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ASSESSMENT OF POST-HARVEST PROCESSING, STORAGE AND TRANSPORTATION PRACTICES AMONG SMALLHOLDER FARMERS IN BENIN CITY, NIGERIA

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ABSTRACT

Post-harvest losses reduce the quantity, quality and market value of agricultural commodities and are particularly important for smallholder food systems handling highly perishable crops. This study assessed post-harvest processing, storage and transportation practices in selected parts of Benin City, Edo State, Nigeria, and identified the principal constraints limiting improved post-harvest management. A descriptive field-survey design was used, combining a structured questionnaire administered to 67 respondents with direct observations of farms, processing centres, markets and storage facilities. The study covered Oredo, Egor and Ovia North-East Local Government Areas, with the Nigerian Institute for Oil Palm Research (NIFOR) included as an institutional case study. Descriptive statistics were used to summarize respondent characteristics and technology use, while field observations were used to document processing and storage conditions. Traditional processing was the dominant system, used by 34 respondents (50.7%), followed by semi-mechanized systems used by 22 respondents (32.8%) and modern/institutional systems used by 11 respondents (16.4%). Major practices included firewood smoking of fish, manual cassava peeling, cassava grating and pressing, fresh marketing of tomatoes, pepper, cucumber and watermelon, bag storage of groundnuts, cold storage of frozen foods, and modern palm-oil processing at NIFOR. Quantitative field evidence available in the dataset indicated approximately 3–5% transportation loss for cucumber and watermelon before market arrival, mainly associated with poor roads. Groundnut losses were associated with pest infestation, moisture and mould, while cold-storage operations were constrained by unstable electricity. The findings indicate that post-harvest losses in the study area are embedded in interacting technological, infrastructural, financial and institutional constraints. Community-based storage, solar-powered preservation, improved roads, affordable credit, extension services, improved packaging and locally fabricated equipment are recommended. The study deliberately distinguishes observed deterioration from measured loss and does not extrapolate the 3–5% transportation estimate to commodities for which respondent-level quantity data were unavailable.

Keywords: Post-harvest losses; Processing; Storage; Transportation; Smallholder farmers; Perishable crops

1.0 INTRODUCTION

Agricultural production does not by itself guarantee food availability or food-system efficiency because a proportion of harvested produce may deteriorate before it is consumed or sold. Food loss refers to a decrease in the quantity or quality of food along the supply chain before retail, and the Food and Agriculture Organization emphasizes that effective interventions require identification of the specific stages and causes of loss rather than reliance on generalized loss estimates (FAO, 2019).

Post-harvest management encompasses handling, processing, drying, storage, packaging, transportation and marketing. These operations determine the shelf life, safety, quality and

economic value of harvested commodities. The problem is especially acute for fruits, vegetables and fish because high moisture content, respiration, microbial activity and physical damage can accelerate deterioration. Recent evidence from Nigeria confirms that inadequate post-harvest technologies, poor infrastructure, limited market coordination and weak handling practices continue to constrain food-system efficiency (Barau et al., 2023; Yami et al., 2025).

Smallholder farmers often rely on traditional technologies because they require relatively low initial capital and use locally available materials. Such systems can be useful where resources are limited, but they may provide inconsistent control of moisture, temperature, hygiene, airflow and pest exposure. Research on Nigerian plantain value chains has shown that small-scale-friendly post-harvest practices can be associated with lower self-reported quantitative and qualitative losses, supporting the importance of technologies that are appropriate to the scale and resources of smallholder operators (Morris et al., 2019).

Improved technologies are available for many of the problems observed in the study area. Solar-powered evaporative cooling, for example, has been demonstrated under Nigerian conditions as a practical method for extending the storage life of fruits and vegetables where conventional electricity is unreliable (Olosunde et al., 2016). Low-cost evaporative cooling systems have similarly demonstrated potential for preserving tomatoes under ambient tropical conditions (Ndukwu, 2011). For stored grains, recent Nigerian research emphasizes the importance of moisture control, ventilation, pest exclusion and improved structural integrity, with hermetic systems offering an important option for reducing storage deterioration (Okparavero et al., 2024).

Packaging and transportation are also critical. A recent study of Nigerian tomato producers found that adoption of reusable plastic crates remains limited by cost and availability even though improved packaging can reduce physical damage during transport and facilitate access to higher-value markets (Yami et al., 2025). Similarly, a recent Nigerian study reported that transportation mode and farm-to-market distance significantly influence tomato post-harvest losses and recommended improved roads and transportation systems (Arua et al., 2025). The study aimed to assess post-harvest processing, storage and transportation practices among agricultural stakeholders in selected areas of Benin City, Nigeria.

2. Materials and Methods

2.1 Study Area

The research was conducted within selected Local Government Areas of Benin City, Edo State, Nigeria (Figure 1). Benin City lies within the humid tropical rainforest ecological zone characterized by relatively high annual rainfall, high humidity, and temperatures suitable for year-round agricultural production. The area is recognized for the cultivation and marketing of cassava, maize, vegetables, yam, plantain, palm produce, fruits, and fisheries products.



Figure 1: Map of Nigeria and Benin City, Edo State, Nigeria, showing key agricultural zones – Source: Google Maps, 2024. Benin City, Edo State, Nigeria – Agricultural zones. Retrieved from http://www.google.com/maps

2.2 Research Design

A descriptive field-survey design was adopted. The approach combined structured questionnaires, direct observation, informal interviews and photographic documentation. This design was retained because the available dataset was primarily descriptive and because the research objective was to assess existing practices and constraints rather than to establish causal effects using an experimental design.

2.3 Sample and Respondents

A total of 67 respondents participated in the survey. Respondents comprised smallholder farmers, processors, produce marketers, storage-facility operators and other stakeholders involved in post-harvest activities. Questionnaire administration covered communities and markets including Efehi, Okhuoromi, Uselu Market, Adolor and Eguavoen, together with other locations within the three LGAs. NIFOR was assessed separately as an institutional case study.

2.4 Research Instrument

A structured questionnaire was used as the principal quantitative instrument. It contained two main parts: Part I, Processing Systems; and Part II, Storage Systems. Each part contained three sections: Section A, background information; Section B, processing/storage practices; and Section C, challenges faced. Both closed-ended and open-ended questions were used. The instrument collected information on age, sex, education, household size, location, commodity handled, processing method, storage facility, technology level and major constraints.

2.5 Field Observation

Field observations were conducted at processing centres, farms, local markets, storage facilities and institutional processing units. Observations focused on equipment type and condition, storage

structures, product handling, hygiene, energy sources, road conditions and evidence of deterioration. Photographs were taken to document representative facilities and practices.

2.6 Data Analysis

Data were coded and summarized using frequencies and percentages. The percentage of respondents in each category was calculated as P = (f/N) × 100, where f is the observed frequency and N is the total number of respondents. Field observations were thematically summarized by commodity and loss stage.

Where an empirical loss estimate was available, the loss percentage was reported directly from the field data. The general physical-loss expression is:

$$Post - harvest\ loss\ (\%) = \left[{}^{(Q_s - Q_m)}/_{Q_s} \times 100\right] \quad 1$$

Where:
Q_s is quantity supplied and
Q_m is quantity successfully marketed or otherwise retained for use.

2.7 Quality and Evidence Triangulation

Questionnaire responses were compared with direct observations and photographic evidence. This triangulation was used to distinguish reported practices from directly observed facilities and to identify where quantitative evidence was available. In particular, the reported 3–5% transportation loss for cucumber and watermelon is treated as a field-survey estimate and is not generalized to all commodities.

3. Results and Discussion

3.1 Socioeconomic Characteristics

The socioeconomic characteristics of the respondents provide important insights into the human resources available for post-harvest processing and storage activities among smallholder farmers in Benin City. Socioeconomic characteristics are presented in Tables 1 to 4 and as well in Figures 2 to 5. Respondents aged 25–35 years formed the largest group (37.3%), followed by those aged 36–45 years (29.9%) (Table 1 and Figure 2. The age profile indicates substantial participation of economically active adults in processing and marketing activities. The result also highlights the importance of designing technology-transfer and enterprise-support programmes that can be accessed by younger operators. SSCE holders constituted the largest educational group (29.9%), while 26.8% had B.Sc./HND qualifications (Table 2 and Figure 3). Respondents without formal education represented 14.9%. The distribution suggests that extension and technology-adoption programmes should use practical demonstrations and locally understandable training materials in addition to written information. Male respondents constituted 59.7% and females 40.3% Table. Field observations indicated strong female participation in fish smoking, tomato vending and other small-scale preservation activities, while men were more represented in mechanized operations.

The relatively substantial participation of women supports the need for gender-responsive financing, training and shared equipment programmes.

Table 1: Age distribution of respondents

Age group (years)	Frequency	Percentage (%)
25–35	25	37.3
36–45	20	29.9
46–50	15	22.4
>50	7	10.4
Total	67	100.0

(Source: Field Survey)

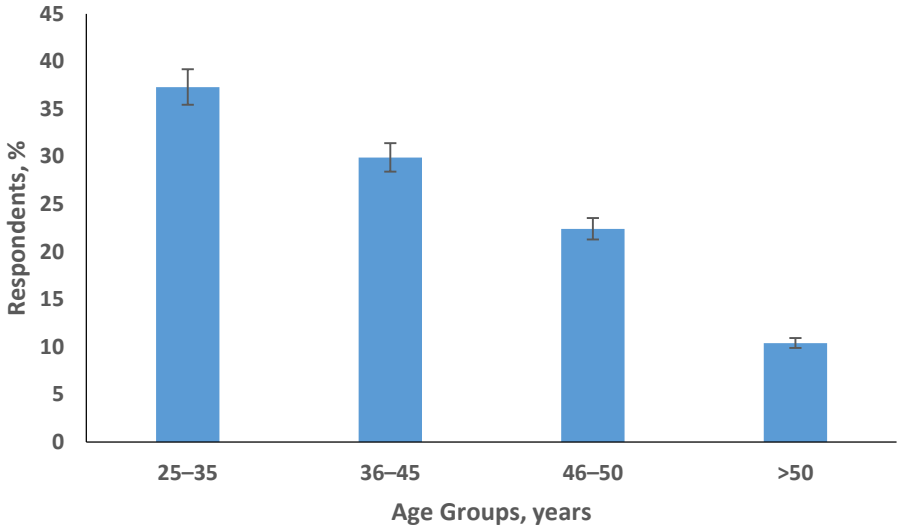


Figure 2: Age distribution of respondents

Table 2: Educational qualification of respondents

Educational qualification	Frequency	Percentage (%)
No formal education	10	14.9
JSSCE	12	17.9
SSCE	20	29.9
B.Sc./HND	18	26.8
OND	4	6.0
NCE	3	4.5
Total	67	100.0

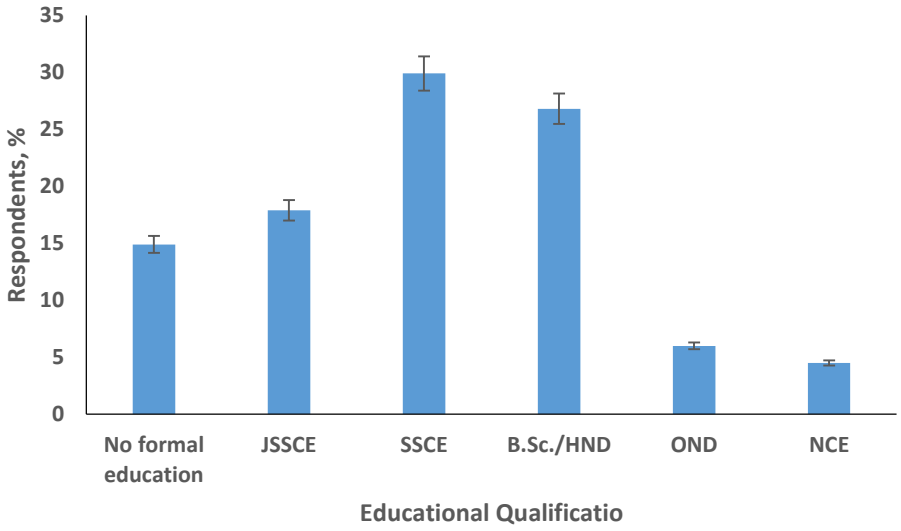


Figure 3: Age distribution of respondents

Table 3: Household-size distribution of respondents

Household size	Frequency	Percentage (%)
1–2	8	11.9
3–5	42	62.7
>5	17	25.4
Total	67	100.0

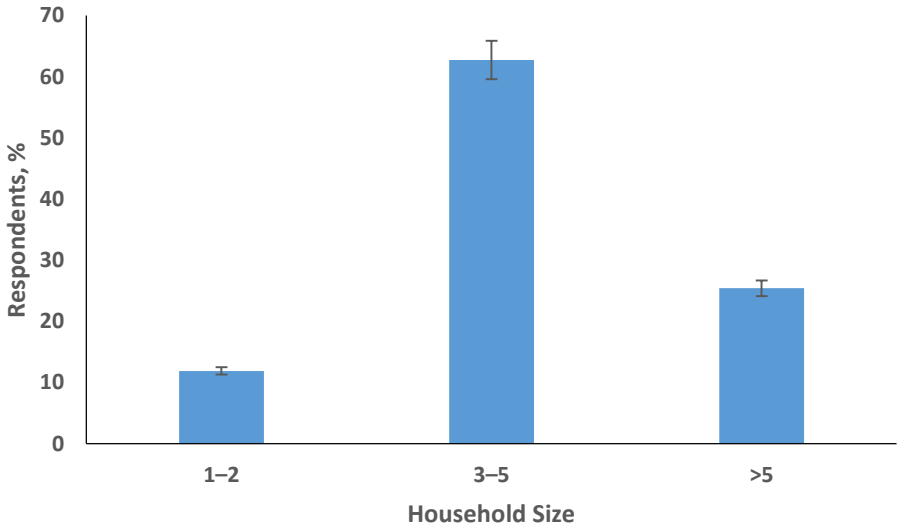


Figure 4: Household Size of respondents

Table 4: Gender distribution of respondents

Gender	Frequency	Percentage (%)
Male	40	59.7
Female	27	40.3
Total	67	100.0

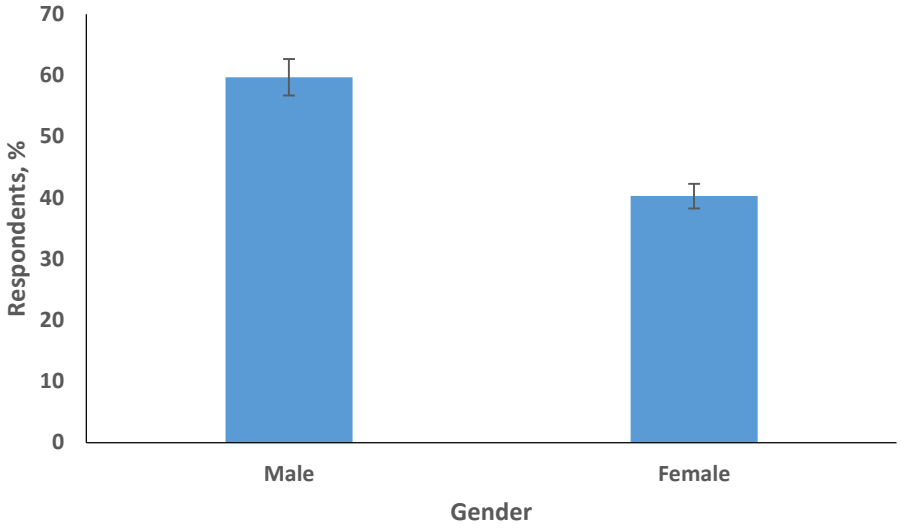


Figure 5: Gender distribution of respondents

3.2 Processing Infrastructure

The field survey identified three principal categories of processing infrastructure, namely traditional processing systems, semi-mechanized facilities and institutional mechanized processing units (Table 5 and Figure 6) also shown in Plate 1, 2 and 3, respectively. Traditional processing was dominant, accounting for 34 respondents (50.7%). Semi-mechanized processing was reported by 22 respondents (32.8%), while 11 respondents (16.4%) were associated with modern or institutional-scale systems. This pattern is central to the revised interpretation of the study: technology adoption is present, but access is uneven and modern systems remain concentrated in better-resourced facilities. Traditional practices observed included firewood smoking of fish, manual cassava peeling, fresh marketing of tomatoes and pepper, shade preservation and water sprinkling, and drying/storage of groundnuts. These methods require relatively little capital but provide limited control over contamination, temperature, humidity and product uniformity. This finding is consistent with Nigerian evidence that small-scale operators often require post-harvest technologies designed around their financial and operational realities (Morris et al., 2019). Semi-mechanized cassava processing represented an intermediate technology level. Locally fabricated graters, hydraulic presses and roasting equipment reduced labour and improved throughput compared with completely manual operations, but maintenance, capital availability and power supply remained constraints. Fish processing relied mainly on firewood-powered smoking kilns. Smoking is effective for reducing moisture and extending shelf life, but traditional kilns may produce uneven heating and expose workers to smoke. A 2024 review of fish post-harvest losses in sub-Saharan Africa identifies poor handling, lack of storage and transportation infrastructure, and inadequate preservation as important loss drivers (Abelti et al., 2024).

Table 5: Distribution of respondents by processing technology. *Percentages sum to 99.9 because of rounding

Processing technology	Frequency	Percentage (%)
Traditional	34	51
Semi-mechanized	22	33
Modern/institutional	11	16
Total	67	100

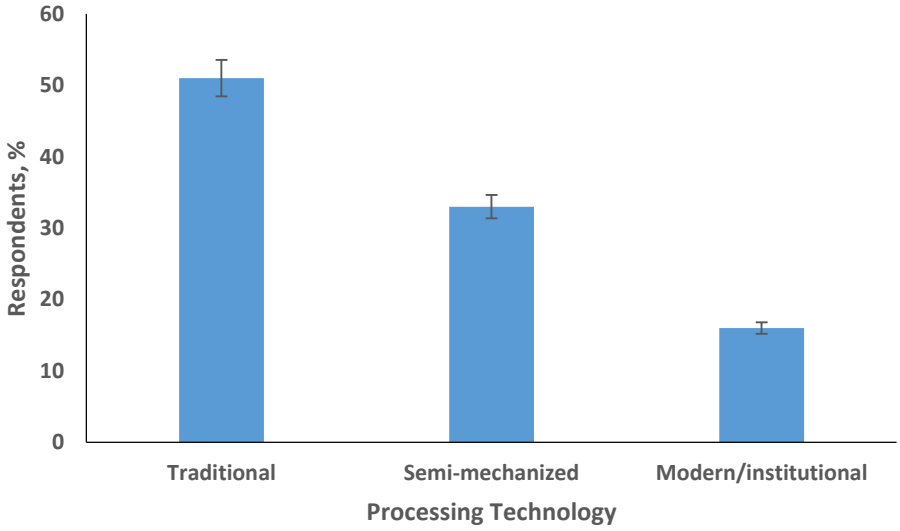


Figure 6: Distribution of respondents by processing technology



Plate 1: Locally fabricated cassava processing/grating equipment observed during the field survey



Plate 2: Grated cassava mash packed in a woven sack for dewatering during garri processing (Source: Field Survey)



Plate 3: Smoked fish arranged on racks during traditional fish processing (Source: Field survey)

3.3 Major Agricultural Products Processed

The survey revealed that cassava, palm fruits, fish, vegetables, fruits and groundnuts constituted the principal agricultural commodities processed within the study area (Tables 6 and 7). These commodities represent major components of the agricultural economy of Benin City and serve both household consumption and commercial markets. Cassava processing into garri was the most dominant post-harvest activity because of the crop's high production volume, widespread consumer acceptance and relatively short shelf life in its fresh state. Conversion of fresh cassava into garri substantially extends storage life while increasing market value and reducing post-harvest losses. Similarly, processing palm fruits into palm oil and fish into smoked products

represents important value-addition strategies that improve product preservation and profitability. However, vegetables and fruits were largely marketed fresh with minimal processing, exposing them to rapid deterioration and significant quantitative and qualitative losses. These observations agree with reports that inadequate processing infrastructure remains a major contributor to post-harvest losses in developing countries (FAO, 2019).

Table 6: Major processed agricultural commodities

Raw Material	Final Product
Cassava	Garri
Palm fruits	Palm oil
Fish	Smoked fish
Groundnut	Dried kernels
Vegetables	Fresh market vegetables
Fruits	Fresh fruits

(Source: Field Survey)

3.3 Commodities and End Products

Table 7 shows major commodities and corresponding processing/marketing forms. Cassava and fish were important processed commodities, while many vegetables and fruits were marketed fresh. Fresh marketing reduces opportunities for value addition and exposes produce to rapid deterioration when storage and transport conditions are poor. This pattern is consistent with recent evidence from Nigeria showing that improved post-harvest technologies are particularly important for horticultural commodities (Yami et al., 2025).

Table 7: Major commodities and corresponding processing/marketing forms

Raw material/commodity	Major processing or marketing form
Cassava	Garri
Fresh fish	Smoked fish
Groundnut	Dried kernels
Palm fruits	Palm oil
Frozen foods	Frozen/preserved products
Vegetables	Fresh or dried vegetables
Tomatoes and pepper	Fresh produce
Cucumber and watermelon	Fresh market sale



Plate 4: Tomatoes and other vegetables displayed in an open market environment. (Source: Field survey)

3.4 Processing Facilities

The technological gradient was clear. Smallholder operations relied largely on simple tools and locally fabricated machines, whereas NIFOR had industrial processing equipment (Table 8). The NIFOR case demonstrates that advanced processing is technically feasible within the study environment, but it also illustrates the accessibility gap between institutional facilities and smallholder enterprises (Plates 5 and 6). Traditional storage remained dominant among smallholders. Groundnuts stored in bags were vulnerable to pest infestation and fungal growth, especially under humid conditions. Recent review evidence from Nigeria similarly emphasizes the importance of moisture control, ventilation, pest management and structural integrity in storage design (Okparavero et al., 2024).

Table 8: Processing facilities identified during the field survey

Commodity/product	Facility/equipment observed	Technology category
Cassava	Grater, hydraulic press, roasting equipment	Semi-mechanized
Fish	Firewood smoking kiln	Traditional
Vegetables	Solar dryer	Modern
Tomato/pepper	Shade preservation and water sprinkling	Traditional
Palm fruits	Sterilizer, clarifier, digester screw press, bunch stripper	Modern/institutional



Plate 5: Modern palm-oil processing equipment observed at NIFOR. (Source: Field survey)



Plate 6: Freshly processed palm oil during cooling and packaging at the institutional facility (Source: Field survey)

3.5 Storage Facilities and Practices and Quantitative Evidence of Post-Harvest Loss

Table 9 shows storage facilities and practices identified in the study area, also in plate 8. Table 10 shows quantity of post-harvest loss. The strongest commodity-specific quantitative evidence available in the field dataset was the reported approximately 3 - 5% transportation loss for cucumber and watermelon before reaching markets. The study attributed this loss principally to poor roads (Plate 9). The estimate should be interpreted as a reported field-survey value for the observed supply chains and should not be generalized to all produce. For tomatoes and pepper, field observations documented spoilage and daily removal of deteriorated items, but the dataset did not contain complete quantities supplied, sold and discarded that would support a defensible percentage estimate. The same limitation applies to groundnut storage losses (Plate 7). This distinction is important because loss magnitude requires a defined measurement basis. Recent work on post-harvest loss reporting also emphasizes the need for consistent measurement and clear denominators when comparing loss estimates across supply-chain stages (Fukah et al., 2026). The transportation finding is consistent with broader evidence from Nigeria. Yami et al. (2025) reported that packaging innovation can improve tomato handling and that adoption remains constrained by cost and availability. Arua et al. (2025) similarly found transportation mode and farm-to-market distance to be important determinants of tomato post-harvest losses. These studies reinforce the interpretation that infrastructure and handling are key points of intervention.

Table 9: Storage facilities and practices identified in the study area

Commodity	Storage practice/facility	Main risk or advantage
Groundnut	Polypropylene bags/raised platforms	Weevils, moisture and moulds
Watermelon/cucumber	Ventilated storage and padded handling	Physical damage and heat exposure

Frozen foods	Cold room	Good temperature control but power dependent
Grains	Silo	Improved pest and moisture protection
Palm oil	Storage tanks	Improved product protection
Vegetables/fruits	Ambient/shade storage	Short shelf life



Plate 7: Groundnuts undergoing drying before storage. (Source: Field survey)



Plate 8: Modern silo facility observed during fieldwork for large-scale grain storage. (Source: Field survey)



Plate 9: Poor rural road conditions affecting movement of agricultural produce. (Source: Field survey)

Table 10. Quantitative and qualitative evidence of post-harvest losses

Commodity	Loss stage	Reported loss	Principal cause	Evidence status
Cucumber	Transportation	Approximately 3–5%	Poor rural roads	Field-survey estimate
Watermelon	Transportation	Approximately 3–5%	Poor rural roads	Field-survey estimate
Tomato	Market/handling	Not quantified in dataset	Rapid deterioration and inadequate storage	Observed/reported
Pepper	Market/handling	Not quantified in dataset	Rapid deterioration and inadequate storage	Observed/reported
Groundnut	Storage	Not quantified in dataset	Weevils, moisture and mould	Observed/reported
Frozen foods	Storage	Not quantified in dataset	Unstable electricity	Observed/reported

3.7 Processing and Storage Constraints

Unreliable electricity was identified as a system-wide constraint (Table 11). It affected small-scale processors and also modern facilities that required refrigeration or mechanized equipment. Dependence on generators increases operating costs and may undermine the economic viability of cold storage. Solar-powered and evaporative cooling systems are therefore particularly relevant where grid reliability is poor (Plate 10). Olosunde et al. (2016) demonstrated that a solar-powered evaporative cooling system could extend the shelf life of several fruits and vegetables substantially beyond ambient storage. Financial constraints were also central. High equipment acquisition costs, limited credit and inadequate institutional support restricted access to improved processing and storage systems. This is consistent with recent Nigerian evidence showing that post-harvest technology adoption can be limited by cost, availability and weak incentives (Yami et al., 2025).

Table 11: Major constraints affecting post-harvest management

Constraint	Observed effect	Main stage affected
Unreliable electricity	Downtime; generator dependence; cold-chain interruption	Processing and storage
High equipment cost	Low mechanization and limited access	Processing/storage
Poor rural roads	Transit delays and physical damage	Transportation
Limited access to credit	Low investment capacity	All stages
Limited technical skills	Poor operation and maintenance	Processing/storage
Pest infestation	Quantity and quality deterioration	Storage
High humidity/moisture	Mould and deterioration	Storage
High firewood/fuel cost	Higher operating cost	Fish/cassava processing
Limited solar-dryer access	Continued reliance on traditional drying	Processing/storage



Plate 10: Solar drying structure observed during fieldwork, illustrating a renewable-energy option for post-harvest preservation. (Source: Field survey)

3.8 Variation across the Study Locations

Oredo displayed relatively greater access to commercial cold storage and fish-smoking activities, although electricity and fuel costs remained important constraints. Egor was characterized by market-based handling of tomatoes, pepper and groundnut using shade, water sprinkling and bag storage. Ovia North-East represented a stronger production and cassava-processing environment where semi-mechanized equipment was used but finance, road access and processing space limited expansion. NIFOR represented the institutional end of the technology spectrum, with modern palm-oil processing and storage equipment.

The observed urban-rural gradient indicates that post-harvest interventions should not be identical across locations. Urban markets may require cold-chain and packaging improvements, while rural production areas may benefit more from feeder roads, shared processing centres, solar drying and equipment-rental schemes. FAO (2024) similarly emphasizes integrated post-harvest management, capacity development, partnerships, entrepreneurship and climate adaptation rather than isolated technology deployment.

4. Conclusion

The study established that post-harvest management in selected areas of Benin City remains predominantly traditional, with 50.7% of surveyed respondents using traditional processing, 32.8% using semi-mechanized systems and 16.4% associated with modern/institutional systems. The results confirm a clear technology-access gap between smallholder enterprises and institutional facilities such as NIFOR. Loss risks were identified across processing, storage, transportation and market handling. The only commodity-specific quantitative transportation estimate available in the dataset was approximately 3–5% for cucumber and watermelon before market arrival. Other commodities showed evidence of deterioration, but complete quantity-based records were unavailable; therefore, the study does not extrapolate or fabricate additional percentages. The major constraints were unreliable electricity, poor rural roads, high equipment and fuel costs, limited access to credit, insufficient technical capacity, pest and moisture damage, and limited access to modern storage and drying systems. These constraints are interconnected and require coordinated interventions rather than isolated technology projects.

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