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Effect of post-harvest losses on profitability of rice (*Oryza sativa*) processors in Benue State, Nigeria

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ABSTRACT

This study assessed the impact of post-harvest losses on the profitability of rice processors in Benue State, Nigeria. The objectives were to describe the socio-economic characteristics of rice processors, estimate the extent of post-harvest losses, and analyze their influence on profitability. A total of 150 rice processors were selected using a combination of purposive, multi-stage, and simple random sampling techniques, with Taro Yamane's formula guiding the determination of the sample size. Data were analyzed using descriptive statistics, gross margin analysis, and Ordinary Least Squares (OLS) regression. Results showed that the average age of the processors was 41 years, with 47.33% being married and 74.67% having a formal education. Most processors (44.67%) handled between 7 and 10 bags of 100 kg weekly, and 36.67% had 10–15 years of processing experience. Inadequate drying facilities accounted for the highest post-harvest losses (61.56 kg or 25.60%), while pest and rodent damage contributed the least (30.14 kg or 12.53%). Gross margin analysis revealed an average gross income of ₦90,000 per 100 kg bag and a net farm income of ₦10,467. Regression analysis (adjusted R^2 = 0.59) identified key determinants of losses and profitability, with milling technology, labor, drying, and transportation showing significant adverse effects on losses. The scale of operation and rice prices significantly enhanced profitability. The study recommends investments in modern processing technologies, improved infrastructure, and training to reduce losses and boost profitability.

Keywords:
Estimates, Post-harvest losses, Profit, Rice processors

1. Introduction

Agricultural losses constitute one of the greatest problems facing agricultural production in Nigeria; this has raises serious concern for key stakeholders including research scientists, extension workers, farmers, and policy makers [1]. Between 10% and 40% of rice that is grown in Nigeria never reaches the market or consumers table because of poor post-harvest operations from harvesting, processing and storage techniques. Not only do these losses threaten food and nutrition security in the country, but it also adds to cost of production and slows down the marginal increase in yield recorded [2]. The money, the country is losing could be annual budget of more than 20 countries, because almost one quarter of the staple and perishable foods produced in Nigeria never reach the consumers [3]. FAO [4] noted that about 1.3 billion tons of food are wasted or lost annually. Every year African smallholder farmers experience huge post-harvest losses of their crops. These losses represent significant costs at household and national level.

Food security in Africa has remained elusive, huge postharvest food loss account for about 40% this significantly reduces the amount of food available to consumers, reduces number of marketable products, as a result income loss of 15% or more for the 470 million smallholder farmers, as well as for food traders, processors,

transporters and retailers. A total of N 2.1 trillion food products were imported into the country from January through to September in 2021 indicating a 75 percent rise when compared to N 1.2 trillion in the corresponding period in 2020 [5]. Post-harvest losses during processing of rice could worsen the situation if unchecked. Several studies have been conducted on post-harvest losses and processing techniques by researchers differently and on various crops [4,6,7] rice post-harvest losses during processing if not properly mitigated, may translate not just into human hunger and financial losses to farmers, but into tremendous economic and environmental waste as well. Limited research has been conducted on post-harvest losses during processing particularly in the study area, owing to the fact that rice processors lack resources and depend so much on traditional processing practices. The Justification of the Study therefore is that post-harvest losses of rice during processing have important implications on profitability in that it affects profit of rice processors. Ultimately, it affects the level of rice output achieved, income, welfare, Standard of living, and economic growth especially in Nigeria where most of the population cite agriculture as their main occupation. Information on analysis of post-harvest losses of rice, by smallholder rice processors would represent important contributions to existing bodies of knowledge and assist policy makers in designing policies that would reduce post-harvest losses among smallholder rice processors.

Objectives

i. Describe the socio-economic characteristics of smallholder rice processors;
ii. Estimate post-harvest losses incurred by smallholder rice processors in the study area;
iii. Analyze profitability obtained by rice processors in the study area;
iv. Determine impact of post-harvest losses on profit of rice farmers in the study area.

Study Hypothesis

H_o: There is no significant relationship between post-harvest losses of rice during rice processing and profit of rice processors

2. Methods

2.1. The Study Area

Benue State is geographically located between longitudes 8°4′E and 10°E and latitudes 6°30′N and 8°10′N. The state is known for its rich agricultural resources, with approximately 80% of its population engaged in farming and related activities [8]. It boasts favourable climatic conditions and fertile soils suitable for rearing animals and cultivating various crops such as rice, cassava, yam, maize, and vegetables. The climate features a tropical pattern with distinct wet (April–October) and dry (November–March) seasons, and annual rainfall ranging from 1,250 mm to 1,750 mm. The state's topography is largely undulating plains at elevations between 150 m and 300 m above sea level, providing suitable conditions for diverse agricultural practices. Makurdi serves as the state capital, with 23 local government areas actively involved in agriculture [9].

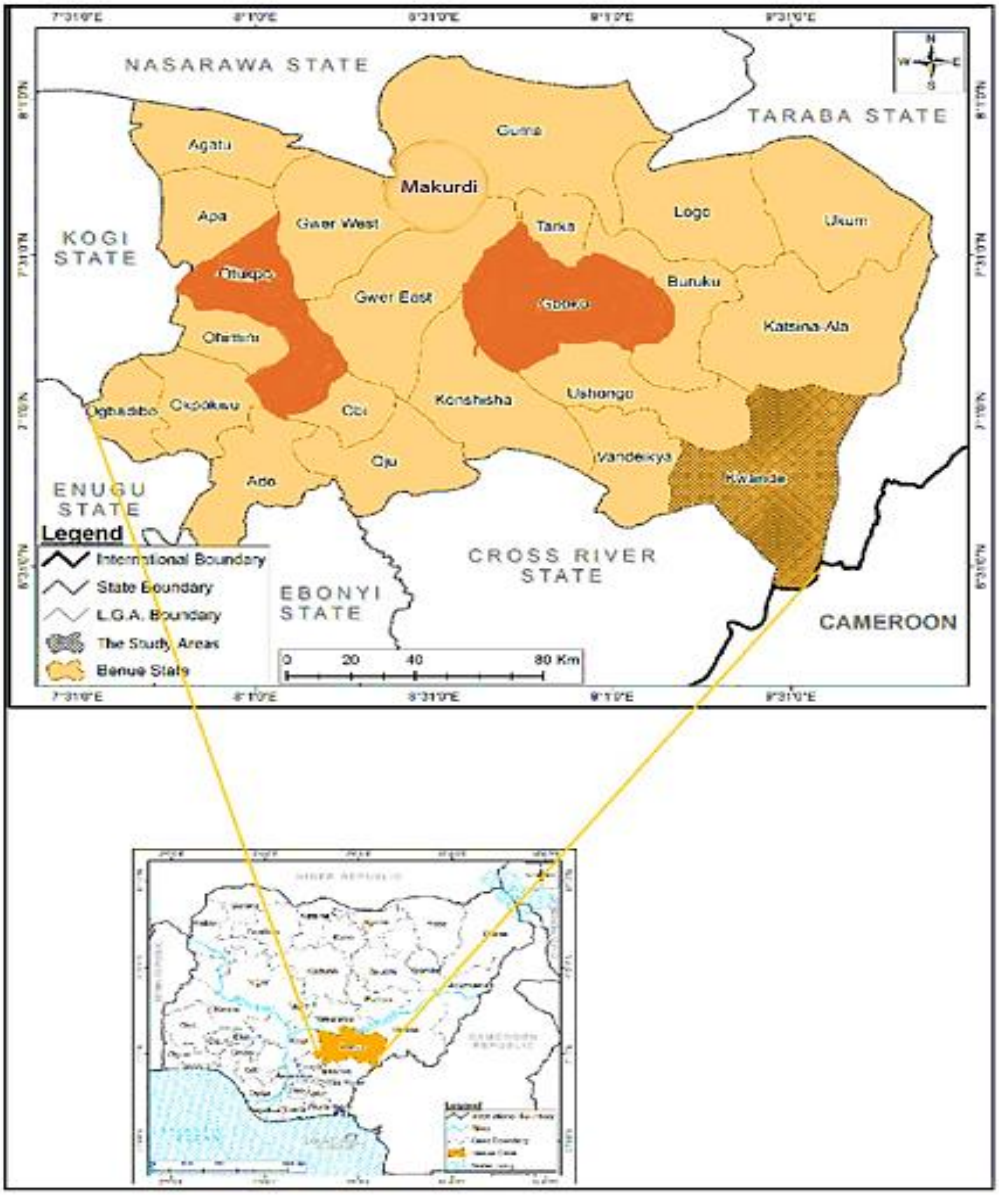

Figure 1. Map of the study area

2.2. *Population and Sampling Technique*

The target population comprised rice processors in Benue State. A multi-stage sampling approach was employed to select respondents, combining purposive, stratified, and simple random sampling techniques to ensure representativeness: First stage: Three ADP zones (Central, Eastern, and Northern) were purposively selected based on rice processing activity levels. Second stage: Within each zone, one local government areas (LGA) actively engaged in rice processing was purposively selected: Otukpo in the Central Zone, Kwande in the Eastern Zone, and Gboko in the Northern Zone. Third stage: one rice-processing communities within each selected LGA was purposively chosen based on their high rice processing activity, totalling three communities. Final stage: From each community, a simple random sampling method was used to select rice processors. A total sample size of 150 respondents was determined using Taro Yamane's formula [10], with a 5% margin of error.

2.2.1. Sample Size Selection

The sample size for this study was determined based on the 238 Rice processors obtained from the preliminary survey conducted in Benue State using Taro Yamane's formula:

$$n = \frac{N}{[1+(Ne^2)]} \quad (1)$$

n = required sample size
N = population sample
e = error limit at 5% (standard error of 0.05)
1 = constant value

Table 1. Sample selection (sampling)

BNARDA ZONES	LGAs	Communities	Sampling Frame	Sample Size (%)	Interval
Central Zone	Otukpo	Otukpo Rice mill	52	33	1.595
Eastern Zone	Kwande	Adikpo Rice Mill	79	50	1.595
Northern Zone	Gboko	Gboko Rice mill	107	67	1.595
Total			**238**	**150**	

Source: Preliminary field survey, 2024

2.2.2. Sample Size Calculation

Based on a preliminary survey conducted in 2024, the estimated population of rice processors in the selected areas was N = 238. Applying Yamane's [10] formula:

$$n = \frac{N}{I+Ne2} = \frac{238}{1+238\times(0.05)^2} = \frac{238}{1+238\times0.0024} = \frac{238}{1+0.595} = \frac{238}{1.595} = 149.5$$

Thus, a sample size of 150 respondents was used for the study.

2.3. Data Collection Methods

Primary data were collected directly from rice processors through structured questionnaires designed to capture socio-economic characteristics, processing practices, post-harvest losses, and profitability factors. The questionnaires were pre-tested in a similar context to ensure clarity and reliability. Data collection was conducted over a period of four weeks, with trained enumerators administering questionnaires face-to-face to facilitate accurate responses and clarify questions where necessary. Additional qualitative data were gathered through informal interviews and field observations to complement quantitative findings.

2.4. Data Analysis Techniques

Data analysis involved both descriptive and inferential statistical methods, supported by relevant software to ensure accuracy and robustness.

2.4.1. Descriptive Statistics

Descriptive statistics such as frequency distributions, percentages and means were used to summarize respondents' socio-economic characteristics and estimate post-harvest losses. The mean was calculated as:

$$\bar{x} = \frac{\Sigma fxi}{\Sigma fi} \quad (2)$$

where:
$\bar{x}$= mean
fi = frequency of observations in classes i
xi = value of observations in class i
Σ = summation observations

2.4.2. Gross Margin Analysis

Gross margin analysis was employed to evaluate the profitability of rice processing. According to Olukosi and Abraham [11], this model is used when the fixed cost component is negligible, the gross margin (GMr) per 100 kg bag was calculated as:

$$GMr = GIr - TVCr \quad (3)$$

where:
Gir = Gross farm income per 100 kg bag (Naira)
TVCr = Total variable cost per 100 kg bag (Naira)

This approach assumes fixed costs are negligible, which is typical in small-scale processing contexts.

2.4.3. Regression Analysis

An Ordinary Least Squares (OLS) regression model was used to identify the factors influencing profitability and their relationship with post-harvest losses. The model specification is:

$$Y=b_o+b_1X_1+b_2X_2+b_3X_3+b_4X_4+ b_5X_5+b_6X_6+b_7X_7+b_8X_{8+} \epsilon \quad (4)$$

Where:
Yi = Profit from rice processing (Naira per ton)
x_1 = Rice milling technology (categorical: 1=modern, 2=semi-modern, 3=traditional)
x_2 = Cost of labor (Naira per ton)
x_3 = Scale of operation (dummy: 1=large-scale, 0=small-scale)
x_4 = Drying method (dummy: 1=mechanical, 0=sun drying)
x_5 = Market price of processed rice (Naira)
x_6= Storage losses (kg)
x_7= Transportation/handling losses (kg)
x_8= Pests/diseases losses (kg)
b_0 = Intercept term
b_1-b_8 = Parameter estimates
ϵ = Error term

The regression was conducted using Stata 14.1 software, which facilitated robust estimation and diagnostic testing [12].

3. Results and Discussion

3.1. Socio-economic Characteristics of Respondents

3.1.1. Age of Respondents

The age distribution of respondents is presented in Table 2. The data indicates that the largest proportion (43.33%) falls within the age group of 43–50 years, followed by 31.33% in the 31–44 years bracket. A smaller percentage (14.67%) is within the 59–72 years and above. The mean age of respondents was 41 years. This suggests that active, middle-aged individuals predominantly engage in rice processing activities, likely due to their energy levels and experience. The involvement of youths in their prime age highlights the availability of an energetic workforce essential for processing activities. This result aligns with [1], who observed that rice farmers in Benue State are mainly within the middle age group capable of contributing meaningfully to processing tasks.

3.1.2. Sex of Respondents

As shown in Table 2, 63% of smallholder rice processors were male, while 37% were female. Both sexes participate actively in rice processing, with women often involved in activities such as winnowing, parboiling, and transportation [13]. In Benue State, gender roles in rice milling and post-harvest handling are well recognized, with women primarily handling parboiling and other post-harvest activities. The division of labor reflects traditional gender roles but also underscores the importance of gender-sensitive policies to promote equity and improve household food security [1].

3.1.3. Marital Status

The marital status distribution (Table 2) shows that 47.33% of respondents are married, 26.67% divorced, 16.67% single, and 9.33% widowed. The high proportion of married respondents suggests that they may have greater responsibilities, which could influence their engagement and investment in rice processing. In African societies, marriage often signifies maturity and increased responsibilities, potentially motivating farmers to invest more in agricultural activities [14]. Additionally, married farmers may benefit from family labor, thereby enhancing processing efficiency and productivity [15].

3.1.4. Scale of Rice Processed per Week

Most respondents (44.67%) processed 7–10 bags of rice weekly, followed by 26.67% processing 4–6 bags, and 16.67% processing 1–3 bags (Table 2). A small percentage (6.66%) processed 11–13 bags, and only 5.33% processed 14 or more bags weekly. This indicates that rice processing in the study area is predominantly at a subsistence or small-scale level, likely due to limited capital for modern equipment and inputs [1].

3.1.5. Educational Attainment

Education enhances managerial skills and awareness of modern processing techniques. The data shows that 36.66% of respondents attained secondary education, 25.33% had no formal education, 22% attended primary school, and 16% had tertiary education (Table 2). The average years of formal education were approximately 4 years. The high literacy level implies that most processors can read and interpret information, which is vital for adopting new technologies and reducing processing

losses. As noted by [4], access to education positively influences the adoption of improved agricultural practices.

Table 2. Socio economic characteristics of the respondents

Variable	Frequency	Percentage	Mean
Age			
17–30	16	10.67	
31–44	47	31.33	
45–58	65	43,33	37.50
59–72 and above	22	14.67	
Total	**150**	**100**	
Sex			
Male	102	68.00	
Female	48	32.00	
Total	**150**	**100**	
Marital Status			
Married	71	47.33	
Single	25	16.67	
Divorced	40	26.67	
Widow/widower	14	9.33	
Total	**150**	**100**	
Scale of rice processed /week			
<1-3 bags	25	16.67	
4-6 bags	40	26.67	
7-10 bags	67	44.67	30.00
11-13bags	10	6.66	
14 bags and above	8	5.33	
Total	**150**	**100**	
Educational Attainment			
No formal Education	38	25.33	
Primary Education	33	22.00	
Secondary Education	55	36.66	4.33
Tertiary Education	24	16.00	
Total	**150**	**100**	
Rice Processing experience			
<1-5 year	18	12.00	
6-10 years	45	30.00	
10-15years	55	36.67	10.00
16 years and above	32	21.33	
Total	**150**	**100**	

Source: Field survey, 2024

3.1.6. Processing Experience

Regarding processing experience, 36.67% had 10–15 years, 30% had 6–10 years, 21.33% had 16 or more years, and 12% had 1–5 years of experience (Table 2). The average processing experience was about 10 years, indicating a seasoned workforce with substantial expertise, which could influence the efficiency and outcomes of processing activities.

3.2. Estimates of Post-Harvest Losses during Rice Processing

Table 3 presents the estimated post-harvest losses at various processing stages. The highest losses (25.60%) were attributed to inadequate drying facilities; the high losses attributed to drying suggest a lack of modern drying equipment or infrastructure. Such as; Limited access to mechanized drying systems leading to inconsistent moisture removal, Poor weather conditions delaying or complicating sun drying and Lack of drying yards or controlled drying environments to prevent spoilage. This was followed by processing-related losses (24.44%) using traditional and modern methods. Inefficient transportation accounted for 18.12%, signifying that Insufficient training on best transport practices will lead to grain damage. Poor storage conditions contributed 19.30% while pest/rodents damages caused 12.53%. Storage Conditions and Pest Infestation, Storage-related losses could be due to, absence of modern storage facilities with pest control measures, inadequate pest management practices leading to rodent and insect infestations and storage facilities lacking proper ventilation or humidity control. The total average post-harvest loss was approximately 240.48 kg, representing all respondents' combined losses, which is significant and consistent with prior research by Dzahan and Onu [16], who reported a 19.18% loss in Benue State. These losses have profound economic implications, reducing effective output, income, and overall standards of living. The substantial post-harvest losses underscore the need for improved processing and storage techniques to enhance rice output and profitability.

Table 3. Estimates of post –harvest losses of rice at the processing stage

Variables	Losses Incurred (kg)	Mean loses (kg)	Percentage (%)
Inadequate Drying Facilities	9,234	61.56	25.60
Poor storage Conditions	6,963	46.42	19.30
Processing	8,817	58.78	24.44
Inefficient Transport	6,537	43.58	18.12
Pest/Rodents	4,521	30.14	12.53
Total	**36,072**	**240.48**	**100**

Source: Field survey, 2024

3.3. Profitability Analysis using Gross Margin

Table 4 illustrates the profitability of rice processing activities in Benue State. The total variable cost (TVC) per 100 kg of rice was ₦76,500, representing approximately 96.18% of the total cost of production (TCP). The major component of TVC was the purchase of paddy rice at ₦65,000, accounting for 81.72% of TVC. This high cost directly influences profitability as paddy prices rise, processors can produce less paddies, leading to reduced processing volumes and lower sales. Other significant variable costs included parboiling and drying (₦6,000; 7.54% of TVC), milling charges (₦3,000; 3.77%), and firewood for parboiling (₦2,500; 3.14%). Although these costs appear moderate individually, they collectively amount to 14.45% of TVC and directly impact gross margins by increasing processing expenses. Reliance on firewood, for instance, not only raises operational costs but also prolongs parboiling times, thereby affecting efficiency and increasing labor inputs. The gross income (GI) from processing one 100 kg bag of rice was ₦90,000. After deducting variable costs, the gross margin (GM) was ₦13,500, equivalent to 15% of gross income. Further

deducting fixed costs of ₦3,033 (3.82% of TCP), the net farm income (NFI) amounted to ₦10,467, representing an 11.63% profit margin. The rate of return on investment was estimated at 13.16%, indicating that rice processing remains a profitable venture in the region [17]. Compared to earlier findings by Tondo [18] which reported gross margins of ₦16,770 per 100 kg for modern processors and ₦4,143 for traditional processors in Benue State, the current gross margin of ₦13,500 suggests that processors in this study fall between traditional and modern practices. This underscores the need for technological upgrades to reach higher profitability levels. The low level of investment in fixed assets (₦3,033 per 100 kg) indicates that rice processing in Benue State remains largely informal and small scale. Most processors lack access to modern equipment, such as efficient parboilers, de-stoners, and automated milling machines, which could significantly reduce post-harvest losses and enhance output quality. Targeted investments in fixed assets facilitated through

Table 4. Gross margin analysis of rice processors in Benue State

S/No.	Items	Average Cost/Bag (₦)	% of TCP
A. Variable Costs			
	Purchase of paddy rice (100kg)	65,000	81.72
	Firewood for parboiling	2,500	3.14
	Parboiling and drying	6,000	7.54
	Milling charges	3,000	3.77
	Total Variable Cost (TVC)	**76,500**	**96.18**
B. Fixed Costs			
	Parboiling drums (rental)	1,000	1.26
	Containers	1,700	2.14
	Depreciation on equipment	333	0.42
	Total Fixed Cost (TFC)	**3,033**	**3.82**
C. Total Cost of Production (TCP)	**TVC + TFC**	**79,533**	**100**
D. Returns			
	Gross Income (GI)	90,000	—
	Gross Margin (GI – TVC)	13,500	—
	Net Farm Income (GI – TCP)	10,467	—
	Rate of Return on Investment (%)	(NFI/TCP) × 100 =	**13.16%**

Source: Field survey, 2024

Financing schemes, government subsidies, or cooperative support could modernize the sector and boost profitability. Modernizing the processing chain is especially critical given the inefficiencies in key cost areas. For instance, transitioning from

firewood to solar dryers or energy efficient stoves could reduce fuel costs, speed up parboiling, and improve product quality. Similarly, upgraded milling machines with better throughput and less grain breakage could increase yield and revenue. The net farm income of ₦10,467 per 100 kg of rice represents an 11.63% profit margin. While this appears promising, its significance is better understood when compared with findings from similar rice-producing regions. For example, studies from Ebonyi State and parts of Northern Nigeria have reported average profit margins ranging from 8% to 14% for small- to medium-scale rice processors [19]. This suggests that processors in Benue State are operating within a competitive range but still have room for improvement. Increased mechanization, improved storage, and better access to credit could further enhance profitability. Moreover, the relatively low investment in fixed assets (₦3,033 per 100 kg) points to limited capital outlay in equipment and infrastructure. This reflects either constrained access to financing or a lack of awareness about the long-term benefits of modernizing processing systems. To remain competitive and increase margins, processors may need targeted support to acquire fixed assets such as automatic parboilers, de-stoners, or packaging equipment, which can reduce costs and add value to the final product.

Overall, while current profitability is encouraging, rice processors in Benue State operate below optimal efficiency. Enhancing access to modern equipment, reducing variable costs through energy innovations, and increasing scale through cooperative models or public-private support could significantly improve returns and long-term sustainability.

3.4. Effect of Post-Harvest Losses on Profitability

The regression analysis (Table 5) employed various functional forms; the double-log model provided the best fit with an R-squared of 0.62 and an adjusted R-squared of 0.59, implying that approximately 59% of the variation in rice processors' profit is explained by the included variables. Key findings include losses incurred as a result of the use of Milling Technology which was Significant at 1%, with a negative coefficient (-1.26), indicating that traditional or semi-modern milling techniques which are prevalent in the study area increase post-harvest losses, thereby reducing profit. The use of traditional stone mills, semi-mechanized hulling machines will increase processing losses and only a small percentage use fully automated rice mills. Modern rice mills typically offer higher output throughput, lower breakage, and better quality. Training farmers on these technologies and providing access can improve yields and reduce losses. Processors adopting the use of modern, efficient milling machines through training and subsidies, which will reduce losses associated with traditional methods and therefore increase profit. Labour Cost was also Significant at 5%, with a negative coefficient (-0.39), suggesting higher labour costs decrease profitability, processors are encouraged to explore mechanization options (e.g., automated cleaning and milling equipment) to reduce reliance on manual labor, which can be costly and inconsistent. High labour costs can reduce profitability, introducing mechanized stages such as automated dehulling and polishing can save time, reduce labour costs and Increase processing capacity and consistency. Drying Facilities was also Significant at 1%, with a negative coefficient (-0.77), implying that poor drying methods increase losses and reduce profit, access to improved drying technologies such as solar dryers or mechanical dryers will minimize moisture related losses. Transportation and Handling was Significant at 10%, with a negative

coefficient (-0.11), indicating that inefficient transport reduces profitability. Losses during transportation may stem from Poor Road infrastructure causing delays and physical damage and lack of appropriate transport vehicles or containers that protect rice from pests or moisture. Scale of Operation was Significant at 1%, with a positive coefficient (0.66), suggesting larger processing scales enhance profit. Market Price was also Significant at 5%, with a positive coefficient (0.12), indicating that higher selling prices increase profit. Encourage processors to expand their scale of operation and explore better market outlets to capitalize on higher sale prices, thereby increasing profitability. Other variables such as storage losses and pest/disease damage were not statistically significant, although their signs align with economic expectations. The results confirm that post-harvest losses during rice processing, especially due to inadequate drying, traditional milling, and inefficient transportation, significantly impact the profitability of smallholder rice processors. Addressing these loss factors through technological upgrading and improved handling practices could substantially enhance income levels and overall rice output in the study area.

Table 5. Effect of post-harvest losses on profitability of rice processors in Benue State

Variable	Coefficient	t-ratio	Significance Level	Notes
Log milling technology	-1.255009	-4.66	***	Significant at 1%
Log labor cost	-0.3987973	-2.20	**	Significant at 5%
Log scale of operation	0.6554368	3.51	***	Significant at 1%
Log drying facilities	-0.7691884	-3.05	***	Significant at 1%
Log selling price	0.1229453	2.13	**	Significant at 5%
Log storage	0.0416548	0.74	NS	Not significant
Log transport	-0.1075753	-1.91	*	Significant at 10%
Log disease/pest	-0.2153408	-1.23	NS	Not significant
Constant	3.703031	11.73	***	Significant at 1%

Source: Field survey, 2024
Notes:
- *** $p < 0.01$ (highly significant)
- ** $p < 0.05$ (significant)
- * $p < 0.10$ (significant at 10%)
- NS: Not significant

4. Conclusion

This study has shown that post-harvest losses among rice processors in Benue State, Nigeria, are both significant and detrimental to the profitability and sustainability of rice processing enterprises. Major contributing factors include inadequate drying facilities, poor storage conditions, inefficient transportation systems, and frequent pest and rodent infestations. These issues collectively reduce the quality and quantity

of processed rice, thereby lowering potential earnings. The economic analysis revealed an average net farm income (NFI) of ₦10,467 per 100 kg of processed rice. However, with post-harvest losses averaging 240.48 kg per respondent, a substantial portion of potential output and revenue is lost during processing and handling. These losses translate into a notable percentage of forgone gross revenue, ultimately eroding profitability. As a result, net income and return on investment are negatively impacted, potentially discouraging processors from adopting improved technologies or expanding their operations. To address these challenges, the study recommends investment in modern drying and storage infrastructure, comprehensive training on post-harvest handling and management, improved transportation networks for better logistics, effective pest and rodent control strategies and increased funding and policy support for post-harvest initiatives. Reducing post-harvest losses is not only crucial for enhancing profitability but also for strengthening food security and promoting sustainable livelihoods among rice processors. Implementing targeted interventions based on these findings will significantly improve processing efficiency, increase income levels, and boost the contribution of rice processing to both the state and national economy.

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