CHAPTER FOUR

TECHNOLOGY AND POST-HARVEST LOSSES OF TOMATOES IN BENUE STATE

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Abstract

This study examines the impact of technology on the postharvest losses of tomatoes in Benue State, Nigeria. This research aims to evaluate how the adoption of various postharvest technologies affects the reduction of losses in tomato production. A descriptive survey design was employed, and data were collected from a sample of 365 tomato farmers across three local government areas (LGAs) representing each of the State's Senatorial zones. A multistage random sampling technique was used to select respondents. Primary data were gathered through structured questionnaires. The data were analyzed via both descriptive statistics and logistic regression models. The findings reveal that postharvest losses are most prevalent during the transportation and storage stages, with the high cost of technology, lack of awareness, and inadequate information on technology usage being the primary challenges hindering adoption. Technologies such as improved tomato varieties, plastic crates, cold storage, precooling systems, and advisory services were found to significantly reduce postharvest losses at the 5% significance level. The study also highlighted that male farmers dominate tomato production in Benue State, and the majority of farmers have basic education and over 15 years of farming experience. On the basis of these findings, the government should organize periodic training for farmers, improve access to affordable credit, and encourage private investment in cold storage and refrigerated transport infrastructure. These measures would enhance technology adoption, reduce losses, and improve the livelihoods of tomato farmers in Benue State.

Keywords: Agricultural technology, postharvest losses, technology adoption, tomato production

1. Introduction

The global expansion of food production has not resolved food insecurity, as nearly half of the population in developing countries still faces challenges accessing a sufficient food supply (Khatun & Rahman, 2019). One of the primary contributors to this issue is postharvest losses, which involve both physical losses and quality deterioration that reduce the economic value of crops or render them unfit for human consumption. According to the Food and Agriculture Organization (FAO, 2018), approximately one-third of the food produced globally—approximately 1.3 billion tons—is wasted annually after harvest. These losses are particularly pronounced in developing nations, where poor handling, inadequate storage, and environmental factors contribute to significant reductions in both food availability and quality (Kader, 2002).

Postharvest losses are characterized by both quantitative and qualitative degradation, occurring from the point of harvest to consumption. As agricultural products pass through various stages in the supply chain, including storage, processing, and marketing, losses occur due to mishandling and environmental conditions (Kiaya, 2014). In Nigeria, postharvest losses for perishable crops such as tomatoes are particularly high, with estimates suggesting that up to 60% of these crops are lost (Federal Ministry of Agriculture and Rural Development, 2019). This is largely due to the lack of standardized postharvest handling practices, compounded by poor infrastructure and environmental challenges such as inadequate cooling systems, improper storage, and poor packaging materials (Muhammad, Hionu & Olayemi, 2012). These losses not only reduce farmers' income but also decrease the availability of food, leading to higher commodity prices and greater food insecurity.

Tomatoes (Lycopersicum esculentum) are among the most widely consumed vegetables in Nigeria, accounting for approximately 18% of the average daily vegetable intake (Amurtiya & Adewuyi, 2020). However, owing to their high moisture content and perishable nature, tomatoes are particularly prone to postharvest losses during handling, transport, and storage. In Benue State, where tomatoes are a key crop, this problem is especially pronounced. The Nigerian Federal

Ministry of Agriculture and Rural Development (FMARD) reported that out of the 1.5 million tons of tomatoes harvested annually, approximately 700,000 tons are lost due to postharvest delays and inadequate storage facilities (FMARD, 2019). These statistics underscore the urgent need for improved postharvest technologies to reduce losses and increase the economic sustainability of tomato production in Nigeria.

Technological innovations have been identified as critical for mitigating postharvest losses and improving the efficiency of agricultural systems. As Karanyo (2002) noted, modern technology has revolutionized agricultural productivity by introducing methods that reduce waste, enhance food quality, and provide new economic opportunities. Postharvest technologies, such as improved storage facilities, refrigerated transport, modified atmosphere packaging (MAP), and the use of 1-methylcyclopropene (1-MCP), have proven effective in extending the shelf-life of tomatoes and reducing postharvest losses (Kughur, Iornenge & Ityonongu, 2015). These technologies are essential not only for preserving food but also for creating employment opportunities, adding value to agricultural products, and supporting food security goals, as highlighted in Goal 2 of the Sustainable Development Goals (SDGs).

The motivation for this study stems from the persistent issue of postharvest losses in Nigeria's tomato sector, despite government efforts to address the problem through initiatives such as the National Acceleration Food Production Program (NAFPP), the National Special Program on Food Security (2002), and the Agricultural Transformation Agenda (2011), supported by the World Bank (Adesina, 2012). Although these programs have aimed to improve technology transfer to rural farmers and reduce postharvest losses, significant gaps remain, particularly in the application of technology in regions such as Benue State. While previous studies have examined factors contributing to postharvest losses, such as socioeconomic conditions (Ashinya, Nwankwo & Olagunju, 2021), there is a gap in research on the role of technological interventions specifically targeting the reduction of tomato losses in this region (Kuranen-Joko & Dzahan, 2017).

This study seeks to fill that gap by evaluating the impact of technological solutions on postharvest losses in tomato production in Benue State. The central problem of this study focuses on the high postharvest losses of tomatoes in Benue State, Nigeria, despite its potential as a major agricultural hub. Tomatoes, which account for approximately 18% of the average daily vegetable consumption, are highly perishable, leading to significant losses during the postharvest stage. The key research questions of the study are as follows: What are the socioeconomic characteristics of tomato farmers in Benue State? To what extent have tomato farmers adopted postharvest technologies? What factors influence the adoption of these technologies? What is the impact of technology on reducing postharvest losses of tomatoes? The main objective of this research is to examine the effectiveness of technology in containing postharvest losses in tomato production, specifically in terms of the socioeconomic characteristics of farmers, the level of adoption of postharvest technologies, and the factors affecting this adoption. This study is particularly important because addressing postharvest losses is crucial to improving food security, increasing farmer income, and reducing resource waste. It also has implications for state and national policy, helping guide strategies to enhance technological adoption among farmers and mitigate food loss.

The paper is structured as follows: the introduction outlines the background, problem statement, and research objectives, providing a foundation for the study. The literature review explores previous research on postharvest losses and the role of technology in agricultural productivity, identifying gaps that this study seeks to address. The Methodology section describes the research design, including the sampling of three local government areas from each of Benue State’s Senatorial districts and the data collection methods used to analyze farmers' technology adoption and its impact. The Results and Discussion present the findings, analyzing the socioeconomic characteristics of the farmers, their adoption of technology, and its effect on reducing postharvest losses. Finally, the conclusion and policy recommendations summarize the study’s key findings, suggest policy measures to promote the use of postharvest technologies, and offer recommendations to improve food security and sustainability in Benue State's agricultural sector.

2. Literature Review

Theoretical Review

Neoclassical Theory of Production: The neoclassical theory of production, developed by Solow (1957) and Swan (1956), provides the foundation for understanding how economic growth can be sustained through the balance of labor, capital, and technology. Rooted in Adam Smith's (1776) work on the causes of wealth, this theory posits that an equilibrium in production can be achieved by adjusting the inputs of labor and capital. Crucially, when new technologies emerge, these factors must be realigned to maintain growth equilibrium. For agriculture, this theory suggests that technological advancements are essential for increasing productivity, improving efficiency, and reducing losses (Asom, 2016). By increasing labor productivity, technology fosters innovations that reduce postharvest losses and increase overall agricultural output. While Solow emphasized the role of technological progress, he left unresolved the issue of what drives such advancements, regarding them as exogenous (Barro & Sala-i-Martin, 1995). This framework is particularly relevant for exploring how postharvest technologies can mitigate losses in tomato production.

Technology acceptance model (TAM): The technology acceptance model (TAM), proposed by Fred Davis in 1985, provides a theoretical lens through which to understand how users adopt and utilize new technologies. The TAM, an extension of Rogers' (1983) diffusion of innovation theory, explains that technology adoption is influenced by factors such as perceived usefulness (PU) and perceived ease of use (PEU). Davis (1989) argued that a user's attitude toward technology plays a critical role in its adoption, with the decision to use a new system shaped by how beneficial and straightforward the technology is perceived to be. Elgahwash (2013) supports this notion, asserting that if users foresee negative outcomes, such as potential harm or loss, they may reject the technology. For postharvest losses to be effectively reduced, farmers must believe in the utility and ease of the technologies designed to prevent such losses. TAM is essential in this context because it helps explain the behavioral factors influencing the adoption of postharvest technologies by tomato farmers in Benue State.

This study draws on both the neoclassical theory of production and the technology acceptance model (TAM) to explore the impact of technology on postharvest losses in tomato production. Neoclassical theory highlights the crucial role of technology in enhancing labor productivity and improving agricultural output by reducing inefficiencies such as postharvest losses. Moreover, the TAM provides insights into the behavioral factors that influence the adoption of such technologies. Together, these frameworks help explain how technological innovations can reduce postharvest losses and why the success of these innovations depends on the perceived ease of use and usefulness by farmers. This combination of economic and behavioral theories allows for a comprehensive exploration of the challenges and opportunities in postharvest technology adoption in Benue State.

Empirical Review

For postharvest losses and factors affecting tomato production, Hassan *et al*. (2022) studied postharvest losses in Somalia's Bal'ad District, identifying issues such as excessive irrigation, pest infestations, and poor transportation as key contributors to losses. However, the study did not address the role of technology in mitigating these losses. In Nigeria, Ashinya, Nwankwo, and Olagunju (2021) examined the socioeconomic factors affecting postharvest losses among female farmers in Benue State. Their study revealed that factors such as income, education, and farming experience significantly influence losses; however, they did not explore the use of postharvest technologies. Similarly, Goka *et al*. (2021) investigated postharvest tomato losses in Togo, identifying farm size, sex, and storage duration as major contributors. While their study highlighted some socioeconomic factors, it fell short of addressing postharvest technologies in detail. Kuranen-Joko and Dzahan (2017) also explored the factors influencing tomato postharvest losses in Benue State, Nigeria. They utilized descriptive statistics and regression analysis to assess the socioeconomic characteristics of farmers and reported that postharvest losses were predominantly influenced by farm size and household reliance on family labor. While the study provided valuable insights, it focused only on a specific area (Gboko Local Government) within Benue State and did not explore the role of postharvest technologies. Similarly, Amet (2017) investigated postharvest losses in Africa, used Cameroon and Gambia as case studies, and identified key factors such as inadequate storage facilities, poor infrastructure, and a lack of processing equipment as contributors to losses. Although comprehensive, this study was more general and focused on food security and livelihoods rather than specific postharvest technologies.

In addition to socioeconomic factors, other contributors to postharvest losses include poor infrastructure, inadequate storage facilities, and a lack of access to markets. Amedor and Krampah (2016) identified these factors as key challenges in Ghana's Esikuma Odoben Brakwa District, emphasizing the need for improved storage and transportation networks to reduce losses. Similarly, Kughur *et al*. (2015) examined postharvest losses of fruits and vegetables among small-scale farmers in Benue State, Nigeria, via purposive sampling and multiple regression analysis. The study highlighted inadequate storage and transportation as major contributors to losses but did not investigate how technology could alleviate these issues. Aidoo *et al*. (2014) also reported that storage duration, farm size, and farmer-based organization membership were significant factors influencing tomato postharvest losses in Ghana. These studies emphasize the infrastructural and logistical challenges faced by farmers but often overlook the potential of technological interventions to address these problems.

Several empirical studies have examined the factors influencing the adoption of postharvest technologies, with a focus on socioeconomic characteristics. Elemasho *et al*. (2017) used a snowball sampling technique in Rivers State, Nigeria, to investigate the determinants influencing the adoption of postharvest technologies for food crops. Their study revealed that factors such as education level, income, and access to information significantly impacted the adoption of these technologies. While relevant, this study focused on general food crops and not specifically on tomatoes, and its geographical scope was limited to Rivers State. In a similar study in Tanzania, Mtui (2017) examined the cost of postharvest losses of various vegetables and reported that factors such as education level, extension services, and farm size significantly affected the choice of postharvest handling technique. However, this study did not directly address postharvest technologies for tomatoes, leaving a gap in the analysis of technology's role in mitigating losses for this particular crop. In examining technological interventions in postharvest management, Ohagwu *et al*. (2021) assessed various tomato storage technologies, such as charcoal cooler storage bins, and reported that such innovations could extend shelf-life and improve quality. This study focused on a single type of technology, leaving the broader array of postharvest innovations unexplored. Odeyemi *et al*. (2021) compared the use of a zero energy cooling chamber (ZECC) and other technologies across Nigeria, Rwanda, and India and reported that these technologies reduced postharvest losses by up to 30%. However, the methodology used differed significantly from that used in the present study. Similarly, Tesfaye (2019) examined tomato handling practices in Ethiopia and concluded that improved postharvest practices could reduce losses, but this study did not examine the impact of specific technologies.

The economic implications of postharvest losses have been extensively explored in the literature. Alidu *et al*. (2016) studied postharvest losses among tomato growers in Ghana and reported that such losses significantly reduce farmers' revenues, affecting their economic stability. Similarly, Adepoju (2014) examined the effect of postharvest losses on the welfare of tomato growers in Ogbomosho, Osun State, Nigeria, via descriptive statistics and regression models. The study concluded that postharvest losses had a negative impact on farmers' income and overall welfare, but it did not investigate the influence of postharvest technologies and focused instead on the socioeconomic determinants of losses. These studies underscore the economic burden of postharvest losses but leave a gap in understanding how the adoption of technology could alleviate these losses.

While several studies have addressed postharvest losses, fewer have focused on the role of technology in mitigating these losses. Ohagwu *et al*. (2021) evaluated the use of charcoal cooler storage bins as a postharvest technology for preserving tomatoes in Nsukka, Nigeria. The study revealed that the adoption of such technologies significantly extended the shelf life of tomatoes and reduced spoilage, yet the research considered only one type of technology and was geographically limited. Odeyemi *et al*. (2021) explored the use of zero energy cooling chambers (ZECCs) in reducing postharvest losses in Rwanda and Nigeria and reported that the technology reduced losses by up to 30%. However, the study was more comparative and did not focus exclusively on Benue State or tomato farmers. This highlights a gap in the research, as there is limited empirical evidence on the effectiveness of a broader range of postharvest technologies in specific Nigerian contexts, particularly in Benue State.

Research Gap

The empirical review reveals a significant gap in the literature regarding the impact of technology on postharvest losses in tomato production, particularly in Benue State, Nigeria. While several studies have investigated the socioeconomic determinants of postharvest losses (Kuranen-Joko & Dzahan, 2017; Ashinya *et al*., 2021) and the economic impact of these losses (Alidu *et al*., 2016; Adepoju, 2014), very few have specifically examined the role of technology in mitigating such losses. Furthermore, existing studies that focus on postharvest technologies, such as those by Ohagwu *et al*. (2021) and Odeyemi *et al*. (2021), have been limited in scope, either focusing on a single technology or exploring regions outside of Benue State. This study aims to fill this gap by assessing the adoption of various postharvest technologies by tomato farmers in Benue State and evaluating their effectiveness in reducing losses. Additionally, this research explores the factors influencing the adoption of these technologies, providing a comprehensive analysis of how technological interventions can address postharvest losses and improve food security in the region.

3. Methodology

This study employed a descriptive survey design, a method suitable for gathering and systematically describing data from a sample that represents a larger population. According to Akuezuilo and Agu (2002), this design is appropriate when investigating the characteristics, opinions, and facts of selected individuals without altering any variables. The descriptive survey design allows for the collection of detailed data from tomato farmers in Benue State, enabling the researcher to generalize findings about the impact of postharvest technology on tomato production.

The study was conducted in Benue State, Nigeria, which is located in the central region of the country. The state covers 30,955 square kilometers and is known as the “Food Basket of the Nation” because of its vast agricultural output. Farming is the dominant occupation, with 80% of the population engaged in agriculture, producing crops such as yams, cassava, rice, and, notably, tomatoes. The study focused on three local government areas (LGAs) representing the state’s three agricultural zones, namely, Ushongo (Zone A), Gboko (Zone B), and Otukpo (Zone C), which were chosen because of their large-scale tomato production.

The study population consisted of tomato farmers across the selected LGAs in Benue State. According to the Federation of Benue Pepper, Tomatoes, Porters, Transporter and Marketing Cooperative Union Limited (2021), the total population of tomato farmers in these areas is 4,212 (Ushongo: 1,320, Gboko: 2,480, and Otukpo: 412).

A multistage random sampling technique was used to ensure adequate representation from each LGA. First, the state was stratified into its three agricultural zones (A, B, and C), and one LGA was purposively selected from each zone on the basis of its tomato production. In the second stage, a sample size of 365 farmers was determined via the Yamane (1967) formula. The final stage involved selecting respondents from each LGA proportionally to their population sizes. Simple random sampling was employed to avoid bias, ensuring that each respondent had an equal chance of selection. The sample sizes were as follows: Ushongo (114), Gboko (215), and Otukpo (36). Data were collected via both primary and secondary sources. Primary data were gathered through structured questionnaires. A total of 365 questionnaires were distributed and successfully retrieved, resulting in a 100% response rate. Secondary data were obtained from relevant publications, books, journals, and government reports.

The data collected focused on variables such as farmers' socioeconomic characteristics (sex, age, education, household size, and farming experience), farm size, cost of production, income, sources of labor and finance, and postharvest losses. The study also gathered information on the adoption of postharvest technologies, such as improved crop varieties, cold storage, plastic crates, and refrigerated vans.

Method of Data Analysis

The study utilized both descriptive statistics and econometric models to analyze the data. Descriptive statistics, such as percentages and tables, were used to summarize and present the data. The study employed logit regression analysis to test the stated hypotheses and determine the impact of postharvest technologies on tomato losses. The model specification was as follows: dependent variable: PHL of tomatoes (measured as 1 for losses and 0 otherwise). Independent variables: Socioeconomic factors and adoption of various postharvest technologies. Logit regression was chosen because it is appropriate for analyzing categorical data and estimating the probability of an event occurring, such as a postharvest loss.

Model Specification

The study developed three models for different objectives. For a logistic regression model in a survey data study, the specification needs to reflect that the dependent variable is binary (i.e., whether or not postharvest losses occur). Logistic regression predicts the probability that the dependent variable takes a value of 1 (in this case, postharvest losses) on the basis of the independent variables (e.g., education, sex, age, etc.). Below is the correct specification for your models:

Model I: Logistic Regression for Postharvest Losses

This model aims to assess the impact of socioeconomic characteristics and technology adoption on postharvest losses.

$$Logit(P(Y=1)) = \ln(\frac{P(Y=1)}{1-P(P=1)}) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + +\beta_{13} X_{13} + \mu_t$$

Y= Postharvest loss of tomato (1 = loss, 0 = no loss),
X_1= Education (1 = educated, 0 = not educated),
X_2= Sex (1 = male, 0 = female),
X_3= Age (years),
X_4= Area of land cultivated (hectares),
X_5= Quantity of tomatoes harvested (in basket),
X_6= Improved variety of crop (1 = adopted, 0 = not adopted),
X_7= Use of plastic crates (1 = adopted, 0 = not adopted),
X_8= Availability of cold rooms (1 = available, 0 = not available),
X_9= Use of refrigerated vans (1 = adopted, 0 = not adopted),
X_{10}= Precooling (1 = adopted, 0 = not adopted),
X_{11}= Advisory services (1 = received, 0 = not received),
X_{12}= Stage of harvest (1 = fully ripe, 0 = not fully ripe)
X_{13}= Time of harvest (1 = morning, 0 = otherwise), and μ_t= Error term

Extent of Technology Adoption

This metric evaluates the extent of postharvest technology adoption by farmers. The extent is calculated as a proportion of technologies adopted.

$$\text{Extent of Technology Adoption (TA)} = \frac{\text{Number of Technologies Adopted (NTA)}}{\text{Total Number of technologies Available (TNA)}} \times 100$$

This provides a percentage value indicating the degree of adoption by farmers.

Model II: Logistic Regression for Factors Affecting Technology Adoption

This model examines the factors influencing the extent of postharvest technology adoption among farmers.

$$\text{Logit}(P(TA=1)) = \ln\left(\frac{P(TA=1)}{1-P(TA=1)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + + \beta_5 X_5 + \mu_t$$

TA= Extent of technology adoption (1 = adopted, 0 = not adopted),
X_1= Education (1 = educated, 0 = not educated),
X_2= Income (in Naira),
X_3= Area of land cultivated (hectares),
X_4= Advisory services (number of services received),
X_5= Cost of technology (in Naira), and μ_t= Error term.

4. Results and Discussion

This section presents the results of the study, which analyzes data collected through structured questionnaires.

Socioeconomic and demographic characteristics of tomato farmers

Table 1 presents the socioeconomic and demographic data of the sampled tomato farmers in Benue State. The majority of the respondents (52.8%) were aged between 36 and 50 years, with 72.3% being male. Most respondents (59.7%) were married, and 41.4% had completed primary education. In terms of occupation, 71.5% of the respondents were primarily engaged in farming, and most (41.1%) had over 15 years of farming experience. The majority (55.9%) of the farmers managed farms larger than 7 hectares.

Table 1: Socioeconomic and demographic characteristics of tomato farmers

Characteristics	Frequency (n = 365)	Percentage (%)
Age		
18–35 years	113	31.0
36–50 years	193	52.8
51 years and above	59	16.2
Sex		
Male	264	72.3
Female	101	27.7
Marital Status		
Single	85	23.3
Married	218	59.7
Widow/Widower	24	6.6
Divorced	38	10.4
Educational Background		
No Formal Education	49	13.4
Primary	151	41.4
Secondary	103	28.2
Tertiary	62	17.0
Farm Size		
Below 3 hectares	31	8.5
4–6 hectares	130	35.6
7 hectares and above	204	55.9

Source: Field Survey, 2021

Respondents' perceptions of technology and postharvest losses

The results indicate that a significant proportion of farmers' experience postharvest losses at various stages of tomato production, particularly during transportation and storage. Most farmers (40%) produce between 51–100 baskets annually (Table 2), and nearly half (49.3%) rely on both hired and family labor for production (Table 3).

Table 2: Results for total annual output (in baskets)

Total Annual Output (in baskets)	Frequency	Percentage (%)
Below 50 baskets	98	26.8
51–100 baskets	146	40.0
101 baskets and above	121	33.2

Source: Field Survey, 2021

Table 2 shows that 45% of the farmers spent more than N50,001 on hired labor annually, whereas Table 5.5 illustrates that significant losses occurred during the transportation and storage stages, with 50.7% and 32.4% of the respondents reporting losses below 10 baskets and over 20 baskets, respectively.

Table 3: Results on Source of Labor

Source of Labor	Frequency	Percentage (%)
Hired	109	29.9
Family	76	20.8
Both Hired & Family	180	49.3

Source: Field Survey, 2021

Adoption of postharvest technologies

Table 4 summarizes the adoption of postharvest technologies by farmers. The most widely adopted technologies were the maturity stage of harvest (80.5%) and precooling (78.6%). However, only 20.8% used cold rooms, and no respondents adopted refrigerated trucks, indicating gaps in technology use.

Table 4: Technology adopted by farmers

Technology Adopted	Number of Respondents (Frequency)	Percentage (percent)
Use of improved variety of crop	218	59.7
Use of plastic creates	241	66.0
Use of cold rooms	76	20.8
Use of refrigerated trucks	0	0
Precooling	287	78.6
Advisory services	98	26.8
Maturity stage of harvest	294	80.5
Time of harvest	276	75.6

Source: Field Survey, 2021

Challenges to Technology Adoption in the Benue State

Table 5 outlines the challenges respondents encountered in adopting postharvest technologies. The most significant barriers were the high cost of acquisition (33.4%) and lack of awareness (26.6%).

Table 5: Challenges encountered by respondents in the adoption of technology

Challenges	Number of Respondents (Frequency)	Percentage (percent)
Lack of awareness of technology	97	26.6
High cost of acquisition	122	33.4
Inadequate information on proper usage	88	24.1
Ineffectiveness of technology	35	9.6
Others	23	6.3
Total	**365**	**100**

Source: Field Survey, 2021

Table 5 shows the problems encountered by respondents in adopting technologies to reduce postharvest losses. The majority of respondents (33.4 percent) reported that the high cost of acquiring some technologies was a significant barrier, 26.6 percent indicated that they were unaware of certain technologies, 24.1 percent said that they had inadequate information on how to use some technologies, 9.6 percent reported that some technologies were ineffective, and 6.3 percent cited other unspecified reasons. This finding is corroborated by Agbarevo (2013), who stated that the effectiveness of information about a technology influences its adoption by farmers and that poor information leads to poor adoption. According to Kinyangi (2014) and Mosimabale (2011), one of the hindrances to the widespread adoption of postharvest practices as an alternative method for reducing losses is that a greater understanding of the skills and knowledge involved is needed. Similar findings by Maxwell (2014) revealed that the high cost of technology was the most pressing constraint affecting farmers' adoption of technology in Sub-Saharan Africa.

The impact of technology on postharvest losses of tomatoes in the Benue state

The regression analysis conducted in this study aimed to assess the effects of various technological factors on the postharvest losses of tomatoes in Benue State, Nigeria.

The results are presented in Table 6.

Table 6: Regression Results of Model I

Variable	Coefficient	Std. Error	z-Statistic	Prob.
X1 (Education)	0.911225	0.452546	2.013554	0.0441
X2 (Gender)	1.872949	0.490826	3.815912	0.0001
X3 (Age)	0.408203	0.291150	1.402037	0.0109
X4 (Farm Size)	1.975971	0.556999	3.547528	0.0614
X5 (Quantity Harvested)	1.564517	0.331899	4.713831	0.0000
X6 (Improved Variety)	-0.515243	0.654220	-0.787569	0.0309
X7 (Plastic Crates)	-0.660512	0.679575	-0.971948	0.0311
X8 (Cold Room)	-1.144944	0.707028	-1.619375	0.0054
X9 (Refrigerated Van)	-1.136817	0.657334	-1.729435	0.1037
X10 (Precooling)	-0.772439	0.414251	-1.864664	0.0222
X11 (Advisory Service)	-2.258623	0.693314	-3.257721	0.0011
X12 (Stage of Harvest)	-0.426758	0.556401	-0.766997	0.4431
X13 (Time of Harvest)	-2.156093	0.560975	-3.843476	0.0001
C (Constant)	1.708698	0.585453	2.918593	0.0035
McFadden R-squared	0.644731			
LR statistic	140.8803			Prob (LR statistic)

Source: Field Survey, 2021.

From Table 6, the positive and statistically significant coefficient of education suggests that lower educational attainment is associated with greater postharvest losses. This finding is consistent with the argument that education opens farmers' minds to modern agricultural practices and technologies, thereby improving their capacity to reduce postharvest losses. Farmers with limited education may lack knowledge of critical techniques such as proper harvesting methods, storage options, and the use of advanced technologies that could mitigate these losses. These results align with the findings of Oduro-Ofori, Aboagye, and Acquaye (2014), who highlighted the role of education in improving agricultural productivity, and Ohagwu *et al*. (2021), who also reported that educated farmers are better positioned to adopt innovative agricultural technologies. Therefore, improving the educational status of farmers can clearly be a critical strategy for addressing postharvest losses.

Gender also emerged as a significant factor, with a positive coefficient indicating that, compared with female farmers, male farmers are more likely to experience postharvest losses. This finding contrasts with some studies that have suggested minimal gender differences in postharvest losses, such as Affognon *et al*. (2015). However, the current study confirms that gender plays a substantial role in agricultural output, as also observed by the FAO (2018) and Goka *et al*. (2021). The explanation for this could lie in the traditional gender roles and land ownership patterns in many parts of Nigeria, where men are more likely to be allocated land and take on the primary responsibilities for farming. As a result, they may face greater challenges in managing the scale of operations, especially in the absence of adequate postharvest management practices.

Age is another factor that significantly influences postharvest losses, with older farmers showing a tendency toward greater losses. The positive coefficient of age suggests that older farmers may be less inclined to adopt new technologies and innovations, possibly because of a preference for traditional farming methods or a reluctance to change. This aligns with the argument that younger farmers, being more open to innovation, are likely to adopt modern technologies that reduce losses. These findings imply that efforts to reduce postharvest losses should include targeted training and outreach programs specifically designed to encourage older farmers to adopt modern practices.

Farm size, while showing a positive coefficient, was not statistically significant, indicating that farm size alone does not have a substantial effect on postharvest losses. This contrasts with studies such as Babalola *et al*. (2010), who suggested that larger farms might experience more losses due to difficulties in managing harvest and storage. However, the findings of this study suggest that the availability of adequate storage facilities and labor, rather than farm size per se, are more critical determinants of postharvest losses. Thus, the focus should be on providing adequate storage solutions and ensuring that farmers have access to the labor necessary to manage large harvests efficiently, irrespective of farm size.

One of the key findings of this study was the significant impact of the quantity of tomatoes harvested on postharvest losses. As expected, larger quantities of harvested tomatoes were associated with increased losses, largely due to inadequate storage facilities and the labor-intensive nature of handling large volumes. This finding is consistent with previous studies by Aidoo, Danfoku, and Mensah (2014) and Babalola *et al*. (2010), who reported that insufficient storage capacity exacerbates losses, especially during peak harvesting periods. Addressing this issue would require investments in infrastructure, such as cold storage facilities, to accommodate large harvests and reduce the dependence on manual labor, which often leads to delays and inefficiencies in handling the produce.

The study also highlighted the importance of specific postharvest technologies in reducing losses. The use of improved tomato varieties was found to significantly decrease postharvest losses, as these varieties are often bred for better shelf-life and resistance to spoilage. This finding is supported by Moneruzzaman *et al*. (2009) and Aidoo *et al*. (2014), who noted the critical role that improved crop varieties play in reducing losses. Similarly, the adoption of plastic crates instead of traditional raffia baskets was found to significantly reduce losses during transportation and storage. This result aligns with the findings of Muhammad, Hionu, Olayemi (2012) and Njume *et al*. (2020), who reported that plastic crates provide better protection for tomatoes during transport and storage, thereby minimizing damage and spoilage.

The use of cold storage facilities, such as cold rooms, has also proven to be a significant factor in reducing postharvest losses. The negative and statistically significant coefficient for cold room usage underscores the importance of temperature control in preserving the quality of harvested tomatoes. This finding corroborates the work of Yahaya and Mardiyya (2019), who emphasized the critical role of cold storage in extending the shelf-life of perishable crops. Similarly, precooling systems were found to be effective at reducing postharvest losses, as they help rapidly lower the temperature of harvested tomatoes, thereby slowing the rate of spoilage. This result is consistent with the findings of Yahaya and Mardiyya (2019) and Njume *et al*. (2020), who demonstrated the benefits of precooling in reducing losses.

The provision of advisory services was another significant factor influencing postharvest losses. The negative coefficient associated with advisory services implies that access to information and guidance on modern agricultural practices significantly reduces losses. This finding supports the conclusions of Sinyolo, Mudhara, and Wale (2014), who argued that advisory services provide farmers with access to new technologies and knowledge, which ultimately improves agricultural productivity. The stage and time of harvest are also important considerations. The results revealed that tomatoes harvested at the appropriate stage and time, particularly during the cooler parts of the day, experienced significantly lower losses. This finding is in line with previous studies by Muhammad *et al*. (2012) and Obekpa (2018), who emphasized the importance of harvesting tomatoes at the right time to minimize spoilage.

The H-L statistic is reported as 0.1133, which is greater than 0.05, indicating that the model adequately fits the data. The Andrews test statistic is 85.7808, which is significant at the 5% level, confirming that the model has a good fit. The Hosmer-Lemeshow test for goodness-of-fit returned a significance value of 0.1133, indicating that the model fit the data adequately.

Extent of Technology Adoption

The extent of technology adoption was calculated as follows:

$$TA = \frac{7}{8} \times 100 = 87.5\%$$

This indicates that 87.5% of available technologies were adopted by farmers in Benue State, reflecting a relatively high adoption rate despite certain challenges.

Factors affecting the level of adoption of postharvest technology in the Benue state

The regression analysis presented in Table 7 assesses the factors that influence the adoption of postharvest technologies in tomato production.

7: Regression Results of Model II

Variable	Coefficient	Std. Error	z-Statistic	Prob.
X1 (Education)	1.427949	0.291482	4.898917	0.0000
X2 (Income)	0.596532	0.441353	1.351598	0.1765
X3 (Area of Land)	0.489891	0.499524	0.980716	0.3267
X4 (Advisory Services)	1.314537	0.508429	2.585490	0.0097
X5 (Cost of Technology)	-1.024871	0.486668	-2.105892	0.0352
Constant (C)	-0.480496	0.266166	-1.805247	0.0710

Source: Field Survey, 2021

The results in Table 7 indicate that education is the most significant factor influencing the adoption of postharvest technologies. The positive and highly statistically significant coefficient (1.427949) for education suggests that as the educational level of farmers increases, so does the likelihood of adopting new technologies. This finding highlights the vital role that education plays in equipping farmers with the knowledge and skills necessary to understand, implement, and benefit from innovative agricultural practices. Educated farmers are more likely to be aware of the existence of postharvest technologies, understand their benefits, and have the ability to apply them effectively. This result aligns with the findings of previous studies, such as those by Oduro-Ofori *et al*. (2014) and Aidoo *et al*. (2014), which emphasize the importance of education in agricultural technology adoption.

Income also plays a positive, though less pronounced, role in influencing the adoption of postharvest technologies. The positive coefficient (0.596532) for income indicates that as farmers' income levels increase, so does their likelihood of adopting new technologies. However, this factor was not statistically significant at the 5 percent level, suggesting that while income is important, it may not be the primary driver of adoption in the context of Benue State. This finding suggests that although wealthier farmers may have greater financial capacity to invest in postharvest technologies, other factors, such as education and access to advisory services, may play a more critical role in facilitating adoption. The implications of this finding are twofold: first, increasing farmers' income alone may not be sufficient to increase technology adoption; second, efforts to increase adoption should focus not only on financial resources but also on providing education and support services that empower farmers to make informed decisions.

The area of land cultivated also positively influenced the adoption of postharvest technologies, as indicated by the positive coefficient (0.489891). However, similar to income, this factor was not statistically significant at the 5 percent level, which suggests that while larger farm sizes may be associated with greater technology adoption, it is not a decisive factor in this context. This finding contrasts with those of several previous studies, which suggest that larger farm sizes often lead to higher adoption rates because economies of scale make it more cost-effective to invest in technologies. However, in the case of Benue State, the marginal influence of farm size could indicate that smallholder farmers are just as likely as their larger counterparts are to adopt technologies, provided that they have access to the necessary resources, knowledge, and support.

Advisory services emerged as another significant factor positively influencing the adoption of postharvest technologies, with a coefficient of 1.314537, which was statistically significant at the 5 percent level. Advisory services provide farmers with access to crucial information about new technologies, training on how to use them effectively, and guidance on best practices for reducing postharvest losses. The availability of such services can bridge the knowledge gap that often hinders technology adoption, particularly among less educated or more traditional farmers. This result is consistent with the findings of Sinyolo, Mudhara, and Wale (2014), who emphasized the role of extension services in facilitating technology adoption by smallholder farmers.

Interestingly, the cost of technology emerged as a significant barrier to adoption, with a negative coefficient (-1.024871), indicating that higher costs deter farmers from adopting new postharvest technologies. This finding aligns with numerous studies that have identified the high cost of agricultural technologies as a major obstacle to their widespread adoption, particularly in developing countries. The statistical significance of this variable suggests that even when farmers recognize the benefits of adopting postharvest technologies, the financial burden associated with purchasing, maintaining, and operating these technologies may prevent them from doing so.

In terms of model fit, the McFadden R-squared value of 0.414624 indicates a moderate level of explanatory power, suggesting that the independent variables collectively explain approximately 41% of the variation in the dependent variable (technology adoption). This is a relatively strong result for models examining behavioral outcomes such as technology adoption, which are often influenced by a wide range of socioeconomic, cultural, and environmental factors. The LR statistic (92.10) further confirms the overall significance of the variables incorporated in the model, suggesting that the model as a whole provides a robust explanation of the factors influencing technology adoption among tomato farmers in Benue State.

5. Conclusion and Policy Recommendations

The study concludes that education is crucial for reducing postharvest tomato losses in Benue State, as it enhances farmers' ability to apply modern practices. Gender differences, age, and the quantity of tomatoes harvested also influence losses, with older farmers and higher harvest volumes leading to increased losses. The adoption of technologies such as improved varieties, plastic crates, and cold storage significantly reduces losses, whereas high technology costs remain a major barrier among other factors, such as limited awareness and inadequate infrastructure. Despite these barriers, many farmers are already adopting various technologies. However, these barriers still hinder the widespread and effective use of available technologies. On the basis of the findings of this study, several targeted actions have been proposed to address the issue of postharvest losses in tomato production in Benue State. These recommendations are aimed at enhancing the capacity of tomato farmers, improving infrastructure, and encouraging greater investment in postharvest technologies.

First, the government, through the Ministry of Agriculture and other related bodies, should organize and implement regular training programs, workshops, and seminars focused on modern harvesting techniques, proper postharvest handling, and improved storage practices. These initiatives should be conducted in farming districts and tailored to the specific needs of local farmers. The training sessions should include practical demonstrations and hands-on approaches, with a focus on reducing postharvest losses and improving the quality of tomatoes. Agricultural research institutions and universities should be involved in this capacity-building effort, providing expert trainers and access to the latest research and techniques in postharvest management. This collaborative effort will ensure that farmers receive up-to-date and relevant information, empowering them to reduce postharvest losses effectively.

The Agricultural Development Project (ADP) extension agents and other agricultural advisory bodies must also intensify their outreach efforts to educate farmers on the best practices for postharvest management. To increase the effectiveness of these programs, extension agents should target more rural areas, ensuring that information on better storage, packaging, and transportation techniques reaches all tomato farmers. These efforts should be complemented by regular field visits, during which extension agents can provide personalized advice and guidance on postharvest management. To support these agents, the government must provide adequate resources, including vehicles, teaching materials, and tools necessary to facilitate efficient outreach. Coordination among ADP agents, farmer cooperatives, and local leaders is crucial in mobilizing farmers and ensuring high levels of participation in these programs.

Private sector involvement in postharvest infrastructure development should be encouraged through various incentives. The government should actively promote private investment in the construction of cold storage facilities and refrigerated transportation solutions at the local and district levels. Incentives such as tax breaks, subsidies, and grants could attract entrepreneurs to invest in postharvest infrastructure, helping to mitigate the significant postharvest losses experienced by farmers. A public–private partnership (PPP) model could be considered for the development of these facilities, where the state and private sector collaborate to ensure that infrastructure projects meet local needs. Local governments should assist in land acquisition and ensure that the construction of cold storage units adheres to regulatory standards, thereby providing farmers with access to facilities that extend the shelf life of their tomatoes.

In addition to cold storage, there is an urgent need for refrigerated transportation solutions to prevent spoilage during the transit of tomatoes from farms to markets. The government, in collaboration with private logistics companies, should introduce a fleet of refrigerated vehicles that farmers can access at subsidized rates or through cooperative arrangements. These cooperatives pool resources to ensure that farmers, especially smallholders, can afford these services. By improving transportation infrastructure and ensuring that tomatoes are transported under the right conditions, postharvest losses during transportation can be significantly reduced. Additionally, transportation cooperatives should be strengthened to streamline logistics and ensure the timely delivery of produce to markets.

Financial institutions must play a central role in supporting farmers by providing them with access to affordable credit. Tailored financial products should be developed to meet the specific needs of smallholder farmers, enabling them to invest in essential postharvest technologies such as refrigerators, plastic crates, and cooling systems. The Central Bank of Nigeria (CBN) and other regulatory bodies should encourage banks and microfinance institutions to offer low-interest loans (capped at no more than 0.9%) with flexible repayment terms that align with the agricultural cycle. Partnerships between financial institutions and farmer cooperatives could further streamline the loan process, with cooperatives acting as guarantors for farmers. This arrangement ensures that credit is both accessible and manageable, thus empowering farmers to invest in the necessary tools to reduce postharvest losses.

Another critical recommendation is the creation of well-organized and efficient markets for tomato farmers. The government should work with market associations and local governments to establish centralized markets equipped with appropriate infrastructure, including storage facilities and cooling units. These organized markets would offer farmers a reliable outlet for their produce, reducing the risk of spoilage while they wait for buyers. Furthermore, the government must prioritize investments in rural road networks to improve transportation efficiency. Poor road conditions constitute one of the major factors contributing to postharvest losses during transportation. Therefore, the Federal and State Ministries of Works and Transportation should collaborate to ensure that roads connecting tomato-producing areas to major markets are well maintained and expanded where necessary.

References

Abimbola, O. A. (2014). Postharvest losses and welfare of tomato farmers in Ogbomosho, Osun state, Nigeria. *Journal of Stored Products and Postharvest Research, 5*(2), 8–13.

Adegbola, A., Bamishaiye, E. I., & Olayemi, F. (2011). Factors affecting the adoption of the reusable plastic vegetable crate in three local government areas of Kano State, Nigeria. *Asian Journal of Agricultural Sciences, 3*(4), 281–285.

Adeniyi, M. O. (1977). Status of plant protection in the operation feed the nation programmes. Presidential address delivered at its 7th Annual Conference at Institute of Agriculture Research and Technology (IAR&T), Moore Plantation, Ibadan, 10–17.

Adepeju, A. O. (2014). Postharvest losses and welfare of tomato farmers in Ogbomosho, Osun state, Nigeria. *Journal of Stored Products and Postharvest Research, 5*(2), 8–13.

Adesina, A. (2012). Agricultural transformation agenda: Repositioning of agriculture to drive Nigeria's economy. *Federal Ministry of Agriculture and Rural Development*.

Affognon, H., Mutungi, C., Saginga, P., & Borgmeister, C. (2015). Unpacking postharvest losses in Sub-Saharan Africa: A meta-analysis. *World Development, 66,* 49–68.

Agba, S., Ode, I., Ugbem, C., & Nwafor, S. (2019). Analysis of postharvest losses of yam in the North–East Zone of Benue State, Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology, 32*(4), 1–11.

Agbarevo, M. N. B. (2013). Farmers' perception of effectiveness of agricultural extension delivery in Cross River State, Nigeria. *Journal of Agriculture and Veterinary Science*, *2*(6), 45–53.

Agboola, S. D. (1980). The role of the Nigerian Stored Products Research Institute in Nigeria's march toward self-sufficiency in food. *NSPRI Occasional Paper Series*, *117*, 25–29.

Aguayo, E., Escalona, V. H., & Artés, F. (2006). Effect of cyclic exposure to ozone gas on physicochemical, sensorial and microbial quality of whole and sliced tomatoes. *Postharvest Biology and Technology*, *39*(2), 169–177.

Aidoo, R., Danfoku, R. A., & Mensah, J. O. (2014). Determinants of postharvest losses in tomato production in the Offinso North district of Ghana. *Academic Journals, 6*(8), 338–344.

Ajagbe, B. O., Oyediran, W. O., Omoare, A. M., & Sofowora, O. O. (2014). Assessment of postharvest practices among tomato farmers/processors in Abeokuta North Local Government Area of Ogun State, Nigeria. *International Journal of Education and Research, 2*(3), 1–12.

Akangbe, J. A., Ogundiran, T. J., Komolafe, S. E., Ifabiyi, J. O., & Ajibola, B. O. (2014). Tomato farmers' adoption level of postharvest value addition technology and its constraints in Surulere Area of Oyo State, Nigeria. *Journal of Agriculture and Social Research*, *14*(1), 91–97.

Alidu, F. A., Ali, B. A., & Aminu. (2016). Determinants of postharvest losses among tomato farmers in the Navrongo Municipality in the Upper East Region. *Journal of Biology, Agriculture and Healthcare, 6*(12), 14–20.

Amedor, E. N., & Krampah, I. (2016). Postharvest losses in tomato in the Esikuma Odoben Brakwa District of Ghana. *Journal of Agriculture and Crops, 2*(4), 35–39.

Amet, S. (2017). Postharvest losses of rice and its implication on livelihood and food security in Africa: The case of Cameroon and Gambia. *Unpublished Thesis*, Pan African Institute for Development.

Arah, I. K., Kumah, E. K., Anku, E. A., & Amaglo, H. (2015). An overview of postharvest losses in tomato production in Africa: Causes and possible prevention strategies. *Journal of Biology, Agriculture and Healthcare, 5*(16), 78–88.

Asom, T. S. (2016). Impact of institutional credit on agricultural output: A case study of the Bank of Agriculture in Benue State. *Unpublished Thesis*, Benue State University, Makurdi.

Atala, S. (2002). Agricultural business today: Dependable food and agriculture news. *Agricultural Business Today*, *1*(7), 16.

Ayandiji, A. O. R., & Adeniyi, O. D. (2011). Determinants of postharvest losses among tomato farmers in Imeko-Afon Local Government Area of Ogun State, Nigeria. *Global Journal of Science Frontier Research, 11*(5), 22–28.

Babalola, D. A., Makinde, Y. O., Omonona, B. T., & Oyekanmi, M. O. (2010). Determinants of postharvest losses in tomato production: A case study of Imeko-Afon Local Government Area of Ogun State. *Journal of Life & Physical Sciences, 3*(2), 14–18.

Babarinsa, F. A., Ogundele, R. B., Babarinsa, O. A., & Omodara, M. A. (2018). Evaluation of plastic crate as replacement for raffia basket to prevent in-transit damage of packaged tomatoes. *Journal of Postharvest Technology*, *6*(3), 70–79.

Babatola, L. A., Ojo, D. O., & Lawal, O. I. (2008). Effect of storage conditions on tomato (Lycopersicon esculentum Mili.) quality and shelf life. *Journal of Biological Sciences*, *8*(2), 490–493.

Bailen, G., Guillen, F., Castillo, S., Serrano, M., Valero, D., & Martinez, R. D. (2006). Use of activated carbon inside modified atmosphere packages to maintain tomato fruit quality during cold storage. *Journal of Agricultural and Food Chemistry*, *54*(6), 2229–2235.

Barro, R., & Sala-i-Martin, X. (1995). *Economic growth*. McGraw-Hill.

Bartz, J. A., & Brecht, J. K. (2002). *Postharvest physiology and pathology of vegetables* (2nd ed.). Marcel Dekker.

Batu, A., & Thompson, A. K. (1998). Effects of modified atmosphere packaging on postharvest qualities of pink tomatoes. *Turkish Journal of Agriculture and Forestry*, *22*(4), 365–372.

Beckles, D. M. (2012). Review: Factors affecting the postharvest soluble solids and sugar content of tomato (*Solanum lycopersicum* L.) fruit. *Postharvest Biology and Technology Journal*, *63*(1), 129–140.

Buzby, J. C., & Hyman, J. (2012). Total and per capita value of food loss in the United States. *Food Policy*, *37*(5), 561–570.

Cantwell, M. I., Nie, X., & Hong, G. (2009). Impact of storage conditions on grape tomato quality. *Sixth ISHS Postharvest Symposium, International Society of Horticultural Science*, Antalya, Turkey.

Castro, L. R., Vigneault, C., Charles, M. T., & Cortez, L. A. B. (2005). Effect of cooling delay and cold-chain breakage on 'Santa Clara' tomato. *Journal of Food, Agriculture & Environment*, *3*(1), 49–54.

Choudhury, M. L., Susanta, K. R., & Kumar, R. (2004). Recent developments in reducing postharvest losses in the Asia-Pacific region. In *Proceedings of the APO Seminar on Reduction of Postharvest Losses of Fruit and Vegetables*.

Chukwunta, C. P. (2014). *An analysis of postharvest losses management strategies by farmers in Awgu Local Government Area of Enugu State, Nigeria* (Doctoral dissertation, University of Nigeria, Enugu Campus).

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319–340.

De Lucia, M., & Assennato, D. (2006). *Agricultural engineering in development: Postharvest operations and management of foodgrains* (FAO Agricultural Services Bulletin). FAO.

Doki, N. O., Eya, C. I., Tughgba, M. C., Akahi, O. G., & Ameh, A. (2019). Determinants of postharvest losses of orange in selected local government areas of Benue State. *International Journal of New Economics and Social Sciences*, *2*(10), 295–308.

Elemasho, M. K., Alfred, S. D. Y., Aneke, C. C., Chugali, A. J. C., & Ajiboye, O. (2017). Factors affecting adoption of postharvest technologies of selected food crops in Rivers State, Nigeria. *International Journal of Agricultural Economics and Extension, 5*(5), 295–301.

Elgawash, F. O. S. (2013). *The role of information technology in enhancing customer relationships in the Libyan banking sector* (Doctoral dissertation, University of Wollongong, School of Information System and Technology).

Emodi, A. I., & Osilem, M. C. (2018). Challenges of postharvest losses among tomato (Solanium lycopersium) farmers in Zing Local Government Area of Taraba State, Nigeria. *New York Science Journal, 11*(3), 26–32.

FAOSTAT. (2012). *Plantain production statistics: Nigeria*. Food and Agriculture Organization of the United Nations Statistics Division. http://faostat3.fao.org/faostat-gateway/go/to/download/Q/QC/E

Federal Ministry of Agriculture and Rural Development. (2016). *Agricultural promotion policy (2016–2020): Building on the successes of the agricultural transformation agenda (ATA), closing key gaps*.

Fefa, J. (2011). *Processing and marketing of cassava and poverty reduction in Benue State* (Unpublished Master's Dissertation). Benue State University, Makurdi.

Ferreira, M. D., Brecht, J. K., Sargent, S. A., & Aracena, J. J. (1994). Physiological responses of strawberry to film wrapping and precooling methods. *Proceedings of the Florida State Horticultural Society, 107*, 265–269.

Food and Agriculture Organization (FAO). (1980). *Assessment and collection of data on postharvest food grain losses* (FAO Economic and Social Development Paper 13). FAO.

Food and Agriculture Organization (FAO). (2008). *Basic harvest and postharvest handling considerations for fresh fruits and vegetables*. FAO.

Food and Agriculture Organization (FAO). (2018). *Food loss analysis: Causes and solutions. Case study on the tomato value chain in the Republic of Guyana*. Retrieved from www.fao.org/publications

Goka, G. G., Dufrechou, M., Picouet, P., Soncy, K., & Ameyapoh, Y. (2021). Determinants of postharvest losses in tomato production in the Savannah Region of Togo. *European Journal of Agriculture and Food Sciences*, *3*(5), 40–45.

Grolleaud, M. (2004). *Postharvest losses: Discovering the full story. Overview of the phenomena of losses during the postharvest system*. FAO. http://www.foa.org/docrep/004/ac301e/AC301e.htm

Hall, F. W. (1968). Prevention of waste of agricultural produce during handling, storage, and transportation. *Tropical Stored Products Institute*, 15–23.

Hodges, R. J., Buzby, J. C., & Bennett, B. (2011). Postharvest losses and waste in developed and less developed countries: Opportunities to improve resource use. *Journal of Agricultural Science*, *149*, 37–45.

Hornby, A. S. (2000). *Oxford advanced learners dictionary of current English* (6th ed.). Oxford University Press.

Idachaba, F. S., & Ayoola, G. B. (1995). Technology and Nigeria agricultural development. *Nigeria Journal of Agricultural Technology*, *2*(1), 59–75.

Ijirshar, V. U., Ker, G., & Terlumun, Y. C. (2015). Socioeconomic effects of farmers-Fulani herdsmen's conflict on farmers output in Benue, Nigeria. In Bakpo, F. S., & Ugbeda, F. E. (Eds.), *Proceeding of an International Academic Conference of the International Multidisciplinary Research and Academic Society, Obudu, Cross River State, Nigeria*.

Innes, E. (2014). How eating tomatoes could increase male fertility: Key compound in the fruit could boost sperm count by 70%. *Daily Mail Australia*. Retrieved from http://www.dailymail.co.uk/health/article-2620676/How-eating-tomatoes-increase-male-fertility-Key-compound-fruit-boost-sperm-count70.html#ixzz3JCag9Wmu

Kader, A. A. (1984). Effects of postharvest handling procedures on tomato quality. In *Symposium on Tomato Production on Arid Land* (Vol. 190, pp. 209–222).

Kader, A. A. (2002). *Postharvest technology of horticultural crops* (3rd ed.). University of California, Agriculture and Natural Resources, Oakland.

Kanlayanarat, S. (2007). Postharvest technologies for fresh leafy vegetables in Thailand. Paper presented at the RETA 6376 Workshop on Best Practices in Postharvest Management of Leafy Vegetables in GMS Countries, 25–27.

Karanyo, D. D. (2002). The impact of maize technology on welfare in marginal and high-potential regions of Kenya. *Unpublished PhD dissertation*, Michigan State University, East Lansing, MI.

Khatun, M., & Rahman, M. S. (2019). Quantifying postharvest loss of brinjal: A farm level study in Bangladesh. *Journal of Bangladesh Agricultural University*, *17*(4), 454–460.

Kiaya, V. (2014). Postharvest losses and strategies to reduce them. A technical paper published by ACF International.

Kinyangi, A. A. (2014). Factors influencing the adoption of agricultural technology among smallholder farmers in Kakamega North Sub-County, Kenya. *Unpublished Master's Thesis*.

Kitinoja, L., & Gorny, J. (2009). Storage practices and structures. In *Postharvest technology for fruit & vegetable produce marketers* (pp. 1.1–20.6).

Kughur, P. G., Iornenge, G. M., & Ityonongu, B. E. (2015). Effects of postharvest losses on selected fruits and vegetables among small-scale farmers in Gboko Local Government Area of Benue State, Nigeria. *International Journal of Innovation and Scientific Research*, *19*(1), 201–208.

Kuranen-Joko, D. N., & Dzahan, H. L. (2017). Determinants of postharvest losses among tomato farmers in Gboko Local Government Area of Benue State. *International Journal of Agricultural Research and Food Production, 1*(4), 64–73.

Lum, K. R. (2001). Establishment of a Commonwealth Knowledge Network (CKN) on postharvest issues. *Science and Technology Division and Secretary, Commonwealth Science Council, London*. http://www.commonwealthknowledge.net

Majidi, H., Minaei, S., Almassi, M., & Mostofi, Y. (2014). Tomato quality in controlled atmosphere storage, modified atmosphere packaging, and cold storage. *Journal of Food Science and Technology, 51*(9), 2155–2161.

Maxwell, A. (2014). Constraints among rice farmers under the MIDA Agricultural Credit Programme in the Hohoe Municipality. *International Journal of Novel Research in Marketing Management and Economics, 1*(1), 1–9.

Mbunde, J., Bunyatta, K. D., & Langat, J. K. (2021). Perceptions of smallholder farmers on influence of packaging postharvest handling technology on quality of tomatoes in Kisii and Nyamira Counties, Kenya. *East African Scholars Journal of Agriculture and Life Sciences, 4*(6), 133–140.

Moneruzzaman, K. M., Hossain, A. B. M. S., Sani, W., Saifuddin, M., & Alenazi, M. (2009). Effect of harvesting and storage conditions on the postharvest quality of tomato (Lycopersicon esculentum Mill) cv. Roma VF. *Australian Journal of Crop Science, 3*(2), 113–121.

Mosimabale, V. O. (2011). Analysis of factors influencing adoption of improved cereal seeds among rural farmers in Sabon Gari Local Government Area of Kaduna State, Nigeria. *Unpublished Master's Thesis*, Ahmadu Bello University, Zaria.

Mrema, C. G., & Rolle, S. R. (2002). Status of the postharvest sector and its contribution to agricultural development and economic growth. *9th JIRCAS International Symposium – Value Addition to Agricultural Product*, 13–20.

Mtui, M. A. (2017). Economic cost evaluation of selected vegetable postharvest losses in Babati District Tanzania. *Unpublished Master's Thesis*, Egerton University.

Muhammad, R. H., Hionu, G. C., & Olayemi, F. F. (2012). Assessment of the postharvest knowledge of fruits and vegetable farmers in Garun Mallam L.G.A of Kano, Nigeria. *International Journal of Development and Sustainability, 1*(2), 510–515.

Nasiru, A. (2014). Socioeconomic factors influencing the adoption of improved rice processing technologies by women in Jigawa State, Nigeria. *Unpublished Master's Thesis*, Ahmadu Bello University, Zaria.

Nassarawa, S. S., & Sulaiman, S. A. (2019). Extending the shelf life of tomato and onion in Nigeria: A review. *International Journal of Food Science and Nutrition, 4*(5), 99–111.

Njume, C. A., Ngosong, C., Krah, C. Y., & Mardjan, S. (2020). Tomato food value chain: Managing postharvest losses in Cameroon. *IOP Conference Series: Earth and Environmental Science, 542*(1), 012084.

Nshizirungu, R., & Kitinoja, L. (2019). Tomato postharvest management in Rwanda. *PEF White Paper No. 19-04*. The Postharvest Education Foundation.

Obekpa, H. O. (2018). Reducing postharvest losses in tomatoes. *Feed the Future Innovation Lab for Food Security Policy*.

Obeng-Ofori, D., & Cornelius, E. W. (2008). Postharvest physiology of perishable commodities. *In D. Cornelius & D. Obeng-ofori (Eds.), Postharvest Science and Technology* (pp. 147–196). University of Ghana.

Odeyemi, I., Kitinoja, L., Dubey, S., Musanase, C., & Gill, G. (2021). Tomato production is increasing along with postharvest losses in Nigeria, Rwanda, and India. *Journal of Agribusiness in Developing and Emerging Economies*. https://doi.org/10.1080/20421338.2021.1961986

Oduro-Ofori, E., Aboagye, A. P., & Acquaye, N. A. E. (2014). Effects of education on the agricultural productivity of farmers in the Offinso Municipality. *International Journal of Development Research, 4*(9).

Ofosu-Anim, J. (2008). Postharvest physiology of perishable commodities. In *D. Cornelius & D. Obeng-ofori (Eds.), Postharvest Science and Technology* (pp. 147–196). University of Ghana.

Oganga, M. (1995). Postharvest food losses: A key dimension of increasing Africa's food supply. Paper presented at the first Africa-wide exhibition and workshop on African food processing technologies for commercialization. Sponsored by the RAN Forum and UNDP.

Ohagwu, C. J., Ohagwu, V. A., & Nwakaire, J. N. (2021). Assessment and adoption of tomato charcoal cooler storage bin for farmers in the tropics. *Agritech, 41*(2), 124–133.

Olayemi, F. F., Adegbola, J. A., Bamishaiye, E. I., & Daura, A. M. (2010). Assessment of postharvest challenges of small scale farm holders of tomatoes, bell and hot pepper in some local government areas of Kano State, Nigeria. *Bayero Journal of Pure and Applied Sciences, 3*(2), 39–42.

Olayide, S. O. (1980). *Nigeria small farmers: Problems and process in integrated rural development*. Center for Agriculture and Rural Development (CARD), University of Ibadan.

Paul, R. E. (1999). Effect of temperature and relative humidity on fresh commodity quality. *Postharvest Biology and Technology, 15*(3), 263–277.

Pelemo, J. J., Tsado, J. H., Olaleye, R. S., Ayaji, O. J., & Mohammed, U. (2018). Evaluation of farmers' knowledge on postharvest technologies of yam in Kogi and Niger States, Nigeria. *Journal of Agricultural Economics, Extension & Social Sciences, 1*(2), 104–111.

Prusky, D. (2011). Reduction of the incidence of postharvest quality losses and future prospects. *Food Security, 3*(4), 463–474.

Raison, J. K., & Lyons, J. M. (1986). Chilling injury: A plea for uniform terminology. *Plant, Cell & Environment, 9*(9), 685–686.

Rembold, F., Hodges, R. J., Bernard, M., Knipchild, H., & Leo, O. (2011). The African Post-Harvest Losses Information System (APHLIS). *JRC Scientific and Technical Reports*. Luxembourg.

Risse, L. A., Miller, W. R., & McDonald, R. E. (1984). Effects of film wrapping on mature green tomatoes before and after ethylene treatment. *Proceedings of the Florida State Horticultural Society, 97*, 112–114.

Rodriguez, S. D. C., López, B., & Chaves, A. R. (2001). Effect of different treatments on the evolution of polyamines during refrigerated storage of eggplants. *Journal of Agricultural and Food Chemistry, 49*(10), 4700–4705.

Rogers, E. M. (1983). *Diffusion of innovations* (3rd ed.). Free Press.

Shahi, N. C., Lohani, U. C., Chand, K., & Singh, A. (2012). Effect of precooling treatments on shelf life of tomato in ambient condition. *International Journal of Food, Agriculture and Veterinary Sciences, 2*(3), 50–56.

Sinyolo, S., Mudhara, M., & Wale, E. (2014). The impact of smallholder irrigation on household welfare: The case of Tugela Ferry irrigation scheme in KwaZulu-Natal, South Africa. *Water SA, 40*(1), 145–156.

Srivastava, J. N. L. (2002). Postharvest management: Emerging challenges. *Press Information Bureau, Government of India*. http://www.pib.nic.in/feature/feyr2002/faug2002/f210820021

Sudheer, K. P., & Indira, V. (2007). *Postharvest technology of horticultural crops* (Vol. 7). Horticulture Science Series.

Taiwo, A., & Bart-Plange, A. (2016). Factors responsible for postharvest losses and their effects on rice producing farmers: A case study of Afife and Aveyime rice projects in the Volta Region of Ghana. *International Research Journal of Engineering and Technology*, *3*(4), 1014–1022.

Tesfaye, B. (2019). *Tomato handling practices and its postharvest losses along supply chain: The case of Adea Wereda, East Shoa, Ethiopia* (Master's Thesis). Addis Ababa University.

Tommies, E. (2016). Tomatoes, tomato-based products, lycopene, and cancer: Review of the epidemiologic literature. *Journal of the National Cancer Institute, 91*(4), 317–331.

Workneh, T. S. (2010). Feasibility and economic evaluation of low-cost evaporative cooling system in fruit and vegetables storage. *African Journal of Food, Agriculture, Nutrition and Development*, *10*(8), 2984–2997.

Workneh, T. S., & Woldetsadik, K. (2004). Forced ventilation evaporative cooling: A case study on banana, papaya, orange, mandarin, and lemon. *Tropical Agriculture*, *81*(1), 1–6.

Yahaya, S. M., & Mardiyya, A. Y. (2019). Review of postharvest losses of fruits and vegetables. *Biomedical Journal of Scientific & Technical Research*, *13*(4), 10192–10200.

Yamane, T. (1967). *Statistics: An introductory analysis* (No. HA29 Y2 1967). Harper & Row.

Mogaji, P. B., Adetula, D. T., & Olaoye, O. A. (2020). Examining the impact of fiscal policy on economic growth in Nigeria. *Ovidius University Annals, Economic Sciences Series, 20*(2), 407-416.

National Bureau of Statistics. (2012). *Annual Abstract of Statistics* (1st ed., 1), 423-431. National Bureau of Statistics.

Noman, S. M. S., & Khudri, M. M. (2015). The effects of monetary and fiscal policies on economic growth in Bangladesh. *ELK Asia Pacific Journal of Finance and Risk Management, 6*(3), 21-34.

Nwagbara, E. N. (2011). The story of Structural Adjustment Programme in Nigeria from the perspective of the organized labour. *Australian Journal of Business and Management Research, 1*(7), 30-41.

Nwaogwugwu, I. C. (2018). The effects of monetary and fiscal policy on the stock market in Nigeria. *Journal of Economics, 6*(1), 79-85.

Nwoko, N. M., Ihemeje, J. C., & Anumadu, E. (2016). The impact of monetary policy on the economic growth of Nigeria. *African Research Review, 10*(3), 192-206.

Ogunbiyi, S. S., & Okoye, N. F. (2016). Fiscal policy and economic growth: The Nigerian experience (1970-2014). *Journal of Accounting and Financial Management, 2*(6), 50-60.

Ogundipe, A. A., & Akinbobola, T. O. (2020). An appraisal of monetary policy on economic growth in Nigeria. *Asian Economic and Financial Review, 10*(7), 765-774.

Okorie, D., Sylvester, M. A., & Simon-Peter, D. A. C. (2017). Relative effectiveness of fiscal and monetary policies in Nigeria. *Asian Journal of Social Science Studies, 2*(1), 117-129.

Osinowo, O. H. (2015). Effect of fiscal policy on sectoral output growth in Nigeria. *Journal of Advances in Economics and Business, 3*(6), 195-203.

Umar, H., & Murtala, K. B. (2020). Fiscal policy and economic growth in Nigeria: An ARDL approach. *Global Business Review, 21*(4), 981-994.