NATURE OF POST-HARVEST LOSSES AND ITS' IMPACT ON HOUSEHOLDS ECONOMY IN NORTHEASTERN NIGERIA: A STRUCTURAL EQUATION MODELING APPROACH

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ABSTRACT

Post-harvest food loss poses a significant challenge to achieving food security in Nigeria, with substantial amounts of vegetables, grains, and tubers lost, impacting both national food security and the economic welfare of farmers and households. This study focuses on the nature and impact of post-harvest losses in North-East Nigeria, specifically in Wukari, Takum, and Gassol in Taraba State and Lamurde in Adamawa State. Observed post-harvest losses include rot in yam, theft, and grazing on maize, with crises causing farmers to abandon crops. Data collected through questionnaires were analyzed using descriptive statistics and Structural Equation Modeling (SEM), chosen for its ability to analyze complex variable relationships. Results show a 0.688 coefficient for household food shortage and 0.846 for income decline, indicating that post-harvest losses significantly increase food shortages and reduce household income. The R^2 value of 0.92 demonstrates that post-harvest losses account for 92% of these impacts, all statistically significant with p-values < 0.05. Recommendations include organizing peace treaties to reduce conflict-related food losses and conducting workshops on improved harvesting, processing, and storage techniques

Keywords: *Post-harvest losses, Household economy, Northeastern Nigeria, Structural equation modelling*.

JEL Classification: Q10, Q12, Q13, Q18, R20, O13

1.0 INTRODUCTION

The agricultural sector is vital to Nigeria's economy, serving as the primary livelihood for a significant portion of the population. Despite its importance, the country faces significant challenges that impede agricultural productivity and sustainability. Among these challenges, post-harvest losses are a critical issue with extensive implications for household economies. According to Oketola (2016), post-harvest losses are one of the greatest threats to food security today. These losses refer to the reduction in quantity and quality of agricultural produce from harvest to consumer delivery. They can occur at various stages, including harvesting, handling, storage, processing, packaging, transportation, and marketing.

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According to the FAO (2022), post-harvest losses in Nigeria range from 5-20% for grains, 20% for fish, and as high as 50-60% for tubers, fruits, and vegetables.

According to Sheahan and Barret (2017), Northeastern Nigeria produces more than half of the country's overall crop and livestock. However, like many parts of Nigeria, this region faces numerous issues in food and livestock production, including losses during and after harvest (Kah, 2017). These losses are exacerbated by factors such as inadequate infrastructure, limited access to modern preservation technologies, poor handling practices, and climatic conditions.

The impact of post-harvest losses on household economies in Northeastern Nigeria is profound. According to Obayelu and Akpan (2020), households that rely heavily on agriculture for their income and food security are particularly vulnerable. The economic repercussions of these losses include reduced household income, increased food insecurity, and heightened poverty levels. Moreover, post-harvest losses reduce the overall availability of food in the market, leading to higher prices and further economic strain on households. Understanding the extent and nature of post-harvest losses in Northeastern Nigeria and assessing their specific impact on household economies is therefore crucial. This involves identifying the key stages and factors contributing to post-harvest losses, evaluating the economic consequences for households, and exploring potential strategies to mitigate these losses.

In recent times, Northeastern Nigeria has been affected by conflicts such as farmer-herder clashes, Boko Haram insurgency, and communal violence. Addressing these issues is essential for improving the livelihoods of households in Northeastern Nigeria, enhancing food security, and promoting sustainable agricultural practices. Therefore, this research aims to provide a comprehensive analysis of post-harvest losses and their economic impact, offering insights that can inform policy interventions and practical solutions tailored to the region's unique challenges.

2. LITERATURE REVIEW

2.1 Conceptual Clarification

2.1.1 Post-Harvest Losses

According to the FAO, post-harvest losses (PHL) refer to the measurable quantitative and qualitative loss of food in the supply chain from the time of harvest until its consumption or other end use. Kader (2005) defines post-harvest losses as the reduction in quantity and quality of food available for human consumption, primarily due to improper handling, storage, processing, and packaging. Kitinoja and Gorny (1999) describe post-harvest losses as the degradation in both quantity and quality of a food product from harvest to consumption. This can include physical losses as well as losses in nutritional value, economic value, and consumer acceptability. According to Kumar (2022), post-harvest loss can be defined as the loss from the stage of harvesting to the stage of consumption resulting from qualitative loss, quantitative loss and food waste (by the consumers) altogether. In this study, post-harvest losses refer to the significant amounts of food that are lost or wasted after harvesting during various stages of the value chain, from production to consumption. These losses can occur due to a variety of factors, including poor handling, storage, transportation, and marketing practices. The magnitude of post-harvest losses varies across different crops

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and regions. Still, they are a major problem globally, affecting both the economic viability of farmers and the food security of consumers.

2.1.1a Magnitude of Post-Harvest Losses

According to the Food and Agriculture Organization (FAO), post-harvest losses in fruits and vegetables can reach up to 50% in developing countries (FAO, 2011). Studies by Kader (2005) also highlight that the highest losses occur in fruits, vegetables, and root crops due to their perishable nature. Hodges *et al*. (2011) provide a comprehensive overview, noting that cereals and grains experience losses of up to 20% globally.

2.1.1b Causes of Post-Harvest Losses

The causes of post-harvest losses are multifaceted, encompassing biological, environmental, and socio-economic factors:

Biological Factors: Microbial spoilage is a major cause of losses in perishables. Parfitt *et al*. (2010) emphasize the role of fungi and bacteria in deteriorating stored crops. Insect infestation, as discussed by Boxall (2001), is another significant factor leading to losses in stored grains.

Environmental Factors: High temperatures and humidity levels accelerate the deterioration process. De Lucia and Assennato (1994) outline how poor infrastructure and inadequate storage facilities exacerbate these losses in many developing regions.

Socio-Economic Factors: Poor handling practices and lack of training among farmers and workers contribute significantly to post-harvest losses. Kitinoja *et al*. (2011) stress the importance of education and training in reducing these losses.

2.1.1c Solutions and Mitigation Strategies

Several strategies have been proposed and implemented to mitigate post-harvest losses:

Improved Storage Technologies: The introduction of improved storage technologies, such as hermetic storage systems, has shown to be effective. Research by Moussa *et al*. (2011) demonstrates that hermetic storage can reduce losses in maize by up to 50%.

Cold Chain Management: Maintaining an uninterrupted cold chain from harvest to consumer is crucial for perishables. Olayemi *et al*. (2010) highlight the success of cold storage facilities in reducing losses in the horticultural sector.

Training and Education: Training farmers in better handling and storage practices is essential. Kitinoja *et al*. (2011) show that farmer education programs can significantly reduce losses through improved post-harvest handling techniques.

Policy Interventions: Government policies play a vital role in addressing post-harvest losses. Lundqvist *et al*. (2008) discuss how supportive policies and investments in infrastructure can reduce losses significantly.

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Post-harvest losses remain a critical issue affecting food security and economic stability, especially in developing countries. The literature underscores the importance of a multifaceted approach, combining improved technologies, education, and supportive policies to address this challenge effectively. Continued research and investment in these areas are essential to minimize losses and ensure a more sustainable agricultural supply chain.

2.1.1 Nature of post-harvest losses

Losses that occur after harvest may be direct or indirect. When food vanishes because it leaks or is eaten by pests like rodents, birds, or insects, it is considered a direct loss. Indirect losses happen when a drop in quality makes a customer decide not to buy the meal. The many categories of post-harvest losses are as follows:

i. Weight loss due to spoilage: This type of loss occurs when food is lost due to spoilage caused by microorganisms, insects, or rodents.

ii. Quality loss: This type of loss occurs when the quality of food is reduced due to physical damage, bruising, or other factors.

iii. Nutritional loss: This type of loss occurs when the nutritional value of the food is reduced due to spoilage, processing, or other factors.

iv. Seed viability loss: This type of loss occurs when the seeds of the food are no longer viable for planting and reproduction in subsequent cropping seasons.

2.1.2 Concept of Household Economy.

Ironmonger (2001) describes household economy as the collective economic activities of households. Often, the household economy is called the household sector, which is distinct from the business, government, and foreign sectors. However, the household sector is large enough to deserve the term household economy. Jaeger (--) "household economy" refers to the supply of provisions for a large household or institution on a commercial basis. This definition emerged in the context of the bourgeois women's education movement in the late 19th century. The concept of household economy refers to the management and allocation of resources within a household to achieve its goals and objectives. It involves the strategic use of financial, human, and physical resources to meet the needs and desires of household members

2.2 Theoretical Review

Several theories can be applied to provide a comprehensive framework for understanding the issues and dynamics at play. However, the theory of Post-Harvest Systems, Food Security Theory, and Livelihoods Framework theory are adopted for this study. The theory of Post-Harvest Systems focuses on the entire process from harvest to consumption, emphasizing the importance of each stage in minimizing losses. It includes the examination of harvesting, handling, storage, processing, packaging, transportation, and marketing practices. Applying this theory helps identify where in the post-harvest chain the most significant losses occur and how they impact the overall system. Food security theory is concerned with ensuring that all people at all times have access to sufficient, safe, and nutritious food to maintain a healthy and active life.

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This theory provides a framework for analyzing how post-harvest losses affect food availability, access, utilization, and stability, ultimately impacting household food security and the economy.

In contrast, the livelihoods framework theory examines how households derive their income and sustain their livelihoods through various assets and strategies. This theory helps in understanding the economic impact of post-harvest losses on households by considering factors such as income sources, agricultural practices, and the socio-economic context of the region. Applying these theories, the study can gain a multidimensional understanding of post-harvest losses and their impact on household economies in Northeastern Nigeria. Each theory offers a unique lens for analyzing different aspects of the problem and potential solutions.

2.3 Review of the Empirical Literature

In selected areas of the Karu local government area in the state of Nasarawa, Abubakar and Nasiru (2017) assessed the post-harvest losses of yam (Dioscorea spp.). The study aims to present a technique for evaluating post-harvest losses in yam that are directly related to rats. Agricultural extension workers and key informants who were active yam producers were chosen for a Focus Group Discussion. A 95% Confidence Interval (CI) was utilized to quantify the precision of a respondent's noted response, and descriptive statistics were employed to analyze the data. By calculating the real amounts ingested by representative samples of confined mice in cages, the daily yam requirements of the imprisoned rats in the weight class were ascertained. The study finds that inadequate storage and, to a lesser extent, post-harvest yam handling are the primary causes of post-harvest losses of yam. A correlation between the yams sold, stored, processed, and consumed is revealed by analysis of variance, suggesting a rise in the demand for yams (Dioscorea spp.). Of particular concern was the 10.5 kg of yam that rodents stole during storage, leading to both qualitative and quantitative losses. The study suggested funding post-harvest storage processing technology, education, and appropriate rodent control measures to prevent yam tubers from being destroyed during storage.

Femi (2022) examined Post-Harvest Losses and Food Security in Nigeria and reviewed how, in light of the Nigerian government's renewed push to diversify the economy through increased agricultural productivity, steps must be taken to ensure that the expected rise in production won't result in massive waste. To that end, this paper critically examines the causes and scope of post-harvest loss in Nigeria as well as strategies that should be implemented to reduce such loss. The underlying assumption is that improved food security, which is ensured by reduced post-harvest loss, will help Nigeria achieve SDG 2.

Mada *et al*. (2014) examined the effects of post-harvest technology and yearly grain losses in Ganye, Southern Adamawa State, Nigeria. This essay focuses on how post-harvest losses affect various operational phases. Analysis and quantification of the food supply data balances showed inadequate processing and storage facilities in the study Zone. Through the reduction of important revenue and profitability, post-harvest losses seriously jeopardize the livelihood of farmers and stakeholders throughout the value chain. According to research, cutting post-harvest losses by just 1% can result in an annual gain of $40 million. Government intervention will result in a significant decrease in post-harvest losses and raise participant incomes along the whole agricultural value chain. With the exception of Ganye, Adamawa State, Nigeria, labour-saving post-harvest system engineering has been embraced at previously unheard-of levels in developing nations over the past 50 years. The zone's post-harvest operations had resulted in power

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bottlenecks around the threshing and shelling of groundnuts, cowpeas, and maize. Still, the use of post-harvest machinery improved low unit costs and had an economic benefit of 40%, according to the study. According to data from the study, storage facility issues have caused farmers to sell 20% of their grain. In the research area, between 15 and 20 per cent of farmers reported overall grain losses and waste. The quality of grain after post-harvest operation with photo-type machines is recorded fairly well.

Dooga *et al*. (2021) examine the Ordinal Regression Assessment of orange post-harvest loss determinants among orange farmers. In their research, orange wastage from post-harvest losses has resulted in food scarcity, economic loss and large importation of food goods in Nigeria. The primary goal of the study was to ascertain what factors contribute to orange post-harvest losses among growers in Benue State's Konshisha Local Government, located in Nigeria's North Central Geopolitical Zone. Primary data was obtained from the orange growers through the use of key informant interviews and structured questionnaires. The data was analyzed using an Ordinal Regression model and descriptive statistics. Six (6) criteria were used to perceive the quantity lost. The majority of the farmers (63.7%) were over 34 years old, according to the statistics. In addition, 95.1% of the respondents were men, and 55.3% of them owned relatively big farms with 200 or more orange trees. The percentage of literate farmers was 73.6%. 39.5 of them were members of farmer's organizations. Subsequent findings confirmed the application of the probit link function in the ordinal regression modelling. They indicated that the absence of farmers' associations or groups and their lack of education are the main factors influencing orange post-harvest losses in the region. Farm size is the only significant covariate associated with the post-harvest loss quantity of oranges. The results of the parallel lines test showed that all answer groups have the same location characteristics or slope coefficients.

Doki *et al*. (2019) conducted a study on the factors influencing post-harvest losses of oranges. In two Benue State Local Government Areas, the study looked at the factors that contribute to orange post-harvest losses. The primary objective of this study is to determine the primary cause of orange post-harvest losses in the study area in order to take preventative measures against similar losses in the future. A population of 40 respondents (40) provided primary data for the study. Purposively recruited from two Local Government Areas in Benue State, twenty-two orange marketers and eighteen farmers were given structured questionnaires. The statistical software package, SPSS Version 20.0, was used to examine the data. Logit regression was used to investigate the data and determine the impact of each factor on post-harvest losses in the study locations. The study's findings point to the following factors: The methods of harvesting, handling, and formal education all had a substantial impact ($p<0.05$) on post-harvest losses. The harvesting technique had a 4.698-fold higher probability of influencing post-harvest losses compared to every other research variable. The findings of the second model suggest that many factors, including packaging, handling, storage, and marketer experience, had a noteworthy impact on post-harvest losses within the studied regions. Compared to all other study variables, the storage method had a 5.767-fold higher likelihood of influencing post-harvest losses, according to the findings. The study recommends that scientific approaches like modern harvesting methods, improved storage, and handling facilities should be adopted to reduce post-harvest losses of oranges.

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Jacob, Toba, and Kadjo (2022) researched the Economics of Post-harvest Loss and Loss-Preventing Technologies in Developing Countries," delves into the multifaceted economic impacts of post-harvest losses (PHL) and evaluates various technologies aimed at mitigating these losses. The authors focus on developing countries where PHL significantly affects food security, economic development, and livelihoods. The authors provide detailed statistics on the extent of PHL in developing countries, highlighting that up to 30-40% of agricultural produce can be lost post-harvest. This translates to significant economic losses, amounting to billions of dollars annually. The authors discuss various storage technologies, from traditional methods to modern, improved storage facilities like metal silos and hermetic bags. These technologies help in preserving the quality and quantity of produce. The article by Jacob, Toba, and Kadjo is a thorough and well-researched examination of the economic impacts of PHL and the potential of various technologies to mitigate these losses. Their use of comprehensive data and economic analysis provides a solid foundation for understanding the magnitude and implications of PHL in developing countries. One of the strengths of the article is its holistic approach, considering both microeconomic (farmer-level) and macroeconomic (national and global) perspectives.

Additionally, the detailed cost-benefit analysis of different technologies offers practical insights for policymakers and stakeholders. However, the article could benefit from a more in-depth discussion of the socio-cultural barriers to the adoption of PHL technologies. While economic factors are critical, socio-cultural acceptance is equally important for the successful implementation of new technologies. Furthermore, the authors could expand on the role of international aid and cooperation in addressing PHL. The article makes a significant contribution to the literature on post-harvest losses and loss-preventing technologies in developing countries. By highlighting the economic impacts and offering viable technological solutions, the authors provide valuable insights for policymakers, researchers, and practitioners working towards enhancing food security and agricultural productivity in developing regions. The article underscores the need for integrated approaches that combine technological, infrastructural, and market-based solutions to reduce post-harvest losses effectively.

The article by Ibrahim et al. (2022) addresses the critical issue of post-harvest loss (PHL) and its impact on food security, focusing specifically on major food crops in Katsina State, Nigeria. The study is timely and relevant, considering the global challenge of food insecurity and the significant role that post-harvest losses play in exacerbating this issue. The authors aim to assess the extent of PHL and suggest strategies to mitigate its impact on food security in the region. The study employs a mixed-method approach, combining quantitative data collection through surveys and qualitative insights from interviews with key stakeholders. The authors survey a representative sample of farmers, traders, and other actors in the agricultural value chain to quantify the extent of post-harvest losses. They also conduct in-depth interviews to gain a deeper understanding of the underlying causes and potential solutions. The findings of the study reveal significant post-harvest losses for major food crops in Katsina State, including grains, legumes, and vegetables. The study also highlights the economic impact of PHL, noting that it significantly reduces the income of farmers and contributes to food insecurity in the region. The authors estimate that a substantial percentage of the harvested produce is lost before it reaches the consumer, which undermines efforts to achieve food security. Ibrahim et al. (2022) conclude that reducing post-harvest losses is essential for improving food security in

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Katsina State. They call for a coordinated effort involving government, private sector, and international organizations to implement the suggested interventions. The study provides valuable insights into the scale of the problem and offers practical recommendations for addressing it.

3. 0 METHODOLOGY

3.1 Study area

The study was conducted in selected farming communities in North-East Nigeria. The North Eastern Region of Nigeria comprises six States: Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe. The region is the largest geopolitical zone in the nation, covering nearly one-third of Nigeria's total area. The North East region is primarily divided between the semi-desert Sahelian savanna and the tropical West Sudanian savanna Eco regions. The region has a population of about 26 million people, around 12% of the total population of the country. The region is known for its large production of livestock and crops, which contribute significantly to the country's economy. The crops mostly produced in this region are rice, maize, yam, cassava, groundnut, beans, and vegetables. These regions benefit from favourable climatic conditions and fertile soils, supporting diverse agricultural production.

3.2 Sampling Techniques

A purposive random sampling technique was used to select one LGA in Adamawa state and three LGAs in Taraba state. Purposive sampling, also known as judgmental or selective sampling, is a non-probability sampling technique where the researcher relies on their judgment to select the most appropriate samples. This method is particularly useful when the researcher needs to study a specific subset of the population that is particularly knowledgeable or experienced about the topic of interest. The selected LGAs are Lamurde in Adamawa State and Takum, Gassol and Wukari in Taraba State. These communities have been chosen because they represent different geographical regions within a larger area or country. Practical considerations such as accessibility and logistical feasibility influenced the selection of these communities. A purposive sampling technique was used to select a total of 318 farmers from the four communities in which 318 questionnaires were administered and retrieved. The questionnaires sought responses from the farmers on the nature and impact of post-harvest losses on households' economies.

3.3 Data Collection

The data used in this study were collected through a questionnaire survey of farmers from four selected farming communities within two States (Adamawa and Taraba) in the North Eastern region of Nigeria. The region has an estimated population of 26 million people (National Population Commission estimate from 2006 census). Data collection will be randomly selected within the communities. The questionnaire sought responses from the sample farmers on the nature of post-harvest losses and their impact on households' economies within the northeastern region of Nigeria.

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3.4 Method of data analysis

Data collected through the administered questionnaire were analyzed using descriptive statistics and structural equation modelling (SEM). SEM is a statistical technique developed to analyze the inter-relationship among variables in the model. Justify the choice of SEM in this study.

3.5 Model Specification

In order to examine post-harvest losses in North-East Nigeria with regards to their nature, causes, and effect on food security and household economy, multiple regression using Structural Equation Modeling (SEM) was employed in order to achieve the study objectives.

The regression equation for nature of post-harvest losses is given below

$$PHL = f(Tf, Gr, Ps, Rt, Ab) - (i)$$

$$PHL = \beta_0 + \beta_1 Tf + \beta_2 Gr + \beta_3 Ps + \beta_4 Rt + \beta_5 Ab + e - - - - - - - - - - - - - - - - - - (ii)$$

Where:

PHL= post-harvest losses, Tf=Theft, Gr=grazed or eaten by animals, Ps=Pest infestation, Rt=Rot and decay, Ab=Abandoned, $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5 = Regression\ coefficients$, e=error term

The regression equations for the impacts of post-harvest losses on food security and households' economy are given below Cape low

$$HFS = \beta_0 + \beta_1 PHL + e - (v)$$

$$HID = \beta_0 + \beta_1 PHL + e - (vi)$$

Where: HFS=Household food shortage, HID=Household income decline.

4.0 RESULTS

4.1 Descriptive Statistics

Table 1 shows the demographic characteristics of respondents. The majority of respondents were from Wukari, Taraba State. Most respondents were male, which is typical of African society, where males are the sole owners and managers of farmlands and farms. Most respondents were between 31 and 40 years, the age bracket when most males own their farmlands and venture into farming.

Table 1: Demographic characteristics of sampled farmers

Demographic	Variables	Frequency	Per cent
Location	Gassol	72	23

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	Lamurde	85	27
	Takum	68	21
	Wukari	93	29
	Total	**318**	**100**
Sex	Female	49	15
	Male	269	85
	Total	**318**	**100**
Age bracket	18-30	73	23
	31 and above	245	77
	Total	**318**	**100**

Field Survey, 2023

4.2 Nature of post-harvest losses

The literature has established that the nature of loss incurred during and after harvest depends mainly on the nature of the crop and the farmer's location. Table 2 shows the nature of post-harvest losses in each crop. Maize was reported to be lost in post-harvest, mainly through theft in the field, being eaten by animals, and pest infestation while in storage. Yams were lost primarily to rot, pest infestation, and insecurity (Farmers abandoned harvest due to crises). Rice was lost in post-harvest due to insecurity and theft of produce while in the field.

Table 2: Nature of post-harvest losses

Location	**Crop**	**Nature of post-harvest loss**
Wukari	Maize	Theft, eaten by animals and pest infestation
	Yam	Abandoned harvest due to crises, rot, pest infestation
Takum	Maize	Theft, eaten by animals and pest infestation
	Yam	Abandoned harvest due to crises, rot
	Rice	Abandoned harvest due to crises
Lamurde	Yam	Rot, pest infestation
	Rice	Theft
Gassol	Maize	Theft, eaten by animals
	Rice	Abandoned harvest due to crises

Source: field survey, 2023

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Table 3: Descriptive statistics on the nature of post-harvest losses

Descriptive statistic	*PHL*	*Tf*	*Gr*	*Ps*	*Rt*	*Ab*
Mean	0.853	0.596	1.238	2.421	3.104	4.563
Median	1.000	1.000	2.000	3.000	4.000	5.000
Maximum	1.000	1.000	2.000	3.000	4.000	5.000
Minimum	0.000	0.000	0.000	0.000	0.000	0.000
Standard Deviation	0.147	0.404	0.762	0.579	0.896	0.437
Skewness	0.013	0.015	0.009	0.021	0.089	0.452
Kurtosis	3.102	3.561	2.995	3.007	2.896	3.661
Jarque-Bera	18.54(0.487)	11.36(0.249)	15.13(0.378)	12.25(0.575)	10.45(0.411)	17.23(0.396)
Sum	271	190	197	257	247	290
Observations	318	318	318	318	318	318

Source: Analysis using SPSS version 26

Table 3 shows the descriptive statistics on the nature of post-harvest losses. The mean value of post-harvest losses (PHL) is 0.853, which implies that the majority (about 80%) of sampled farmers in the study area experience at least one form or nature of post-harvest losses by sampled farmers. The mean value for theft (Tf) as one of the natures in which post-harvest losses occurred was 0.596, implying that about 60% of losses incurred in the post-harvest period are lost to theft. About 60% of food lost in the post-harvest period is being grazed or eaten by animals (mean=1.238). Pest infestation (Ps) accounts for about 80% of post-harvest losses in the study area. 78% of crops were reported to be lost as rot in the post-harvest period (mean=3.104). Food loss by sampled farmers in the post-harvest period as a result of abandoned ready-to-be harvested and harvested crops was 91%. The skewness, kurtosis, and Jarque-Bera statistics showed that the dataset is normally distributed (Skewness not significantly deviated from zero, kurtosis values around 3, and p-values of Jarque-Bera statistic greater than 0.05) and therefore fit for all statistical methods used in the study.

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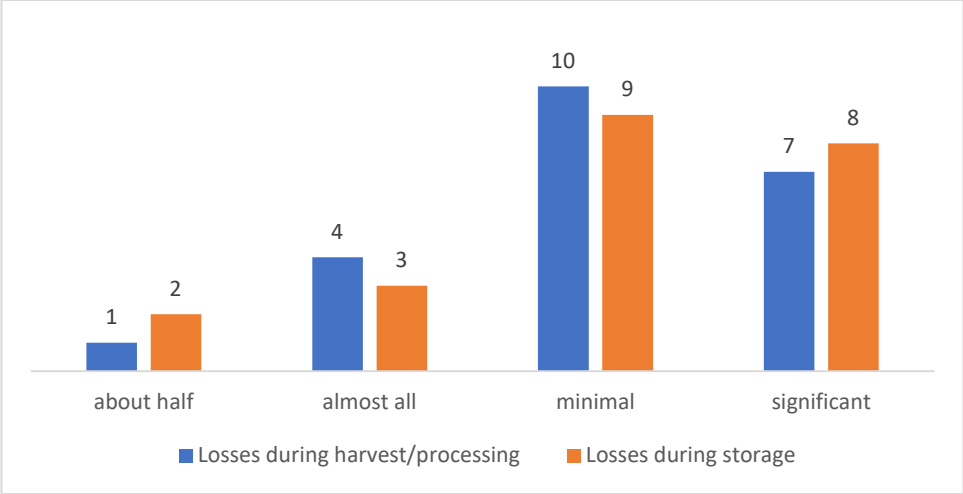

Figure 1: amount of food loss in harvest and storage periods

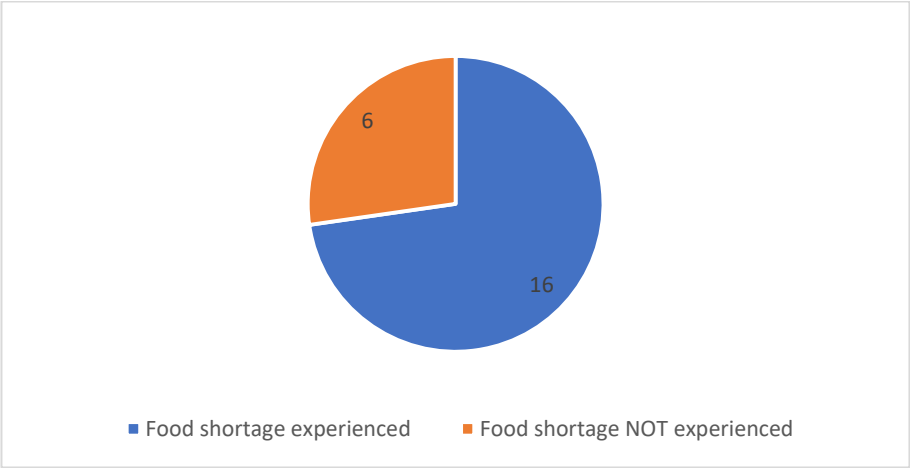

Figure 2: Food sufficiency by households as a result of post-harvest losses

4.3 The Impact of Post-Harvest Losses on Household Economy

The SEM was used to explain the

The impact of post-harvest losses on the household economy and the results are presented below

4.3.1 Structural Equation Results on Nature of post-harvest losses

Table 4: Reliability Coefficients for Final Test

	Reliability test (n=35)		Final test (n=318)	
Variables	No. of items	Alpha (α)	No. of items	Alpha (α)
Post-harvest losses	5	0.768	4	0.759

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Theft	2	0.812	2	0.836
Grazed or eaten by animals	2	0.767	2	0.751
Pest infestation	2	0.759	2	0.767
Rot/decay	2	0.755	2	0.712
Abandoned	2	0.772	2	0.753

Source: Analysis using SPSS version 26

The Reliability test result in Table 5 showed the reliability test for the final study. The Cronbach alpha coefficients for the study were within the range of 0.755 to 0.812, and the range for the final study was 0.712 to 0.836. This implies that all the items which measured the nature of post-harvest losses were found to be reliable since their Cronbach alpha coefficients were more outstanding than 0.7

4.3.2 Measurement model on the nature of post-harvest losses

Figure 3 depicts the modified measurement model, which was arrived at after several adjustments guided by factors loading and modification indices.

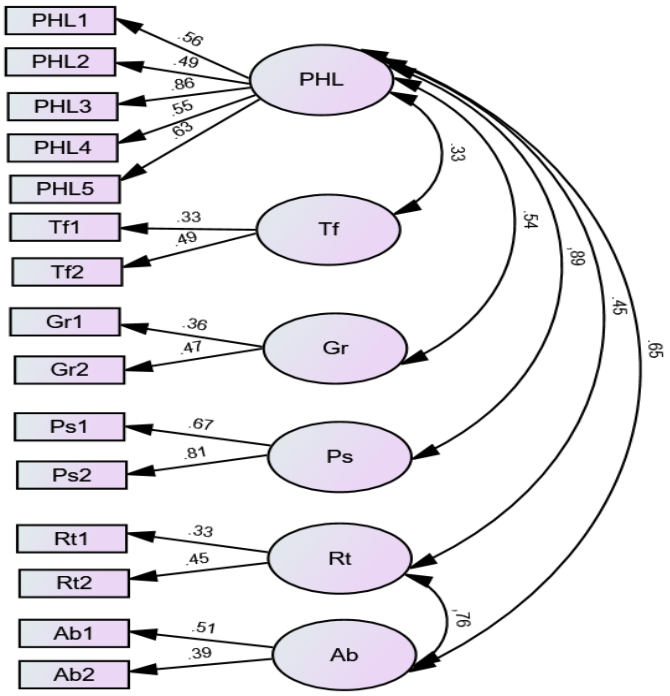

Figure 3: Modified Measurement Model for Nature of post-harvest losses

Source: SPSS AMOS version 26

4.3.2 Unique predictor to dependent variables for nature of post-harvest losses

The nature of post-harvest losses identified in this study are theft, graze/eaten by animals, pest infestation, rot, and abandonment. Therefore, the structural model in Figure 4 consists of five predicting constructs about

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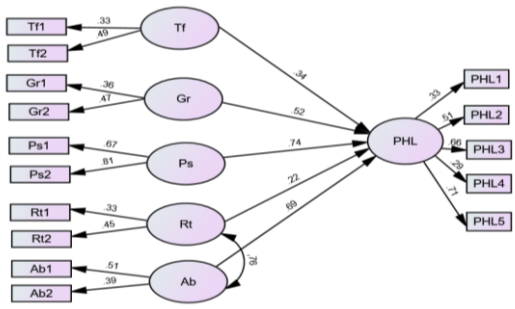
the criteria construct (PHL). Hence, the proposed hypothesis that examines the validity of the model is expressed as follows;

$H_0$1: All independent variables (theft, graze/eaten by animals, pest infestation, rot, and abandoned) are significant when regressed against the dependent variable (post-harvest losses)



Fitness indexes

Standardized estimates

Chisquare:.052

DF=317

Ratio:2.55

p-value: .000

Figure 4: Unique predictor Model for the nature of post-harvest losses

Source: SPSS AMOS version 26

Table 5: Unstandardized and Standardized Regression Weight in the Hypothesized Path Model

Hypothesized relationships	B	S. E	B	CR	ρ
PHL <--- Tf	0.341	0.064	0.301	2.583	0.000
PHL <--- Gr	0.529	0.059	0.573	1.621	0.000
PHL <--- Ps	0.747	0.061	0.739	0.955	0.002
PHL <--- Rt	0.226	0.055	0.265	1.763	0.006
PHL <--- Ab	0.696	0.055	0.665	1.763	0.006
R^2=0.83					

Source: Analysis using SPSS version 26

The coefficients (Unstandardized and Standardized) of structural equation results for the nature of post-harvest losses are contained in Table 5. The coefficient of theft is 0.301. This implies that any unit rise in theft cases will cause post-harvest losses to increase by 30 per cent. The coefficient of grazing is 0.573, implying that any unit increase in indiscriminate open grazing will cause post-harvest losses to increase by about 57 per cent. The coefficient of pest infestation is 0.739, implying that any unit increase in pest infestation of crops either in the field or in storage will cause post-harvest losses to increase by about 74 per cent. The coefficient of rot is 0.265, which implies that any unit increase in crop rot and decay will cause post-harvest losses to increase by about 27 per cent. The coefficient of abandoned crops is 0.665, which implies that any unit increase in conditions that warrant crops being abandoned will cause post-harvest losses to increase by 67 per cent. The coefficient of determination (R^2) of 0.83 implies that theft, grazing/eating by animals, pest infestation, rot, and abandoned crops account for 83 per cent of the nature or how crops are lost in the post-harvest period. The results further showed that all the identified natures in which food is lost in the post-harvest period (theft, grazing/eaten by animals, pest infestation, rot, and

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abandoned) were statistically significant, as indicated by their probability values of 0.000, 0.000, 0.002 and 0.006 respectively. These values are <0.05 and hence statistically substantial.

4.3.4 Structural Equation Results on post-harvest losses and economic impact on household

Table 6: Reliability Coefficients for the final test

	Reliability test (n=35)		Final test (n=318)	
Variables	No. of items	Alpha (α)	No. of items	Alpha (α)
Post-harvest losses	5	0.821	5	0.761
Household food shortage	2	0.796	2	0.828
Household income decline	2	0.815	2	0.789

Source: Analysis using SPSS version 26

The Reliability test result in Table 6 showed the reliability test for the final study. The Cronbach alpha coefficients for the study were within the range of 0.796 to 0.879; the final study range was 0.761 to 0.891. This implies that all the items which measured waste management measures were found to be reliable since their Cronbach alpha coefficients were more outstanding than 0.7

4.3.4 Measurement model on post-harvest losses and economic impact on household

Figure 7 below depicts the modified measurement model, which was arrived at after several adjustments guided by factors loading and modification indices.

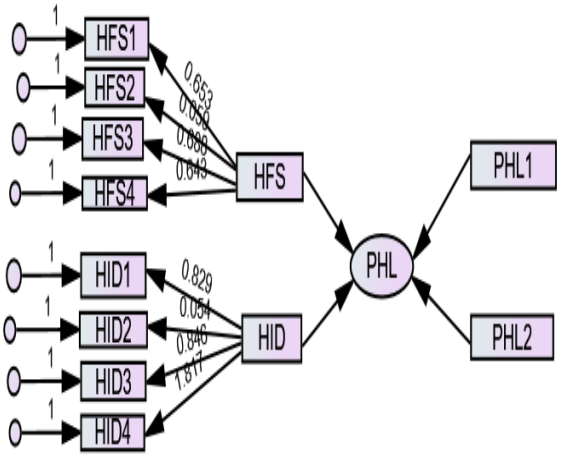

Figure 7: Measurement Model for post-harvest losses and economic impact on household Source: SPSS AMOS version 26

Table 7: Unstandardized and Standardized Regression Weight in the Hypothesized Path Model

Hypothesized relationships	B	S. E	B	CR	ρ
PHL <--- HFS	0.653	0.059	0.688	0.643	0.000
PHL <--- HID	0.829	0.054	0.846	1.817	0.000
R^2=0.92					

Source: Analysis using SPSS version 26

The coefficients (Unstandardized and Standardized) of structural equation results for the post-harvest losses and economic impact on households are contained in Table 7. The coefficient of household food shortage is 0.688. This implies that any unit increase in post-harvest losses will cause a 68 per cent food shortage in the households where such losses are incurred. The coefficient of household income decline is 0.846, implying that any unit increase in post-harvest losses will yield an 85 per cent reduction in household income where

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such losses were incurred. The coefficient of determination (R^2) of 0.92 implies that post-harvest losses account for 92% of households' food shortage and income decline. The results showed that all the effects of post-harvest losses (household food shortage and household income decline) were statistically significant, as indicated by their probability values of 0.000, which is <0.05 and statistically significant.

5.0 Conclusion and Recommendation

Food loss in the post-harvest period is a significant challenge in Nigeria's food production and supply chains. All agricultural produce is perishable in the short or long run; a significant proportion of the food produced is lost in the post-harvest period due to crises and conflicts, open grazing, inappropriate harvest and post-harvest technologies for packaging, sorting, processing, and storage.

In conclusion, the examination of post-harvest losses and their economic impact on households in Northeastern Nigeria underscores the multifaceted challenges facing agricultural communities in the region. The pervasive nature of post-harvest losses, attributed to factors such as poor storage facilities, inadequate infrastructure, and limited access to market information, not only diminishes crops but also exacerbates poverty levels among rural households. The economic repercussions extend beyond individual households to affect entire communities and the broader economy, as diminished agricultural productivity constrains economic growth and perpetuates cycles of poverty.

Efforts to reduce post-harvest losses not only contribute to poverty reduction but also hold significant implications for achieving broader developmental goals, including sustainable agriculture and economic growth. By prioritizing investments in post-harvest management strategies and fostering collaboration among stakeholders across government, civil society, and the private sector, Northeastern Nigeria can unlock the full potential of its agricultural sector and pave the way for inclusive and sustainable development

Promoting peace and adopting appropriate post-harvest technologies for packaging, storage, and processing are crucial to addressing the problem of post-harvest losses. The study recommended that peace treaties and summits be organized for communities in the region to reduce the incidence of conflicts and crises that often lead to food losses due to abandoned harvests and stores. Also, workshops and training be organized for farmers in the region by relevant government and non-governmental organizations on improved harvesting, processing, and storage techniques

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