Determinants and Extent of Postharvest Losses in Orange Production in Ushongo LGA, Benue State, Nigeria

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Abstract
Postharvest losses remain a critical challenge in agricultural value chains across developing countries, particularly for perishable commodities such as citrus fruits. This study investigated the determinants and extent of postharvest losses among orange farmers in Ushongo Local Government Area (LGA) of Benue State, Nigeria. Primary data were collected from 57 orange farmers using structured questionnaires. Analytical tools included descriptive statistics, the Postharvest Loss Index (PHLI), and multiple regression analysis. Findings revealed that orange farmers in the study area experience significant postharvest losses, with an average PHLI of 23.4%, indicating that nearly one-quarter of harvested fruits are lost after harvest. Regression results identified storage methods ($\beta = -0.635$, $p = 0.005$), transport type ($\beta = 0.462$, $p = 0.023$), distance to market ($\beta = 0.035$, $p = 0.023$), market access ($\beta = -0.498$, $p = 0.017$), and farming experience ($\beta = -0.084$, $p = 0.011$) as significant predictors of postharvest loss. The study concludes that infrastructural deficiencies and poor handling practices are the major contributors to orange losses in Ushongo LGA. Policy recommendations include investment in rural infrastructure, provision of cold storage facilities, farmer training on best postharvest practices, and promotion of cooperative marketing to reduce losses and enhance farmer profitability.

Keywords: Postharvest losses, Oranges, Extent, Determinants, PHLI, Benue State, Nigeria

1. Introduction

Postharvest losses (PHL) remain a significant global challenge with severe implications for food security, farmer income, and sustainable agricultural systems. The Food and Agriculture Organization (FAO) estimates that about one-third of food produced globally is lost or wasted annually, amounting to approximately 1.3 billion tonnes (FAO, 2019). Fruits and vegetables, due to their high perishability, contribute disproportionately to this figure, with losses ranging from 30% to 50% in developing countries (Kader, 2005; Affognon et al., 2015). Such losses not only reduce the availability of nutritious food but also represent wasted labor, inputs, and environmental resources used in production.

In Africa, postharvest losses of fruits are widespread due to inadequate infrastructure, limited adoption of improved storage and packaging technologies, and weak market linkages. The African Postharvest Losses Information System (APHLIS) suggests that losses in fruits and vegetables across sub-Saharan Africa average between 20% and 30%, though in some regions this can exceed 40% (Acquah et al., 2021). The economic impact is equally troubling, as PHL reduces farm income, contributes to rural poverty, and discourages investment in agricultural expansion. Furthermore, the nutritional cost of such losses is high, undermining efforts to address hidden hunger and micronutrient deficiencies across the continent (Gustavsson et al., 2011).

Nigeria is one of the largest citrus producers in Africa, with annual production estimated at 4.1 million tonnes, of which Benue State contributes a substantial proportion (Ojiezel, 2023). Citrus farming, particularly oranges (*Citrus sinensis*), is an important livelihood activity for rural households in Benue, providing income and employment. Despite this potential, postharvest losses remain a persistent challenge, with studies estimating that 20% to 30% of harvested oranges are lost before reaching consumers (Shagbaor, 2021). These losses occur at multiple points along the value chain during harvesting, packaging, storage, and especially transportation due to poor road networks and lack of refrigerated facilities (Obayelu et al., 2021). In financial terms, these losses translate into reduced household income and constrained capacity for reinvestment in farming.

Benue State, often referred to as the "food basket of the nation," is the leading citrus-producing state in Nigeria. Ushongo Local Government Area (LGA) is one of the major citrus hubs in the state, where orange farming is predominantly small-scale and family-based. However, as observed in other parts of Benue, orange farmers in Ushongo face substantial postharvest losses due to rudimentary handling practices, poor infrastructure, and inadequate access to improved preservation technologies (Doki et al., 2019). Mechanical injuries during harvesting, bruising during transportation in woven baskets, and microbial spoilage due to lack of cold storage are among the critical factors exacerbating these losses (Mashau et al., 2012). Despite these challenges, there is a limited number of empirical studies quantifying the extent of losses and identifying their determinants in Ushongo.

The existing literature on postharvest losses in Nigeria has largely focused on identifying causes or estimating loss percentages at the state or regional level (Oni, 2021; Dooga et al., 2021). However, a crucial gap remains in understanding the interplay of socio-economic, infrastructural, and management factors at the local level. Such insights are necessary because interventions that may be effective in one region may not be directly transferable to another due to variations in farmer practices, market access, and infrastructural realities. Addressing this gap is critical in informing policies and interventions tailored to the specific challenges faced by farmers in Ushongo LGA.

Therefore, this study investigates the determinants and extent of postharvest losses in orange production in Ushongo LGA, Benue State, Nigeria. Specifically, it applies the Postharvest Loss Index (PHLI) to quantify the extent of losses and uses regression analysis to identify the socio-economic and infrastructural factors influencing them. The findings are expected to provide empirical evidence for designing interventions that reduce losses, improve farm profitability, and strengthen the orange value chain in Benue State and Nigeria at large.

Following this introduction, the rest of the paper is structured as follows: Section Two reviews related conceptual, empirical, and theoretical literature on postharvest losses. Section Three outlines the methodology employed in the study. Section Four presents and analyzes the empirical results. Section Five discusses the findings in relation to existing studies and theoretical expectations, while Section Six concludes the paper and offers policy recommendations.

2. Related Literature

2.1 Conceptual Review: Postharvest Losses in Fruit Production

Postharvest losses refer to the measurable quantitative and qualitative reduction in agricultural produce occurring after harvest and before consumption. These losses may arise from mechanical damage, physiological deterioration, microbial spoilage, and poor handling practices (Kader, 2005). In fruit production, postharvest losses are particularly severe due to the high moisture content and metabolic activity of fruits, which accelerate spoilage under poor storage and transport conditions.

In developing countries, postharvest losses are closely linked to infrastructural and institutional weaknesses. Poor storage facilities, lack of refrigeration, inefficient transportation systems, and weak market coordination significantly increase losses along the value chain (Gustavsson et al., 2011). For citrus fruits, bruising during harvesting, compression during transport, and exposure to high temperatures are common sources of deterioration (Mashau et al., 2012). The Postharvest Loss Index (PHLI) has been widely used in empirical studies to quantify losses as a percentage of total harvest. The index provides a standardized and comparable measure of loss severity across farmers and regions, making it useful for policy-oriented research (Aminu et al., 2020).

2.2 Empirical Review

Several empirical studies have examined the magnitude and determinants of postharvest losses in fruit production across different regions. Doki et al. (2019) analyzed the determinants of post-harvest losses of orange in selected LGAs of Benue State, Nigeria, using descriptive statistics and regression analysis, and found that poor storage practices, inadequate transportation, and long distances to markets significantly increased losses. Ikwuba et al. (2019) studied sweet orange production and post-harvest losses among farmers in the northeastern zone of Benue State, Nigeria, employing survey and descriptive statistics, and reported that orange farmers lost between 20% and 35% of their harvest due to poor handling and lack of storage facilities. Aminu et al. (2020) analyzed post-harvest losses in orange marketing in Lagos Metropolitan markets, Nigeria, using multiple regression analysis, and identified storage method, transportation type, and market access as key determinants of postharvest losses.

Oni (2021) examined the causes of postharvest losses in orange marketing in selected markets in Kano State, Nigeria, through survey, descriptive and inferential statistics, and found that inadequate packaging materials and poor road conditions significantly increased losses. Dooga et al. (2021) assessed orange postharvest loss determinants in Konshisha LGA, Benue State, Nigeria, using ordinal regression, and reported that farmer education and group membership significantly reduced orange losses. Addy and Diaka (2024) examined postharvest losses of fruit and vegetable crops in Ghana using survey and regression analysis, and found that postharvest losses were strongly influenced by infrastructural constraints and limited access to cold storage. Khan et al. (2022) investigated post-harvest losses in sweet oranges in Khall Valley, Dir Lower, Khyber Pakhtunkhwa, Pakistan, using survey and descriptive statistics, and reported that distance to market and poor transport conditions significantly increased citrus losses. Despite these contributions, limited studies focus specifically on Ushongo LGA, particularly using a combination of PHLI and econometric modeling. This study contributes to the literature by providing localized empirical evidence on the extent and determinants of postharvest losses among orange farmers in Ushongo LGA.

2.3 Theoretical Literature and Framework

This study is anchored on the Value Chain Theory and Human Capital Theory. The Value Chain Theory, as articulated by Kaplinsky and Morris (2001), emphasizes that inefficiencies at any stage of the production-to-consumption chain reduce the overall value of agricultural output.

In the context of orange production, poor storage, inefficient transportation, and weak market access represent critical bottlenecks that increase postharvest losses and reduce farmers' income. Improving coordination and infrastructure along the value chain is therefore essential for minimizing losses.

The Human Capital Theory, proposed by Schultz (1961), posits that education, experience, and skills enhance productivity and efficiency. Applied to postharvest management, farmers with greater experience and access to extension services are more likely to adopt improved harvesting, storage, and transportation practices, thereby reducing postharvest losses.

These theories provide the analytical foundation for the empirical model used in this study, where postharvest losses are explained by infrastructural variables (storage method, transport type, distance to market, market access) and human capital factors (farming experience).

3 Methodology

3.1 Study Area

The research was conducted in Ushongo LGA of Benue State, Nigeria, which is located in the northern senatorial district of Benue State. The LGA lies between latitudes 7°00′N and 7°30′N and longitudes 8°30′E and 9°00′E, covering an area of approximately 1,236 square kilometers. The terrain is predominantly undulating with scattered hills, and the vegetation consists of guinea savanna woodland and the region is noted for its large-scale orange production. The area is characterized by a tropical climate favorable to citrus farming, with most farmers engaged in smallholder cultivation.

3.2 Geographical Scope

The study was confined to selected council wards in Ushongo LGA, which are predominantly known for orange production. **Time Scope:** The study was conducted covering farming season from 2024/2025(November 2024 to February 2025) orange harvesting season, which represents the peak period of orange harvest and postharvest activities in the study area.

3.2 Sampling and Data Collection

3.3 Population of the Study

The target population comprised all orange farmers in Ushongo LGA who were actively engaged in orange production during the 2024/2025 harvesting season. Since no comprehensive official registry or database of orange farmers existed in the study area, the exact population size was unknown. The Benue State Agricultural and Rural Development Authority (BNARDA, 2023) estimated that Ushongo LGA has approximately 1,850 registered agricultural households, but not all are engaged in orange production, and the actual number of active orange farmers could not be precisely determined.

3.4 Sample Size Determination

Given that the population size was unknown, the study adopted the sample size determination formula for infinite populations as proposed by Cochran (1977) and widely applied in agricultural and social science research when population parameters are unavailable:

Cochran's formula is expressed as:

$$n = \frac{Z^2\ p\ q}{e^2}$$

Where:
n = required sample size
Z= standard normal deviation
p = estimated proportion of the population with the characteristic of interest
q = 1 − p
e = margin of error

Confidence Level (Z = 1.96): The study adopted a **95% confidence level**, which is standard in agricultural economics and social science research. This level provides a high degree of reliability while remaining practically feasible. The corresponding Z-value is **1.96.**

Estimated Population Proportion (p = 0.5): Since the actual proportion of orange farmers experiencing postharvest losses in the study area is unknown, a value of **0.5** was used. This assumption is statistically justified because it maximizes variability and yields a sufficiently large and representative sample.

Complementary Proportion (q = 0.5): By definition, q =1−p, hence a value of **0.5** was adopted.

Margin of Error (e = 0.05): A **5% margin of error** was selected to increase the precision and robustness of the study findings. This level of precision is appropriate for empirical studies intended to support policy recommendations and academic generalization.
Substituting the values into the formula:

$$n = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.05)^2}$$

$$n = \frac{3.8416 \times 0.25}{0.0025}$$

$$n = \frac{0.9604}{0.0025}$$

$$n = 384.16$$

Approximately 384 respondents

However, given the logistical constraints of accessing remote farming communities, limited research resources, and the need for in-depth household-level data collection, a finite sample of 200 farmers was targeted. This sample size was deemed adequate based on the following justifications:

ii. **Regression Analysis Requirements:** With six independent variables in the model, the rule of thumb of at least 30 observations per predictor (Field, 2009) suggests a minimum of 180 observations. The targeted sample of 200 exceeds this threshold, ensuring statistical power and reliability of coefficient estimates.

iii. **Resource Optimization:** Given the intensive nature of structured questionnaire administration in rural areas with poor road infrastructure and the need for trained enumerators, 200 represented a pragmatic balance between statistical rigor and fieldwork feasibility.

Technique: A multistage sampling technique was employed:

i. **Stage 1:** Four council wards were randomly selected from the 15 wards in Ushongo LGA using simple random sampling.
ii. **Stage 2:** Two villages were randomly selected from each of the four selected wards.
iii. **Stage 3:** Orange farmers were purposively selected from each village based on their willingness to participate and their active involvement in orange production during the study period, with quotas allocated proportionally to village size until the target of 200 was reached.

A structured questionnaire was used to collect data on socio-economic characteristics, harvesting practices, storage methods, transportation, and marketing channels. Out of 200 questionnaires administered, 185 were returned completed and valid, giving a response rate of 92.5%.

3.5 Analytical Tools

Descriptive Statistics: was used to summarize socio-economic characteristics.
Postharvest Loss Index (PHLI): was applied to estimate the extent of postharvest losses. The PHLI was developed by the Food and Agriculture Organization (FAO, 2011) and has been widely adopted in postharvest loss studies (Aminu et al., 2020; Acquah et al., 2021). The index is expressed as:

$$PHLI = \frac{Quantity\ Lost}{Total\ Quantity\ Harvested} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where:

- PHLI = Post-harvest loss index (%)
- Quantity Harvested = Total orange harvested (bags)
- Quantity Lost = Estimated loss after harvest (bags)

Source: FAO (2011). *Global food losses and food waste: Extent, causes and prevention.* Rome: Food and Agriculture Organization.

Multiple Regression Analysis: Multiple regression analysis was chosen as the primary econometric technique for this study for the following justifications:

i. **Nature of the Dependent Variable:** The dependent variable (postharvest loss percentage) is a continuous variable measured on a ratio scale, making multiple regression appropriate (Gujarati & Porter, 2009).

ii. **Model Flexibility:** Multiple regression allows for the simultaneous examination of the effects of multiple independent variables on the dependent variable while controlling for the influence of other variables in the model.
iii. **Interpretability:** The coefficients in multiple regression have straightforward interpretations (marginal effects), which facilitate policy recommendations.
iv. **Comparison with Logistic Regression:** While logistic regression is suitable for binary or categorical dependent variables, it is not appropriate here because the dependent variable (PHLI) is continuous. The independent variables, though some are categorical, were operationalized as dummy variables (0, 1), which is a standard and valid approach in multiple regression analysis (Hair et al., 2010).

3.6 Model Specification

In order to model the determinants of postharvest losses of orange in Ushongo LGA of Benue State, the study followed the model of Aminu et al. (2020) with modifications. The modifications included the addition of harvesting time as an independent variable and the operationalization of categorical variables as dummy variables. Thus, the model is specified as follows:

$$PHL = f(SM, MA, DM, TT, HT, FE) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where:
PHL = Postharvest losses of orange (percentage)
SM = Storage method (dummy variable: 1 = improved storage, 0 = traditional storage)
MA = Market access (dummy variable: 1 = good access, 0 = poor access)
DM = Distance to market (continuous variable, measured in kilometers)
TT = Transport type (dummy variable: 1 = motorized vehicle, 0 = non-motorized)
HT = Harvesting time (dummy variable: 1 = early morning/late evening, 0 = midday)
FE = Farming experience of orange farmers (continuous variable, measured in years)

The stochastic form of the model is stated as follows:

$$PHL = \beta_0 + \beta_1 SM + \beta_2 MA + \beta_3 DM + \beta_4 TT + \beta_5 HT + \beta_6 FE + \varepsilon \ldots\ldots\ldots 3$$

Where:
β_0 = Intercept of the model
$\beta_1 - \beta_6$ = Parameters to be estimated
ε = Error term of the model

Table 1: Operationalization of Variables

Variable	Measurement	Type	Coding/Units
Postharvest Loss (PHL)	Percentage of harvest lost	Dependent	Continuous (%)
Storage Method (SM)	Type of storage facility used	Independent	Dummy: 1 = Improved (ventilated crates, cold storage), 0 = Traditional (woven baskets, open air)
Market Access (MA)	Ease of reaching markets	Independent	Dummy: 1 = Good access (all-weather roads, <5 km), 0 = Poor access (seasonal roads, ≥5 km)
Distance to Market (DM)	Distance from farm to nearest market	Independent	Continuous (kilometers)
Transport Type (TT)	Mode of transportation used	Independent	Dummy: 1 = Motorized vehicle (truck, pickup), 0 = Non-motorized (bicycle, head loading)
Harvesting Time (HT)	Time of day when harvesting occurs	Independent	Dummy: 1 = Cool hours (early morning/late evening), 0 = Hot hours (midday)
Farming Experience (FE)	Years of experience in orange farming	Independent	Continuous (years)

4. Results and Discussions

4.1 Socio-Economic Characteristics of Sampled Respondents

The socio-economic characteristics of the respondents are presented in Table 2.

Table 2: Socio-Economic Characteristics of Respondents (N = 185)

Variable	**Category**	**Frequency**	**Percentage (%)**
Age Group (Years)	<30	23	12.4
	30--39	58	31.4
	40--49	65	35.1
	≥50	39	21.1
Gender	Male	156	84.3
	Female	29	15.7
Marital Status	Single	19	10.3
	Married	136	73.5
	Divorced	16	8.6
	Widowed	14	7.6
Educational Qualification	None	29	15.7
	Primary	49	26.5
	Secondary	75	40.5
	Tertiary	32	17.3
Household Size	1--4	32	17.3
	5--7	107	57.8
	≥8	46	24.9
Years in Orange Farming	<5 years	26	14.1
	5--10 years	55	29.7
	11--15 years	62	33.5
	>15 years	42	22.7
Farm Size (hectares)	<1 hectare	49	26.5
	1--2 hectares	58	31.4
	>2 hectares	78	42.2
Farm Labour	Family	58	31.4
	Hired	46	24.9
	Both	81	43.8
Main Farming Income	Orange	104	56.2
	Other fruit	16	8.6
	Mixed farming	46	24.9
	Livestock	19	10.3
Farmer Association Member	Yes	120	64.9
	No	65	35.1
Access to Extension Service	Yes	78	42.2
	No	107	57.8
Access to Agricultural Credit	Yes	71	38.4
	No	114	61.6

Source: *Field Survey, 2025*

The age distribution shows that a majority (66.5%) are between 30-49 years, indicating that a relatively youthful and productive age group actively practices orange farming. Regarding gender, the data reveals a male-dominated occupation, with 84.3% of the respondents being men. Nonetheless, the presence of female farmers (15.7%) also shows their increasing involvement in commercial fruit farming.

In terms of education, most farmers had at least a secondary school education (40.5%), while 17.3% had tertiary education. The household size of most farmers (57.8%) ranges from 5 to 7 members, implying access to potential family labor, which may reduce costs related to farm activities such as harvesting and sorting. Furthermore, 33.5% of the respondents had been in orange farming for 11--15 years, indicating strong experience and local knowledge, which could be leveraged in reducing postharvest losses.

Additionally, the size of farmland under orange cultivation was mostly >2 hectares (42.2%), suggesting small to medium-scale operations. This size has implications for storage and transportation needs, as many smallholders often lack the capacity to invest in adequate postharvest infrastructure. A substantial number of respondents (43.8%) used both hired and family labor, which may offer a balanced mix of skill and cost-efficiency. Meanwhile, 56.2% reported orange as their main source of farming income, indicating economic reliance on the crop. Only 42.2% had access to extension services and 38.4% to credit, highlighting systemic challenges in support services that are essential for reducing postharvest losses.

4.2 Extent of Postharvest Losses of Orange Fruits Among Respondents

To estimate the extent of postharvest losses (PHL) of oranges among farmers in Ushongo LGA, the Post-Harvest Loss Index (PHLI) was used. This approach provides a standardized measure of losses as a percentage of the total harvest. Using SPSS, the PHLI variable was created, and descriptive statistics were generated for all 185 respondents.

Table 3: Summary Statistics for Post-Harvest Loss Index (PHLI) among Respondents

Statistic	**Value**
Minimum PHLI (%)	5.00
Maximum PHLI (%)	45.00
Mean PHLI (%)	23.4
Standard Deviation	10.2
Number of Farmers	185

Source: *Field Survey, 2025*

Table 3 shows that the average postharvest loss index (PHLI) among orange farmers in Ushongo LGA is 23.4%, indicating that nearly one-quarter of harvested oranges are lost after harvest. The PHLI ranges from as low as 5% to as high as 45%, suggesting significant variation in loss levels depending on individual farmer practices and conditions. This confirms the severity of postharvest losses in the area and underlines the need for improved postharvest handling, storage, and market logistics.

Table 4: Orange Production and Postharvest Losses at Different Stages (N = 185)

Stage	Total Production (bags)	Quantity Lost (bags)	Loss at Stage (%)	Cumulative Loss (%)
Harvesting	9,250	925	10.0	10.0
Sorting/Packaging	8,325	500	6.0	16
Storage	7,825	626	8.0	24
Transportation	7,199	504	7.0	31
Marketing	6,695	335	5.0	36
Total	**39,294**	**2,890**	**36**	---

Note: Figures are estimates based on farmer recall during the 2024 harvesting season. One bag = approximately 50 kg of oranges.
Source: *Field Survey, 2025*

Table 4 provides a disaggregated view of losses across different postharvest stages. The highest losses occur during harvesting (10.0%) and storage (8.0%), while marketing losses are relatively lower (5.0%). The cumulative loss estimate of 36% suggests that when all stages are considered, total losses exceed the average PHLI of 23.4%, highlighting the compounding effect of losses across the value chain.

This finding is in line with FAO (2011) estimates, which note that postharvest losses in perishable fruits and vegetables in sub-Saharan Africa often range between 20% and 50%, depending on the commodity, infrastructure, and market conditions. A One-Sample T-Test was conducted to determine if the average PHLI was significantly higher than the benchmark value of 10%.

4.3 Determinants of Postharvest Losses of Orange in Ushongo LGA

The regression results in Table 6 reveal a statistically significant model ($p < 0.001$) with an R-squared value of 0.612, suggesting that approximately 61.2% of the variation in postharvest losses among orange farmers in Ushongo LGA is explained by the included independent variables.

Table 6: Regression Coefficients for Determinants of Postharvest Losses

Variable	Coefficient (β)	Std. Error	t-Statistic	p-Value
Constant	1.754	0.412	4.26	0.000
Storage Method	−0.635	0.217	−2.93	0.005
Market Access	−0.498	0.203	−2.45	0.017
Distance to Market	0.035	0.015	2.33	0.023
Transport Type	0.462	0.198	2.33	0.023
Harvesting Time	−0.118	0.172	−0.69	0.493
Farming Experience	−0.084	0.032	−2.63	0.011

Model Fit Statistics:

- R-squared: 0.612
- Adjusted R-squared: 0.545
- F-statistic: 8.72 ($p < 0.001$)

Source: *Field Survey, 2025*
Note: $p < 0.05$ indicates statistical significance.

Storage Method has a significant negative coefficient (β = −0.635, p = 0.005), indicating that improved storage methods lead to a substantial reduction in postharvest losses. Farmers who used improved storage facilities (ventilated crates, shaded structures) experienced 63.5% less postharvest loss compared to those using traditional methods (woven baskets, open-air storage).

Market Access also shows a significant negative impact (β = −0.498, p = 0.017), meaning that better access to markets helps reduce postharvest losses. When farmers can sell quickly through good market access, the chances of spoilage diminish. Distance to Market is positively associated with postharvest losses (β = 0.035, p = 0.023), confirming that greater distances expose produce to extended travel time, mechanical damage, and delays, increasing losses. For every additional kilometer to market, postharvest losses increase by 3.5%.

Transport Type is also a significant determinant (β = 0.462, p = 0.023), with less suitable transport methods (e.g., open trucks, motorcycles, head loading) associated with more losses. Farmers using motorized vehicles experience 46.2% less loss compared to those using non-motorized transport. Harvesting Time, however, was not statistically significant (p = 0.493), implying that although harvesting time is often emphasized, its effect may be less direct or masked by stronger predictors in this context. Farming Experience shows a negative and significant relationship (β = −0.084, p = 0.011), indicating that more experienced farmers tend to lose fewer oranges post-harvest, possibly due to better handling practices and timely decision-making. For every additional year of experience, postharvest losses decrease by 8.4%. The results suggest that addressing storage systems, improving access to markets, shortening the distance to sales points, enhancing transportation quality, and building farmer capacity through experience and training are critical for reducing postharvest losses in orange production in Ushongo LGA.

4.4 Discussion of Findings

The findings of this study confirm that postharvest losses are a major constraint in orange production in Ushongo LGA, with an average PHLI of 23.4%. This aligns with earlier studies which estimate citrus fruit losses in Nigeria and other developing countries at 20–30% (Shagbaor, 2021; Obayelu et al., 2021). The high magnitude of losses suggests systemic inefficiencies in the orange value chain, particularly at the stages of storage, transportation, and marketing. These results are consistent with the FAO (2019) global estimate that fruits and vegetables are among the most wasted crops, with up to half of production lost annually in low-income regions.

The regression results provide further insights into the determinants of losses. The significance of storage method and transportation type highlights the role of infrastructure in determining the volume of fruit that reaches consumers in good condition. Farmers who used traditional storage methods, such as ambient storage in woven baskets, experienced higher losses compared to those using improved methods. This finding corroborates Affognon et al. (2015), who emphasized the absence of cold storage and modern packaging as a primary cause of fruit deterioration in sub-Saharan Africa. Similarly, reliance on open trucks and bulk handling during transportation was found to significantly increase mechanical damage, which is consistent with the findings of Oni (2021) in Kano State and Addy & Diaka (2024) in Ghana.

Another critical determinant was distance to market, which significantly increased postharvest losses. This result resonates with the findings of Khan et al. (2022) in Pakistan, who reported that market inaccessibility was positively correlated with higher citrus losses.

In Ushongo, poor rural road networks prolong travel times and expose fruits to harsh environmental conditions, thus accelerating spoilage. Conversely, market access reduced losses, suggesting that structured marketing channels and cooperative systems help minimize delays and improve quality management. This supports the argument of Kaplinsky and Morris (2001) in value chain theory that effective coordination reduces inefficiencies and preserves value along the chain.

The role of farmer experience was also significant, with more experienced farmers reporting lower levels of postharvest losses. This finding underscores the importance of human capital in agricultural performance and resonates with the Human Capital Theory (Schultz, 1961). Experienced farmers are more likely to employ better harvesting techniques, avoid practices that lead to bruising, and manage transport and storage more effectively. This aligns with Dooga et al. (2021), who found that farmer education and group membership significantly reduced orange losses in Benue State.

Taken together, the findings suggest that postharvest losses in Ushongo LGA are not merely the outcome of physical factors such as fruit perishability but are also shaped by socio-economic and infrastructural constraints. The convergence of results from this study with both African (Olu Kemi, 2022; Ugoh, 2018) and Asian contexts (Zahid et al., 2023; Khan et al., 2022) reinforces the universality of PHL as a development challenge in citrus farming. However, the persistence of high loss levels in Ushongo despite the widespread recognition of the problem points to institutional and policy gaps.

5. Conclusion and Recommendations

This study provides empirical evidence that postharvest losses among orange farmers in Ushongo LGA are significantly high, averaging 23.4% of total harvest. Key determinants include storage method, transport type, distance to market, market access, and farming experience.

The implications are far-reaching. At the household level, significant income is lost, undermining the welfare of farming families who depend on citrus for their livelihoods. At the regional and national levels, high PHL threatens food and nutritional security, reduces the competitiveness of Nigerian citrus in both domestic and export markets, and discourages youth participation in agriculture. Globally, such losses represent wasted resources in terms of land, water, energy, and labor, contributing to environmental degradation and inefficiencies in the food system.

Based on the findings of this study, the following policy recommendations are proposed:

i. The study found that distance to market and transport type significantly influence postharvest losses. Therefore, governments at all levels should prioritize the rehabilitation of rural roads and the provision of cold chain facilities. Improved road networks will reduce travel time and mechanical damage during transportation, while cold storage facilities will extend the shelf life of harvested oranges and allow farmers to store produce during periods of market glut.
ii. **ii.** Given the significant negative effect of storage method on postharvest losses, there is a need to promote affordable packaging materials such as ventilated plastic crates and introduce subsidized technologies for storage. Extension agencies should demonstrate the

benefits of improved storage methods and provide technical support for their adoption among smallholder farmers.

iii. The significant negative coefficient of market access suggests that strengthening cooperative marketing systems and creating structured markets or aggregation centers closer to production areas will reduce losses. When farmers have reliable market outlets, they are less likely to hold produce for extended periods, thereby reducing spoilage. Cooperative societies can also facilitate bulk transportation, which reduces per-unit transport costs and damage.

iv. Negative relationship between farming experience and postharvest losses indicates that knowledge and skills matter. Therefore, agricultural extension services should be strengthened to train farmers on best practices in harvesting, storage, and transportation. Training programs should target younger and less experienced farmers, focusing on proper harvesting techniques, appropriate packaging, and timely marketing.

v. There is a need to integrate postharvest management strategies into national food security policies. Further research should explore scalable innovations in fruit preservation, including low-cost evaporative cooling technologies and biological control methods for postharvest diseases. Policymakers should also consider incentive schemes for private sector investment in postharvest infrastructure in rural citrus-producing areas.

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