the pivotal role of technological advancements in enhancing palm oil processing efficiency. Additionally, transportation costs emerge as a notable concern, affecting 32.7% of processors and highlighting the impact of transportation challenges on the industry's cost structure, a point reinforced by Euler et al. (2016). Financial concerns, including inadequate capital (21.7%) and price fluctuations (21.7%), underscore the financial instability and uncertainty prevalent among processors, echoing the broader economic challenges faced by agricultural enterprises, as emphasized by Ume, Kaine and Ochiaka (2020). These multifaceted constraints collectively present a complex diverse challenge that necessitate comprehensive strategies and policy interventions to bolster the efficiency and sustainability of the palm oil sector in Delta State.

4.0 Conclusion

This study demonstrates that palm oil production is a profitable small-scale enterprise in Delta State, with positive profit margins, albeit constraints related to rental and raw material costs, infrastructure limitations, transportation expenses and financial factors persist that necessitate policy interventions. The level of technical efficiency varies substantially although the mean is a reasonably high 0.95, indicating opportunities for enhancing efficiency exist through tailored interventions like providing better access to advanced equipment, facilitating cooperative production models, and increasing access to credit to address key constraints. Overall, the analysis reveals an industry dominated by smallholdings relying on plantation ownership and family-hired labour, utilizing emerging technologies like hydraulic pressing. Based on the findings of the study, the following recommendations are hereby suggested:

i. Palm oil processors in the study area should be given more attention/intervention as regards appropriate small-scale technologies that would enhance the current level of efficiency of palm oil processors in the study area. One major issue from this research work has to do with low returns of palm oil output from the processing activities of palm oil processing in the study area. Government and investors should be

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more pro active in information dissemination on ways of getting better mills with higher extraction efficiency so that these processors can reach out for possible purchase of better palm oil processing mills.

ii. Marital status was found to have significant effect in reducing the inefficiency of palm oil processors, it thus means that those processors that are married are more efficient than those that are single. Also, educational level, family size and age contributed positively to reducing inefficiency of palm oil processors in the study area but they were not significant. Palm oil processors should strive to improve their educational status by attending specific trainings that has to do with oil palm development. This will expose them to recent findings and innovations that relates to oil palm development and thus broaden their knowledge on palm oil processing

iii. In the past, government and non-governmental organization usually have loan schemes and out-growers schemes that are targeted specifically to farmers as beneficiaries. These schemes, especially those from government, though still in yearly budget, are no longer targeted at farmers beneficiaries that need these support. These schemes should be revitalized so that these farmers/processors can have access to funds, to improve their processing business.

iv. One major problem from this research work has to do with the aging of existing plantations. In the past, Delta state government and even PRESCO usually have out growers scheme that are targeted at improving the life of the rural farmers through establishment of 1 to 2 hectares of oil palm plantation per beneficiary. This scheme helped in replanting of old plantations across the state. Recent budgetary provisions especially in the state seems not to be favouring this initiative anymore and this is a problem for the oil palm industry

There is no doubt that this scheme is laudable as it has helped in establishing new plantation. Government and indeed big estate plantations should improved on the existing programme so that more out growers can benefit from the scheme.

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