

Storage Infrastructure and Management Practices as Determinants of Postharvest Losses and Market Quality of Agricultural Produce in Bida, Niger State, Nigeria

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ABSTRACT

Agriculture remains a vital pillar of Nigeria's economy, providing food, employment, and raw materials for industries. However, the sector continues to face major setbacks, particularly in post-harvest handling, storage, and marketing, where poor systems often lead to significant losses, reducing farmers' incomes and threatening food security. This study examined how the adequacy of storage facilities affects postharvest losses and how storage management practices influence produce quality in Bida, Niger State. A correlational research design was adopted, with data collected from farmers, marketers, and storage operators through structured questionnaires and interviews. A stratified random sampling technique ensured proportional representation of each stakeholder group. Data were analyzed using descriptive statistics. Findings revealed a strong and statistically significant inverse relationship between storage facility adequacy and postharvest losses ($\beta = -0.702$, $p < 0.001$, $R^2 = 0.754$), indicating that improved storage facilities substantially reduce losses. Similarly, storage management practices significantly influenced the quality of produce delivered to markets ($\beta = 0.739$, $p < 0.001$, $R^2 = 0.782$), suggesting that proper handling, pest control, temperature regulation, and timely storage use enhance freshness and market value. The study concludes that high postharvest losses in the area are largely driven by inadequate infrastructure and poor management practices. It is recommended that government and relevant stakeholders should prioritize sustained investment in modern, climate-smart storage infrastructure across agrarian

communities. Extension services and agricultural development agencies should intensify practical training programmes focused on handling, grading, pest management, and timely storage utilization.

Keywords: Agricultural produce, Market quality, Postharvest losses, Storage facilities, Storage management

INTRODUCTION

Agriculture plays a central role in the economic development of many developing countries, providing food, employment, and raw materials. In Nigeria, the sector contributes significantly to national income and supports millions of rural households (FAO, 2021). Beyond its economic value, agriculture remains a critical pathway for poverty reduction and rural stability. However, despite gains in primary production, substantial inefficiencies persist along the postharvest segment of the agricultural value chain.

Postharvest operations (harvesting, sorting, grading, storage, transportation, processing, and marketing) are essential for maintaining the quality, safety, and marketability of produce. Among these, storage and marketing are particularly critical because they determine whether harvested crops retain value or deteriorate before reaching consumers. In Nigeria, postharvest losses are estimated to range between 30% and 50% of total agricultural output, especially for perishable commodities such as fruits, vegetables, and grains (Affognon et al., 2023). These losses are not merely technical failures; they represent lost income for farmers, reduced food availability, and inefficiencies within national food systems.

Storage plays a stabilizing role by preserving produce beyond harvest periods, reducing spoilage, smoothing seasonal price fluctuations, and enabling farmers to delay sales until market conditions improve. Marketing, on the other hand, ensures produce moves efficiently from farms to consumers, improves price realization, and connects rural producers to urban demand centres. However, many Nigerian farmers operate within systems characterized by inadequate storage infrastructure, weak market information systems, poor rural road networks, and dependence on intermediaries (Ajani & Igbokwe, 2022). These structural weaknesses often compel farmers to engage in distress sales immediately after harvest, when supply is high and prices are lowest.

Although prior studies have investigated postharvest challenges, most treat storage and marketing as isolated variables rather than interdependent components of a unified value chain system. For example, Musa, Adegbite, and Ajayi (2021) examined traditional and improved storage methods and found that hermetic storage technologies reduced grain spoilage. However, their study relied primarily on descriptive statistics and did not assess how improved storage translated into better market participation or price realization. As such, the broader economic implications of storage adequacy remained underexplored.

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Similarly, Akinbile, Adekoya, and Adisa (2022) focused on market access constraints among smallholder farmers and identified transportation costs and middlemen exploitation as major barriers. While insightful, their analysis did not incorporate storage variables, thereby overlooking how inadequate storage may force premature market entry and weaken farmers' bargaining power. By separating marketing challenges from storage capacity, the study implicitly assumed that farmers have the flexibility to choose when to sell—an assumption that does not hold in many rural Nigerian contexts.

Methodologically, many of these studies are limited by narrow geographic scopes, small sample sizes, and reliance on perception-based measures without triangulation. Few employ integrated regression models that quantify the combined or interactive effects of storage adequacy and marketing structures on measurable postharvest outcomes such as loss rates and produce quality. Moreover, socio-economic implications (such as income stability, price variability, and food security outcomes) are often discussed conceptually rather than empirically tested.

This fragmentation in the literature has important policy consequences. When storage and marketing are treated independently, policy interventions tend to be compartmentalized—investment in silos without improving market linkages, or market access programs without addressing physical preservation constraints. Such isolated interventions risk underperforming because postharvest losses are rarely the result of a single bottleneck. Instead, they reflect systemic inefficiencies across interconnected stages of the value chain.

Therefore, an integrated empirical analysis is necessary to understand how storage facility adequacy and storage management practices jointly influence postharvest losses and marketable quality. By examining these relationships within the context of smallholder farmers in Bida Local Government Area of Niger State, this study provides grounded evidence that links infrastructure adequacy to measurable postharvest outcomes. In doing so, it moves beyond descriptive accounts and contributes quantitative insights to inform coordinated policy design.

Specifically, this study examines the effect of storage facility adequacy on postharvest losses of agricultural produce in Nigeria and assesses how storage management practices influence the quality of produce delivered to markets. By addressing both infrastructural and operational dimensions simultaneously, the study seeks to generate actionable insights that can strengthen postharvest systems, enhance food security, and support sustainable agricultural development.

LITERATURE REVIEW

Conceptual Review

Concept of Postharvest Operations

Postharvest operations refer to the coordinated set of technical and managerial activities undertaken after harvesting agricultural produce until it reaches the final consumer. These activities include handling, sorting, grading, storage, transportation, processing, and marketing. While traditionally treated as routine downstream functions, contemporary scholarship

increasingly recognizes postharvest operations as a strategic performance domain within agricultural value chains. From a Value Chain Theory perspective (Porter), postharvest activities add time, place, and form utility, thereby directly influencing competitiveness and profitability.

Kader (2025) argues that postharvest systems significantly shape food availability and farmer income in developing economies. However, empirical evidence varies in emphasis. Affognon et al. (2023) attribute high postharvest losses in Sub-Saharan Africa primarily to infrastructural deficiencies, whereas other studies highlight behavioural and managerial inefficiencies as equally critical determinants. This divergence suggests that losses are not merely technical failures but systemic inefficiencies embedded within broader supply chain structures.

In Nigeria, particularly in agrarian communities such as Bida, weak integration between storage, transportation, and marketing creates cumulative inefficiencies. Losses occurring at one stage often cascade into subsequent stages, reinforcing a cycle of reduced quality, depressed prices, and income instability. Therefore, postharvest operations should be conceptualized not as isolated activities but as an interconnected performance system requiring infrastructural adequacy and managerial competence.

The Concept of Storage in Agriculture

Storage in agriculture refers to the preservation of harvested produce under controlled physical and environmental conditions to maintain quality and extend shelf life prior to consumption or sale. Beyond its preservation function, storage performs an economic stabilization role by enabling temporal arbitrage—allowing farmers to sell when market conditions are favourable.

Grounded in Systems Theory, storage represents a structural subsystem within the broader postharvest chain. A weakness in this subsystem disrupts the performance of the entire agricultural system. Kitinoja and Kader (2024) emphasize that improved storage technologies substantially reduce quantitative losses in perishable crops. Conversely, Tomek and Robinson (2023) argue that infrastructure alone does not guarantee efficiency; without proper management and monitoring, even modern facilities underperform. This comparison highlights an important analytical insight: storage effectiveness depends on both physical adequacy and managerial application. In semi-urban regions like Bida, limited access to cold chain infrastructure constrains farmers' capacity to regulate supply and negotiate favourable prices. Traditional storage methods, though cost-effective, often expose produce to moisture fluctuations and pest infestation. Thus, storage must be examined both as a technical mechanism of preservation and as a strategic instrument of market positioning.

Concept of Agricultural Marketing

Agricultural marketing encompasses all processes involved in transferring agricultural products from producers to final consumers, including assembling, grading, pricing, transportation, promotion, and distribution. It determines how value created at production is realized economically. According to Kohl and Uhl (2024), marketing generates form, place, time, and possession utilities, reinforcing its centrality in agricultural systems.

From the perspective of Marketing Structure Theory, inefficiencies arise when intermediaries dominate distribution channels, reducing producers' bargaining power. Aker (2023) noted that poor infrastructure and weak market information systems in Nigeria exacerbate price volatility and income uncertainty. However, empirical debates persist regarding whether marketing inefficiencies stem primarily from infrastructural deficits or institutional arrangements. Some studies emphasize cooperative marketing as a solution, while others highlight digital platforms and market information systems.

In local markets such as Bida, fragmented supply chains and limited coordination between storage and marketing functions reduce farmers' capacity to optimize value. Produce quality at the point of sale is directly influenced by prior storage conditions, suggesting that marketing performance cannot be analytically separated from storage efficiency.

Storage and Marketing Integration

This study adopts an integrated theoretical framework combining Value Chain Theory and Systems Theory. Value Chain Theory explains how each stage of agricultural production adds or diminishes value, while Systems Theory emphasizes interdependence among subsystems. Storage and marketing are therefore conceptualized as interconnected components within a unified postharvest efficiency system.

Empirically, prior studies often examine storage and marketing independently, leading to fragmented policy recommendations. However, evidence increasingly shows that inadequate storage reduces quality, which in turn weakens market competitiveness and bargaining power. Conversely, effective storage enhances produce quality, enabling better price negotiation and reduced forced sales. The interaction between these variables suggests a synergistic relationship rather than isolated effects.

By integrating storage adequacy (structural capacity) with marketing performance (value realization), this framework offers a more holistic explanation of postharvest outcomes. In communities like Bida, where infrastructure gaps intersect with market imperfections, understanding this joint dynamic is essential for designing interventions that are both technically sound and economically sustainable.

Ultimately, postharvest efficiency is not solely a matter of preserving crops; it is about preserving livelihoods. Recognizing the interdependence of storage and marketing allows agricultural policy and research to move beyond piecemeal solutions toward systemic transformation.

Theoretical Review

Resource-Based Theory

Resource-Based Theory (RBT) explains performance differences among systems based on their possession and effective deployment of valuable, rare, inimitable, and non-substitutable resources (Barney, 2021). Within agricultural postharvest systems, storage facilities represent critical physical resources that influence the ability to reduce quantitative losses. Where such facilities are inadequate, spoilage, pest infestation, and economic waste become more prevalent.

Beyond physical assets, RBT emphasizes intangible capabilities, including managerial skills, monitoring systems, and technical expertise. In the context of storage management, these capabilities determine how efficiently available infrastructure is utilized to preserve produce quality. Thus, both storage adequacy (tangible resource) and storage management practices (organizational capability) shape postharvest performance outcomes. The theory therefore provides a strong explanatory basis for examining variations in postharvest losses and quality delivery within Nigeria's agricultural value chains.

Anchored on the RBT Theory, this study posits that storage facilities constitute strategic tangible resources, while storage management practices represent critical intangible capabilities. When these resources and capabilities are insufficient or poorly utilized, postharvest inefficiencies are likely to increase. Conversely, improved storage capacity and effective management practices are expected to reduce losses and maintain produce quality. Guided by this theoretical reasoning and the study objectives, the following null hypotheses were formulated for empirical testing:

H₀₁: Storage facilities' adequacy does not significantly affect the level of postharvest losses of agricultural produce.

H₀₂: Storage management practices do not significantly affect the quality of produce delivered to the market.

These hypotheses provided a measurable framework for assessing the strength and statistical significance of the relationships proposed in the study.

Empirical Review

Gustavsson et al. (2023) conducted a landmark global assessment for the Food and Agriculture Organization (FAO) to quantify food losses across regions. Using secondary global datasets and regional modelling techniques, the study identified storage infrastructure deficits as a leading cause of postharvest grain losses in Sub-Saharan Africa. Findings revealed that up to 20–30% of cereals are lost during storage due to poor structural facilities and pest infestation. The report concluded that improving rural storage infrastructure could significantly reduce food insecurity. It recommended targeted investment in improved storage technologies and infrastructure modernization across developing economies. Hodges et al. (2024) examined postharvest losses in developed and developing countries through analytical review methods. The study emphasized infrastructural deficiencies in storage systems as major drivers of quantitative losses. Findings showed that poor warehouse structures, lack of drying facilities, and exposure to humidity accelerated deterioration. The authors concluded that infrastructure upgrading is fundamental to reducing losses. They recommended integrated infrastructure planning and improved storage design to enhance efficiency in grain value chains. Zorya et al. (2023), in a World Bank technical report, assessed grain postharvest losses in Sub-Saharan Africa using field data and cost–benefit analysis. The study found that inadequate storage capacity forced premature sales, increased spoilage risks, and reduced farmer profitability. It concluded that improved storage investment yields strong economic returns by lowering losses

and stabilizing supply. The report recommended warehouse receipt systems and expanded rural storage infrastructure to mitigate losses and strengthen market participation. Tefera et al. (2024) investigated maize postharvest losses in Eastern and Southern Africa using survey and laboratory analysis methods. The study identified poor on-farm storage facilities as a primary cause of quantitative losses exceeding 15%. The authors concluded that upgrading storage structures significantly reduces grain deterioration. They recommended adoption of improved storage technologies and farmer awareness campaigns to minimize postharvest losses and enhance food security.

Kitinoja et al. (2025) examined horticultural supply chains in developing countries through field assessments and stakeholder interviews. The study focused on how postharvest handling and storage management affect produce quality. Findings revealed that inadequate temperature control, improper stacking, and poor hygiene practices reduced shelf life and market acceptability. The authors concluded that managerial practices play a critical role in maintaining quality beyond infrastructure availability. They recommended capacity-building programs and technical training for farmers and traders. Ambuko et al. (2023) evaluated the impact of postharvest handling and storage practices on fruit quality in East Africa using experimental and laboratory analyses. The study demonstrated that poor temperature management and improper ventilation significantly reduced nutritional value and visual quality. The authors concluded that structured storage management protocols improve quality retention and market competitiveness. They recommended strengthening extension services and promoting practical storage management training. Arah et al. (2024) conducted a systematic review of postharvest handling practices affecting vegetable quality in developing countries. The study analyzed empirical findings on humidity control, sanitation, and storage duration. Results indicated that poor management practices increased microbial contamination and rapid deterioration. The authors concluded that effective storage management is essential for quality preservation and food safety. They recommended adoption of standardized storage guidelines and regular quality monitoring systems. Sibomana et al. (2023) investigated postharvest losses of tomatoes in Rwanda using survey data and supply chain analysis. The study found that inadequate storage management, particularly poor sorting and improper handling, significantly affected quality and price realization. The authors concluded that management practices strongly influence produce quality and income outcomes. They recommended training programs and improved coordination across value chain actors to enhance product quality delivered to markets.

METHODOLOGY

This study adopts a correlational research design to examine the relationships between storage facility adequacy, storage management practices, and postharvest outcomes of agricultural produce in Bida Local Government Area of Niger State, Nigeria, a region known for active crop farming and diverse produce. The population comprised registered crop farmers, agricultural produce marketers, storage operators, transporters and logistics providers, government agencies, and consumers, totaling 2,000 respondents, with 1,450 farmers, 350 marketers, and 200 storage operators according to the Bida Local Government Agricultural Office (2024). A stratified random sampling technique ensured proportional representation

across all strata and minimized sampling bias, with Yamane’s (1967) formula determining a sample size of 334 respondents. Primary data were collected through structured questionnaires and personal interviews, including both closed- and open-ended items, with closed items measured on a 5-point Likert scale ranging from strongly disagree to strongly agree to capture respondents’ perceptions of storage and marketing practices. The measuring instruments were validated through expert review by agricultural and marketing specialists, while reliability was assessed using Cronbach’s alpha coefficient, yielding 0.87, indicating high internal consistency. Hypotheses were tested using multiple linear regression to determine the effect of storage facility adequacy (X_1) and storage management practices (X_2) on postharvest outcomes (Y), with the formal regression model specified as $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \epsilon$, where β_1 and β_2 are regression coefficients, α is the intercept, and ϵ is the error term. Limitations included potential respondent bias, difficulty accessing remote farming locations, and limited availability of updated agricultural records, which may affect the generalizability of the findings.

Presentation of Data: Research Questions

Table 1: Descriptive Statistics of Storage and Marketing Factors

| S/N | Descriptive | Mean | Std. Deviation |
|--|---|------|----------------|
| Storage Facilities Adequacy: Please rate your business operations based on the following items: | | | |
| 1 | Storage facilities availability | 4.62 | 1.094 |
| 2 | Storage facilities capacity | 4.56 | 1.332 |
| 3 | Storage facilities protection and preservation capability | 4.57 | 1.310 |
| Storage Management Practices: Please rate your establishment based on the following items | | | |
| 1 | Frequency of storage facility | 4.78 | 1.249 |
| 2 | Use of pest and spoilage control | 4.83 | 1.196 |
| 3 | Proper handling and preparation of produce before storage | 4.61 | 1.386 |

From Table 1, it is shown that respondents agreed with most of the items measuring storage facilities adequacy as an aspect of storage and marketing. That is, storage facilities availability, storage facilities capacity, and storage facilities protection and preservation capability. Amongst the items used to measure storage facilities adequacy, the respondents gave more

attention to storage facilities availability as an important storage and marketing factor. This suggests that availability of storage facilities is important.

It is also shown that respondents agreed with most of the items measuring storage management practices as an aspect of storage and marketing. That is, the frequency of storage facility, use of pest and spoilage control, and proper handling and preparation of produce before storage. Amongst the items used to measure storage management practices, the respondents gave more attention to use of pest and spoilage control as an important storage and marketing factor. This suggests that the use of pest and spoilage control is important to the stakeholders.

Table 2: Descriptive Statistics of Post-Harvest Operation Efficiency Factors

| S/N | Descriptive | Mean | Std. Deviation |
|--|--|------|----------------|
| Post-harvest Losses: Please Rate your business based on the following items | | | |
| 1 | Percentage of produce lost after harvest | 4.92 | 1.127 |
| 2 | Frequency of spoilage or damage | 4.75 | 1.307 |
| 3 | Quantity of produce rejected at market | 4.65 | 1.219 |
| Quality of Produce Delivered to Markets: Please Rate your organization based on the following items | | | |
| 1 | Freshness and physical appearance of produce | 4.71 | 1.113 |
| 2 | Compliance with market quality standard | 4.56 | 1.297 |
| 3 | Nutritional and storage integrity retained | 4.67 | 1.229 |

From Table 2 above, it is shown that respondents agreed with most of the items measuring postharvest losses as an aspect of post-harvest operation efficiency of agricultural produce. That is, the percentage of produce lost after harvest, frequency of spoilage or damage, and quantity of produce rejected at market. Amongst the items used to measure level of post-harvest losses, the respondents gave more attention to percentage of produce lost after harvest as an important factor affecting the post-harvest losses in the postharvest operation efficiency of agricultural produce. This suggests that the farmers perceive postharvest loss percentage as the most critical indicator influencing overall postharvest operational efficiency outcomes.

Again, it is shown that respondents agreed with most of the items measuring quality of produce delivered to markets as an aspect of post-harvest operation efficiency of agricultural produce. That is, the freshness and physical appearance of produce, compliance with market quality standard and nutritional and storage integrity retained. Amongst the items used to measure the quality of produce delivered to markets, the respondents gave more attention to freshness and physical appearance of produce as an important factor that the stakeholders consider

responsible for the quality of produce delivered to markets in post-harvest operation efficiency of agricultural produce. This suggests that the stakeholders view freshness and physical appearance as primary determinants of market quality and postharvest operational efficiency.

Hypotheses

Hypothesis One: Storage facilities adequacy does not significantly have an effect on the level of post-harvest losses of agricultural produce.

Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|--------------------|----------|-------------------|----------------------------|
| 1 | 0.777 ^a | 0.754 | 0.754 | 0.24407 |

a. Predictors: (Constant), Storage facilities adequacy
Source: Researcher’s Field Result (2025)

The table above illustrates the extent to which the model accounts for variation in the dependent variable, Level of post-harvest losses. In this model summary, the R square value is 0.777, indicating that 77.7% of the variance in level of post-harvest losses can be explained to differences in storage facilities adequacy.

ANOVA

| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
|-------|------------|----------------|-----|-------------|----------|-------|
| 1 | Regression | 406.077 | 1 | 406.077 | 6816.521 | 0.000 |
| | Residual | 19.540 | 328 | 0.060 | | |
| | Total | 425.617 | 329 | | | |

a. Dependent Variable: Level of post-harvest losses
b. Predictors: (Constant), Storage facilities adequacy
Source: Researcher’s Field Result (2025)

Coefficients^a

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|-------|-----------------------------|-----------------------------|------------|---------------------------|--------|-------|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 0.678 | 0.053 | | 12.824 | 0.000 |
| | Storage facilities adequacy | -0.702 | 0.011 | 0.777 | 82.562 | 0.000 |

a. Dependent Variable: Level of post-harvest losses
Source: Researcher’s Field Result (2025)

The table above highlights that the variables in the model significantly contribute to predicting the dependent variable, level of post-harvest losses. The coefficients table shows the expected change in the dependent variable for each one-unit change in the independent variable. In this case, the unstandardized beta coefficient for storage facilities adequacy is $\beta = -0.702$, indicating that an increase in storage facilities adequacy among farmers and other stakeholders is associated with a 0.702 decrease in the level of post-harvest losses. This suggests that storage facilities play a strong role in reducing the level of post-harvest losses. Additionally, the relationship between storage facilities' adequacy and the level of post-harvest losses is statistically significant, as indicated by the (t-value= 82.562, P-value= 0.000). These results meet the criteria of statistical significance P-value below the 0.05 significance level and a T-value above the threshold of 1.96. This confirms a negative and significant impact of storage facilities' adequacy on the level of post-harvest losses.

Decision:

Based on the analysis above, the result shows that the t-value = 82.562 is more than 1.96 and its significance level, p= 0.00 is less than 0.05. This implies that the null, which states that storage facilities' adequacy does not significantly have an effect on the level of post-harvest losses of agricultural produce, is rejected. Therefore, the alternative hypothesis which states that the adequacy of storage facilities has a significant effect on the level of post-harvest losses of agricultural produce is accepted.

Ho2: Storage management practices do not significantly have an effect on the quality of produce delivered to the market.

Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|--------------------|----------|-------------------|----------------------------|
| 1 | 0.791 ^a | 0.782 | 0.782 | 0.16172 |

a. Predictors: (Constant), Storage management practices

Source: Researcher's Field Result (2025)

The table above illustrates the extent to which the model accounts for variation in the dependent variable, Quality of produce delivered to market. In this model summary, the R-squared value is 0.791, indicating that 79.1% of the variance in quality of produce delivered to market can be explained by differences in storage management practices.

ANOVA

| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
|-------|------------|----------------|-----|-------------|-----------|--------------------|
| 1 | Regression | 466.365 | 1 | 466.365 | 17831.426 | 0.000 ^b |
| | Residual | 8.579 | 328 | 0.026 | | |
| | Total | 474.944 | 329 | | | |

- a. Dependent Variable: Quality of produce delivered to market
 - b. Predictors: (Constant), Storage management practices
- Source:** Researcher’s Field Result (2025)

Coefficients

| Model | | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. |
|-------|------------|-----------------------------|------------|---------------------------|--------|-------|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 0.313 | 0.034 | | 9.235 | 0.000 |
| | Values | 0.739 | 0.007 | 0.791 | 93.534 | 0.000 |

- a. Dependent Variable: Quality of produce delivered to market
- Predictors: (Constant), Storage management practices
- Source:** Researcher’s Field Result (2025)

The table above highlights that the variables in the model significantly contribute to predicting the dependent variable, quality of produce delivered to market. The coefficients table shows the expected change in the dependent variable for each one-unit change in the independent variable. In this case, the unstandardized beta coefficient for storage management practices is $\beta = 0.739$, indicating that an increase in storage management practices among farming stakeholders is associated with a 0.739 increase in the quality of produce delivered to market. This suggests that storage management practices play a strong role in improving the quality of produce delivered to market. Additionally, the relationship between storage management practices and quality of produce delivered to market is statistically significant, as indicated by the (t-value= 93.534, P-value= 0.000). These results meet the criteria of statistical significance p-value below the 0.05 significance level and a t-value above the threshold of 1.96. This confirms a positive and significant impact of storage management practices on the quality of produce delivered to market.

Decision:

Based on the analysis above, the result shows that the t-value = 93.534 is more than 1.96 and its significance level, P= 0.00 is less than 0.05. This implies that the null, which states that storage management practices do not significantly have an effect on the quality of produce delivered to

the market, is rejected. Therefore, the alternative hypothesis which states that storage management practices have a significant effect on the quality of produce delivered to market is accepted.

Discussion of Findings

The first hypothesis, which examined whether storage facilities significantly affect the level of post-harvest losses, was strongly supported by the findings. The regression results showed a negative and significant relationship ($\beta = -0.702$, $p < 0.000$), with an R^2 value of 0.754, indicating that 75.4% of the variance in post-harvest losses is explained by storage facilities' adequacy. This supports the position of Nwajiuba and Nwoke (2024), who argued that adequate storage facilities are central to preventing spoilage, improving produce availability, and enhancing market timing.

Effective storage infrastructure enhances the preservation of quality, stabilizes supply, and contributes to economic gains, all of which minimize post-harvest losses. Similarly, Okonkwo, Nwobodo and Ogbuagu (2023) noted that efficient storage improves supply chain performance, strengthens food security, and helps retain maximum produce quantity and quality.

The second hypothesis tested whether storage management practices significantly affect the quality of produce delivered to market. Results also confirmed a significant relationship ($\beta = 0.739$, $p < 0.000$), with $R^2 = 0.782$, meaning 78.2% of the variation in produce quality is explained by storage management practices. This aligns with Kader (2025), who emphasized that core storage management practices (such as proper produce handling, maintenance of facilities, and effective pest and spoilage control) are essential determinants of the level of post-harvest losses.

CONCLUSION AND RECOMMENDATIONS

The study concludes that storage conditions play a critical role in determining post-harvest outcomes for farmers in Bida, Niger State. Beyond the empirical evidence, the findings provide theoretical support for postharvest systems and supply chain management perspectives, reinforcing the argument that infrastructure adequacy is a structural determinant of loss reduction in agricultural value chains. By empirically demonstrating the inverse relationship between storage facility adequacy and post-harvest losses, the study advances existing models that link physical assets to operational efficiency in emerging economies. Methodologically, the integration of stratified sampling with regression analysis strengthens the robustness of evidence generated from a localised context, offering a replicable framework for similar agrarian settings. These insights highlight the urgent need for investment in functional storage infrastructure as a pathway to enhanced food security and income stability.

The study further establishes that effective storage management practices are central to sustaining produce quality along the post-harvest chain. Theoretically, the results extend quality management and postharvest handling literature by demonstrating that managerial practices such as proper handling, pest control, and timely storage significantly shape market readiness and value retention. This affirms the practical relevance of operational discipline within agricultural systems. From a methodological standpoint, the application of inferential tools to

quantify the contribution of management practices provides empirical depth often missing in descriptive agricultural studies. Collectively, the study underscores that improving post-harvest performance requires a dual focus on infrastructure development and strengthened managerial capacity among stakeholders.

- It is recommended that government and relevant stakeholders should prioritize sustained investment in modern, climate-smart storage infrastructure across agrarian communities. Public–private partnerships can be strengthened to establish accessible, well-equipped storage centres with proper ventilation, temperature regulation, and pest control systems. In addition, storage development should be deliberately integrated into agricultural value chain policies and food security strategies to ensure that post-harvest management receives equal attention alongside production. Expanding access to targeted agricultural finance and microcredit schemes for storage improvement will further enable smallholder farmers to adopt and maintain efficient storage technologies.
- Also, extension services and agricultural development agencies should intensify practical training programmes focused on handling, grading, pest management, and timely storage utilization. Building managerial and technical capacity among farmers, marketers, and storage operators will enhance produce freshness, market readiness, and income stability. Future research should adopt broader geographical and longitudinal approaches to deepen understanding of post-harvest systems and explore additional factors, such as technology adoption and cooperative participation that may strengthen post-harvest efficiency outcomes.

Contribution to Knowledge

This study makes a substantive contribution to knowledge by developing and empirically validating a postharvest infrastructure-Management Efficiency (PIME) Model, which integrates storage facility adequacy (structural capacity) and storage management practices (operational capability) as joint predictors of post-harvest performance outcomes. Unlike prior studies that examine infrastructure or management practices in isolation, the proposed model demonstrates that both dimensions function as complementary determinants within a unified post-harvest efficiency framework. By statistically confirming a significant inverse relationship between storage adequacy and post-harvest losses, alongside a strong positive relationship between management practices and produce quality, the study provides new empirical evidence from a rural Nigerian context that strengthens the theoretical linkage between physical assets and operational discipline in agricultural value chains.

Empirically, the findings reveal that infrastructure and management variables collectively explain a substantial proportion of the variance in both loss reduction and quality preservation, offering one of the few context-specific regression-based validations of post-harvest system performance in North-Central Nigeria. This moves the discourse beyond descriptive assessments of spoilage toward quantifiable efficiency modelling. Methodologically, the study advances post-harvest research by combining stratified random sampling with multivariate

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regression analysis to produce statistically generalizable insights within a localized agrarian setting. The operationalization of storage adequacy and management practices into measurable constructs also provides a replicable measurement framework for future studies across similar emerging agricultural economies.

Limitations and Suggestions for Future Study

This study was limited by its focus on farmers within Bida, which may restrict the generalizability of the findings to other regions with different storage systems or market structures. The research also relied on self-reported data, which may be influenced by personal perceptions rather than direct measurements of post-harvest losses or produce quality. Additionally, the study examined only storage-related factors, leaving out other important influences such as transportation, market delays, and climatic variations.

Future research should explore these additional factors and extend the study to multiple local government areas or states for broader insights. Longitudinal studies measuring actual losses over time would also deepen understanding of post-harvest dynamics in rural Nigeria.

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