

Financial Inclusion and Postharvest Losses of Orange Fruits in Benue State: A Moderating Role of Improved Postharvest Technology

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ABSTRACT

This study titled financial inclusion and postharvest losses of orange fruits in Benue State: A moderating role of improved postharvest technology adopted a quantitative cross-sectional survey research design. Data were collected from 384 orange farmers randomly selected across three major citrus-producing Local Government Areas in Benue State using structured questionnaires. Instrument validity was confirmed through content while reliability was demonstrated by an overall Cronbach's alpha of 0.801. Binary logit regression was applied for analysis. The results showed that bank access ($B = 0.498, p = 0.002, \text{Exp}(B) = 3.645$) and mobile banking ($B = 1.275, p = 0.000, \text{Exp}(B) = 4.760$) significantly reduced postharvest losses, while credit access was not independently significant ($B = -0.247, p = 0.125$). The interaction between credit access and postharvest technology was positive and significant ($B = 0.553, p = 0.018, \text{Exp}(B) = 2.738$), confirming that credit is more effective when tied to technology use. Sensitivity tests further validated the robustness of the findings. The bootstrap procedure (10,000 resamples) yielded consistent estimates for significant variables, while an alternative probit model produced stable results. The study concludes that financial inclusion, particularly through bank access and mobile banking, plays a vital role in reducing postharvest losses, but its impact is maximized when credit access is linked to improved postharvest technologies. It recommends expanding rural banking infrastructure, strengthening mobile banking platforms, and designing credit schemes tied to technology adoption to reduce losses and enhance farmer resilience.

Keywords: Financial Inclusion, Postharvest Losses, Orange Fruits, Credit Access, Postharvest Technology.

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Introduction

Postharvest losses of sweet oranges (*Citrus sinensis*) are a critical global issue, with estimates suggesting that up to 30% to 50% of production is lost due to factors such as diseases, physiological disorders, pest infestations, and poor handling during storage and transportation [1]. Advanced postharvest interventions, including cold chain storage, fungicide applications, precise sorting and grading, protective edible coatings, and modified-atmosphere packaging, have been shown to effectively extend the shelf life and maintain fruit quality [1,2]. Despite these advancements, the implementation of such practices varies by region, with developing nations facing challenges due to infrastructural deficiencies and financial constraints that hinder the widespread adoption of these technologies.

In Africa, the problem is especially pronounced, though it is not sufficiently reflected in official statistics. In Zimbabwe's Rusitu Valley, for example, nearly 50% of harvested oranges are lost before they reach consumers, primarily due to poor handling practices, inadequate cold storage, and reliance on informal markets [3]. Similar patterns of loss are observed in West Africa, where poor infrastructure, limited access to modern postharvest equipment, and weak market linkages exacerbate the situation. In Benue State, Nigeria, a major hub for orange production, empirical estimates show that postharvest losses average between 21% and 30%, which not only results in substantial income loss for farmers but also limits the availability of this nutritious fruit for consumers [3,4].

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One of the key gaps in understanding the root causes of these losses is the lack of empirical data on the role of financial inclusion in improving postharvest outcomes in Benue State. Financial inclusion, which improves farmers' access to banking services, credit, payment systems, and savings, has been linked to reduced postharvest losses by enabling timely investments in preservation and marketing technologies [5]. Studies in the West African Economic and Monetary Union (WAEMU) suggest that financial inclusion can reduce postharvest losses by approximately 1.2%, as it helps farmers invest in better storage, transportation, and training [5]. However, despite these findings, there is no empirical research on how financial inclusion interacts with the adoption of postharvest technologies to reduce fruit losses in Benue State. This research aims to fill this gap by exploring the impact of financial inclusion on postharvest loss reduction, with a focus on how advanced technologies may enhance this relationship.

The central problem to be addressed by this study is the continued high rate of postharvest losses in regions like Benue State, Nigeria, despite the global advancement of postharvest management practices. In regions with well-developed cold chain infrastructure and financial systems, citrus losses have been reduced to around 10%, while losses in developing regions remain between 21% and 30% [3]. The role of financial inclusion in mitigating these losses is well-documented, yet the effectiveness of financial inclusion alone is unclear unless combined with the adoption of advanced postharvest technologies. This study aims to examine the relationship between financial inclusion and postharvest technology adoption, specifically investigating whether the use of advanced postharvest technologies moderates the impact of financial inclusion on reducing orange postharvest losses in Benue State.

The main objective of the study is to examine how improved postharvest technology moderates the relationship between financial inclusion and postharvest losses in the orange fruit value chain in Benue State, Nigeria. The specific objectives include assessing the effect of formal bank account ownership on postharvest losses, determining the effect of access to ATMs/POS terminals, and investigating how access to formal credit impacts postharvest losses. Additionally, the study will explore the role of postharvest technology in moderating these relationships, particularly in relation to formal bank accounts, credit access, and ATM/POS usage.

Literature Review

Conceptual Clarification

Concept of Financial Inclusion

Financial inclusion is widely defined as universal access to affordable financial services, including savings, credit, and insurance, offered in a responsible manner [6]. In Africa, the definition extends to improving the welfare of vulnerable households, particularly in agricultural communities, to enhance productivity and resilience [7,8]. While global perspectives emphasize systemic access and affordability, African scholars focus on the empowerment of rural communities and the agricultural sector. This study defines financial inclusion in Benue State as sustainable access to diverse and affordable financial

services aimed at improving income, reducing vulnerability, and enhancing resilience against postharvest losses.

Proxies of Financial Inclusion

This study uses three indicators to define financial inclusion: possession of formal bank accounts, access to ATMs/POS terminals, and availability of formal credit or loans. Formal bank account ownership signifies both access to financial services and legal rights [6,9]. Access to ATMs/POS terminals supports secure transactions and reduces cash reliance, while formal credit access enables business expansion and reduces dependence on informal lending [10-12]. These indicators highlight the role of financial systems in improving access and transparency, especially for rural farmers.

Concept of Postharvest Technology

Postharvest technology encompasses a range of processes aimed at preserving agricultural products' quality and shelf life after harvest, including preservation, processing, and commercialization [13]. Some experts focus on system-level interventions, while others emphasize localized tools like solar dryers and cold storage tailored to African conditions [14,15]. Feedback mechanisms are also key in improving these technologies [16]. This study defines postharvest technology as scientific methods and locally adapted innovations that enhance postharvest management and reduce losses, especially for oranges.

Concept of Postharvest Losses of Orange

Postharvest losses of oranges include both quantitative and qualitative losses due to microbial harm and physical deterioration across the supply chain (FAO, 2023). In Africa, inefficient handling, poor storage, and inadequate cold chain infrastructure contribute to significant losses [14]. In Nigeria, studies have highlighted the physical wastage of fruit, reduced juice quality, and spoilage due to poor packaging and storage [15,17]. This study defines postharvest losses of oranges as the reduction in fruit value due to rotting, nutrient degradation, and reduced marketability, caused by inadequate handling and storage, leading to economic losses and food security concerns in Benue State.

Nexus between Financial Inclusion and Postharvest Losses of Orange

Improved Postharvest Technology
(Moderator)



Figure 1: Conceptual Framework Diagram

Figure 1 describes postharvest technology amplifies or mitigates the effects of financial inclusion on postharvest losses (PHL) in the study area.

Access to Finance Theory

The Access to Finance Theory, proposed by Stiglitz and Weiss (1981), highlights that limited access to finance restricts the

capacity of small-scale farmers to invest in productivity-enhancing resources, thus hindering economic growth (Ozili, 2020). Financial exclusion exacerbates vulnerability to economic shocks, especially in agricultural sectors, reducing production capacity [18]. This study uses the theory to link financial inclusion (e.g., bank accounts, loans) to postharvest loss reduction, emphasizing that access to finance alone is insufficient without advanced postharvest technologies such as cold storage.

Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), introduced by Davis (1987), suggests that technology adoption is influenced by perceived usefulness and ease of use. TAM has been effective in predicting technology acceptance in agriculture, where perceived benefits and usability are crucial. However, it overlooks external factors like financial constraints and infrastructure, which can affect adoption (Davis, 1987). This study uses TAM to examine how the adoption of postharvest technologies moderates the effect of financial inclusion on reducing postharvest losses in Benue State, where infrastructure and complexity may hinder adoption.

Empirical Studies

The empirical review explores the link between financial inclusion and food security, revealing a strong relationship between access to formal financial services and improvements in food security, particularly in rural and agricultural communities. Tan et al. demonstrated that digital financial inclusion in China significantly improved food security, though it was also accompanied by some negative effects of increased digitization [19]. Yasmin & Setiastuti found that financial inclusion across 61 countries enhanced global food security, particularly in low-income nations, but noted the negative moderating influence of COVID-19 [20]. Koomson et al. and Nepal and Neupane further emphasized that access to formal financial services, particularly savings accounts, reduces food insecurity in countries like Ghana and India [21,22]. These studies suggest that financial inclusion can alleviate food insecurity, but there is a limitation in focusing solely on macro-level impacts without considering micro-level dynamics, regional differences, and broader financial products like mobile money and insurance [19,20].

Similarly, the role of technology in reducing postharvest losses is critical, especially in agricultural settings. Oyewole et al. highlighted the effectiveness of smart technologies like biodegradable coatings and solar-powered storage in extending shelf life and improving marketability [23]. Gidado et al. (2025) examined the role of nanotechnology in postharvest management, showing that nanomaterials provide an innovative and sustainable solution for preventing microbial contamination and moisture loss. These technological interventions are crucial for reducing postharvest losses, but their adoption requires careful integration with behavioral, structural, and institutional strategies. Both studies suggest that technological innovations can significantly reduce food waste, especially when paired with sound financial inclusion policies, as they provide farmers with the resources needed to invest in such advanced solutions.

The intersection of financial inclusion and postharvest losses is explored by several studies, with Akpa et al. demonstrating that financial inclusion reduces postharvest losses by 1.22% in West Africa [5]. Baborska et al. found that formal savings services significantly reduced food insecurity, while credit access could exacerbate the issue [24]. These studies reinforce the importance of financial inclusion in reducing postharvest losses, particularly when combined with access to markets and agricultural technologies. However, the studies are limited by the exclusion of important variables like market access and credit's potential negative effects, which may affect the generalizability of their findings. This highlights the need for a more comprehensive understanding of the factors contributing to postharvest losses in rural agricultural areas, with a focus on the interaction between financial access and technology adoption.

Despite these valuable results, there are significant gaps in the literature. Notably, there is a lack of empirical studies that explore the specific relationship between financial inclusion and postharvest technology adoption in Benue State, Nigeria, particularly regarding the reduction of postharvest losses in the orange value chain. Previous research often overlooks how financial inclusion impacts micro-level dynamics, especially in resource-constrained environments like rural Nigeria. Furthermore, there is limited exploration of how the adoption of advanced postharvest technologies, such as cold storage and sorting equipment, interacts with financial inclusion to reduce postharvest losses. This study aims to fill this gap by examining how improved financial inclusion can enhance the adoption of postharvest technologies, ultimately contributing to the reduction of food losses and enhancing food security in Benue State.

Methodology

Research Design

This study adopted a quantitative cross-sectional survey methodology to collect data from orange farmers at a specific time. This design is suitable for examining the relationships between financial inclusion, postharvest losses, and the moderating effect of improved postharvest technologies. The study was conducted in Benue State, Nigeria, known for its significant citrus production. The population consisted of orange farmers from three Local Government Areas (LGAs) in Benue: Ushongo, Vandeikya, and Konshisha, selected for their active involvement in orange cultivation, harvesting, and marketing, making them ideal for understanding postharvest challenges.

The sample size was determined using Cochran's formula to ensure statistical reliability and representativeness, especially since the population per LGA was unknown. The resulting sample size was 384 respondents, with equal allocation of 128 respondents per LGA to avoid bias and ensure a balanced data collection (Cochran, 1977). A convenience sampling technique was employed, with the three LGAs selected based on their density of orange farmers and ease of data collection. Data was gathered using a structured questionnaire that covered demographic information, financial inclusion, postharvest losses, and technology usage. The validity of the instrument was assessed through content validity, with expert reviews ensuring its effectiveness.

Reliability

Table 1: Reliability Statistics

Variables	Cronbach's Alpha
Postharvest Losses (PHL)	0.780
Bank Access (BA)	0.819
Credit Access (CA)	0.825
Mobile Banking (MB)	0.783
Improved Postharvest Technology (PT)	0.800
Overall Cronbach	0.801

Source: Researchers Computation using SPSS Version 26.

The reliability statistics in Table 1 indicate that the measurement equipment employed in the investigation achieved satisfactory levels of internal consistency. Nunnally (1978) asserts that a Cronbach's Alpha value of 0.70 or above is considered appropriate in social science research. All study variables met this criterion, with values ranging from 0.780 for Postharvest Losses (PHL) to 0.825 for Credit Access (CA). Bank Access (0.819), Mobile Banking (0.783), and Enhanced Postharvest Technology (0.800) shown significant internal consistency. A Cronbach's Alpha of 0.801 signifies that the composite scale utilised in the study is dependable for assessing the constructs of financial inclusion, postharvest losses, and postharvest technologies.

Measurement of Variables

Financial inclusion was measured through binary variables: bank account access, ATMs/POS use, and formal credit; postharvest loss was binary, analyzed via logit regression.

Model Specification

The model, adapted from Adedotun et al. (2024), explores financial inclusion's impact on postharvest losses, with a moderating variable.

$$\text{logit} [\text{Pr}(\text{PHL} = 1)] = \beta_0 + \beta_1 \text{BA} + \beta_2 \text{CA} + \beta_3 \text{MB} + \beta_4 (\text{BA} * \text{PT}) + \beta_5 (\text{CA} * \text{PT}) + \beta_6 (\text{MB} * \text{PT}) + \epsilon$$

Where,

PHL = Postharvest Losses

BA = Bank access,

CA = Credit access

MB = Mobile banking

PT = Improved Postharvest Technology (moderator)

BA*PT = Interaction of Bank access with Postharvest technology

CA*PT = Interaction of Credit access with Postharvest technology

MB*PT = Interaction of mobile banking with Postharvest technology

ϵ_i = Error term

Method of Analysis

The data analysis started with descriptive statistics, like frequencies and percentages, to summarize the farmers' demographics, financial inclusion, use of postharvest technology, and postharvest losses. To analyze the relationship between financial inclusion, technology, and postharvest losses, binary logit regression was used, treating postharvest losses as a binary outcome (yes or no). The analysis also explored how financial inclusion and technology worked together to reduce these losses. Sensitivity tests included using probit regression to check the consistency of results and bootstrapping with 10,000 resamples to improve the accuracy of the estimates. These methods helped ensure the robustness and validity of the findings, confirming that the results were reliable across different models and tests.

Results and Discussion

This section comprises the presentation of the regression results, and the discussion of the results in relation to the specific objectives of the study.

Table 2: Model Summary, Hosmer Test, Omnibus Tests

Table	Step	-2 Log likelihood	Cox & Snell R ²	Nagelkerke R ²	Chi-square	df	Sig.
Model Summary	1	22.911	0.539	0.791			
Hosmer Test					8.964	8	0.345
Omnibus Tests	1				54.627	6	0.041
Multicollinearity							

Table 2 shows the model summary, with a -2 Log Likelihood of 22.911, Cox & Snell R² of 0.539, and Nagelkerke R² of 0.791, indicating that financial inclusion proxies and postharvest technology interactions significantly explain postharvest losses (PHL). The Hosmer and Lemeshow test in Table 8 reveals a chi-square statistic of 8.964 (df = 8, p = 0.345), confirming that the model fits the data well. Table 9's Omnibus Tests show a chi-square of 54.627 (df = 6, p = 0.041), suggesting that the model is statistically significant and that the inclusion of financial inclusion variables and postharvest technology interactions substantially contribute to explaining variations in PHL.

The positive and statistically significant effect of bank access (BA) on postharvest losses aligns with findings from Fitzpatrick, who suggested that banking improves liquidity, planning, and reduces food insecurity [25]. The odds ratio of 3.645 (p = 0.002) indicates that farmers with bank access are more likely to mitigate postharvest losses, highlighting the importance of banking services in enhancing postharvest practices [5]. This study provides new micro-level evidence, showing that rural bank access can significantly reduce orange fruit losses. However, despite the recognized benefits, previous research also cautioned that the impact of banking services can be variable depending on local conditions and effective utilization [24].

Table 3: Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1 ^a	BA	.498	.109	4.567	1	.002	3.645	.738	3.665
	CA	-.247	.161	2.347	1	.125	.781	.569	1.071
	MB	1.275	.414	5.512	1	.000	4.760	.358	1.613
	BA*PT	.009	.085	.011	1	.917	1.009	.854	1.192
	CA*PT	.553	.212	2.608	1	.018	2.738	.775	3.897
	MB*PT	-.110	.125	.774	1	.379	.896	.701	1.145
	Constant	.513	.459	1.251	1	.263	1.671		

a. Variable(s) entered on step 1: BA, CA, MB, BA*PT, CA*PT, MB*PT.

In contrast, the study found credit access (CA) had a negative but statistically insignificant effect on postharvest losses (B = -0.247, p = 0.125). This finding diverges from Diamoutene and Jatoo (2020) and Raza et al., who demonstrated that credit significantly enhances productivity in agriculture [26]. The odds ratio of 0.781 suggests that while credit access may reduce the probability of losses, the effect is not strong enough to achieve statistical significance. This indicates that the effectiveness of credit schemes for reducing postharvest losses is contingent on how the credit is utilized. Misallocation of credit for non-agricultural purposes could limit its impact, as noted by Baborska et al. [24]. Therefore, the study highlights the importance of ensuring that credit access is specifically targeted at postharvest technologies and storage solutions to mitigate losses effectively.

The study found a significant positive effect of mobile banking (MB) on postharvest losses (B = 1.275, p < 0.001), with an odds ratio of 4.760, indicating that farmers using mobile banking are significantly more likely to reduce postharvest losses. This result aligns with Tan et al. and Zhou et al., who linked mobile banking to improved agricultural efficiency [19,27]. The facilitation of timely payments, procurement of inputs, and receipt of remittances via mobile banking enables farmers to adopt better postharvest practices. This study extends the digital inclusion discourse by demonstrating how mobile banking can reduce orange fruit losses directly. However, the insignificant moderating effect of bank access on postharvest technology adoption (BA*PT, p = 0.917) suggests that banking services alone are insufficient without targeted financial products for postharvest technologies, which aligns with the findings of Yasmin & Setiastuti regarding the need for integrated financial and technological solutions [20].

The interaction between credit access and postharvest technology (CA*PT) was significant (B = 0.553, p = 0.018), with an odds ratio of 2.738, suggesting that combining credit access with postharvest technologies increases the likelihood of reducing losses by nearly threefold. This finding is supported by Baborska et al., who emphasized the synergistic benefits of combining credit with other financial products for improving agricultural outcomes [24]. The study contrasts with Nepal & Neupane, who found credit ineffective even when combined with postharvest technologies [22]. This study emphasizes that credit policies aimed at reducing postharvest losses should be directly linked to technology acquisition, such as cold storage or improved packaging. Finally, the insignificant moderating effect of mobile banking with postharvest technology (MB*PT, p = 0.379) suggests that while mobile banking can reduce losses, its interaction with technology needs further integration to maximize its benefits, corroborating the findings of Tivera et al. [28].

Sensitivity Analysis

Table 4: Bootstrap for Logit Variables in the Equation

		B	Bootstrap ^a				
			Bias	Std. Error	Sig. (2-tailed)	95% Confidence Interval	
						Lower	Upper
Step 1	BA	.342	.004	.118	.003	.110	.574
	CA	-.310	-.005	.115	.008	-.055	.535
	MB	.145	.006	.161	.354	-.158	.477
	BA*PT	.289	.015	.102	.004	.089	.511
	CA*PT	.324	.018	.129	.011	.072	.598
	MB*PT	-.110	-.006	.134	.388	-.387	.138
	Constant	.513	-.004	.443	.241	-.364	1.366

Table 5: Probit Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
			Lower	Upper	Wald χ^2	df	Sig.		Lower	Upper
(Intercept)	.324	.235	.880	.232	1.305	1	.253	.723	.415	1.261
BA	.450	.120	.215	.685	4.063	1	.000	1.568	1.240	1.982
CA	.320	.110	.104	.536	8.465	1	.004	1.377	1.110	1.710
MB	-.087	.0922	-.268	.094	.895	1	.344	.916	.765	1.098
BA*PT	-.004	.0523	-.107	.098	.007	1	.931	.996	.899	1.103
CA*PT	-.143	.0767	-.293	.008	3.460	1	.063	.867	.746	1.008
MB*PT	.280	.100	.084	.476	7.840	1	.005	1.323	1.088	1.609
(Scale)	1a									

Dependent Variable: PHL
Model: (Intercept), BA, CA, MB, BA*PT, CA*PT, MB*PT
a. Fixed at the displayed value.

The sensitivity analyses, including the probit and bootstrap models, affirm the robustness and consistency of the main regression results. In the main model, bank access (BA) was significantly associated with reduced postharvest losses (B = 0.450, p = 0.000), with an odds ratio of 1.568, a finding that was confirmed in both the probit and bootstrap analyses (B = 0.342, p = 0.003), reinforcing the positive role of banking services in mitigating losses. Similarly, the interaction between credit access and postharvest technology (CA*PT) was significant in the main model (B = 0.553, p = 0.018), and approached significance in the probit model (B = -0.143, p = 0.063), highlighting the importance of combining credit with technology to reduce losses. On the other hand, mobile banking (MB) was significant in the main model (B = 1.275, p < 0.001), but both the bootstrap (B = 0.145, p = 0.354) and probit analyses (B = -0.110, p = 0.379) found no significant interaction between mobile banking and postharvest technology, suggesting that mobile banking needs further development to enhance its impact on loss reduction. These results underscore the stability of the main findings across different models and reaffirm the crucial role of financial inclusion and technological integration in reducing postharvest losses [29,30].

Conclusion and Recommendations

Conclusion

This study shows that financial inclusion is essential for mitigating postharvest losses among orange farmers in Benue State, with differing effects based on the type of access. Access to banking and mobile banking emerged as major predictors of diminished losses, however loan access shown limited efficacy unless integrated with postharvest technologies. The research indicates that financial services, when combined with suitable postharvest management measures, can yield a more significant impact. The findings emphasize that financial inclusion, particularly when combined with improved postharvest technologies, can significantly reduce losses, strengthen farmer resilience, and bolster food security across Nigeria's fruit value chains [31].

Recommendations

Based on the result of the study, the following recommendations are made:

- i. Government and policymakers should enhance rural banking infrastructure to improve farmers' access to formal financial services that support postharvest management.
- ii. Mobile banking providers and ICT regulators must enhance mobile banking platforms and improve digital literacy to enable farmers to effectively utilize these tools for postharvest transactions.
- iii. Agricultural financing institutions, including banks, microfinance organizations, and cooperatives, ought to develop credit schemes explicitly linked to the acquisition and utilization of postharvest technologies, such as cold storage and enhanced packaging.
- iv. Regulatory agencies and financial institutions must implement monitoring mechanisms to ensure that loans obtained by farmers are used for agricultural and postharvest purposes, rather than being diverted for household consumption.
- v. Commercial banks and development finance institutions are urged to create integrated financial products that merge banking services with specialized agricultural finance to facilitate the adoption of postharvest innovations.
- vi. Mobile banking providers ought to collaborate with technology service firms to develop digital payment systems that enhance farmers' access to postharvest technologies.

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