Effects of Postharvest Losses of Beniseed on Income of Farmers in Gwer-West Local Government Area of Benue State

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Abstract
This study investigated the effects of postharvest losses of beniseed on income of farmers in Gwer West Local Government Area of Benue State, Nigeria. The main problem that necessitated the study was to examine the individualistic effects of postharvest losses at stocking, threshing, drying, storage and marketing level on beniseed farmers' income. A cross-sectional survey research design was employed, utilizing a structured questionnaire for data collection. The study population comprised of 24,615 beniseed farmers, and a sample of 394 participants were selected. Using the Ordinary Least Squares (OLS), the findings revealed that stocking losses, threshing losses, storage and marketing losses have a statistically significant negative effect on beniseed farmers' income. On the contrary, drying losses of beniseed does not have a statistically significant effect on farmers' income. It was concluded that addressing postharvest losses of beniseed requires a holistic and comprehensive approach directed at addressing stocking losses, threshing, storage and marketing losses. It is therefore recommended that, government should provide subsidies to help farmers access improved postharvest technologies, including modern threshing machines, proper stocking platforms, airtight storage containers, and efficient marketing infrastructure. Additionally, low-interest loans or credit facilities should be made available to support farmers in adopting better postharvest management practices, thereby reducing losses at stocking, threshing, storage, and marketing stages.

Keywords: Beniseed Farmers, Income and Postharvest Losses.
JEL Classification Codes: Q12, Q13, Q18, O13

1. Introduction

Beniseed (*Sesamum indicum L*) belongs to the pedaliacea family and is thought to be one of the world's oldest cultivated plants. It is an oil seed crop grown primarily for its seeds, which contain approximately 50% oil and 25% protein (Tripathi, *et al.*, 2019). It is widely assumed to have originated in Africa, from where it spread through Western Asia to India, China, and Japan, and from there to other parts of the world (Sachan & Chandra, 2023). World production of beniseed is estimated between 2 to 5 million tons, but this number fluctuates due to local economic crop production pressures, weather conditions and postharvest losses (Lawal, 2021).

Since its introduction to Nigeria after the Second World War, it has been regarded as a crop of insignificant importance compared to groundnut and other cash crops. Beniseed also known as sesame is widely grown in the Northern and Central part of the country initially as a minor crop until 1974, when it became one of the major cash earners in Benue, Gombe, Kogi, Jigawa, Kano Nasarawa, Katsina, Plateau, and Yobe States as well as the Federal Capital

Territory (Elom & Oketoboo, 2018). The crop is produced on an extensive area of more than 80,000 hectares in most Northern States, mostly for food production and oil extraction. According to Ukpe, Nwalem, and Dzever (2023), Benue and Nasarawa States in Nigeria are recognized as the primary contributors to sesame production, consistently yielding an annual average output of at least 40,000 metric tons. Additional states where small-scale cultivation of the crop occurs encompass Cross River, Ebonyi, Niger, Gombe, Katsina, Yobe, and Borno States. Additionally, Kwara, Adamawa, Plateau, Kogi, Bauchi, Kebbi, and Taraba State also produce beniseed in relative quantity (National Cereals Research Institute, 2020).

It is known to be a crop with high economic potential in Nigeria, both as source of raw materials for industries and reliable foreign exchange earner (Toungos, 2020). Food and Agricultural Organization (FAO, 2018) reported that annual export of beniseed from Nigeria are valued at about US$20m and Nigeria is the primary supplier of beniseed to the world's largest importer, Japan. Nigeria was the world's sixth-largest exporter of sesame in 2021, making sesame the country's second most lucrative export after cocoa. This particular commodity is gaining prominence among non-oil exports due to its ability to generate foreign exchange for the country. Currently, the contribution to the economy is inconsistent due to the heights of postharvest losses, with farmers having irregular income (Chege, *et al*., 2024).

Postharvest losses refer to the reduction in the quantity or quality of agricultural produce after it has been harvested and before it reaches the consumer. It is the loss between the moments of harvest and consumption covering all postharvest activities. Those postharvest activities include handling patterns like transportation, storage, packaging, marketing, processing and many more. These encompasses a range of interconnected activities that span from harvesting to the consumption by human beings (Tröger, *et al*., 2020). Various scholars, including Abass, *et al*., (2014), Kumar, *et al*., (2017), Gardas, *et al*., (2018), and Doki, *et al*., (2019), identified major contributors of postharvest losses as poor handling practices, microbial activity, environmental conditions, inadequate harvesting techniques, abandoning of stocked beniseed beyond the normal time, insufficient drying prior to threshing, incomplete threshing, rudimentary winnowing methods, inadequate storage facilities, extended distribution periods and shipment, limited market access, and many more. These factors directly and indirectly influence postharvest losses of beniseed causing diminishing income.

In Benue State for instance, farmers face significant challenges in relation to the foreign markets' response to their beniseed. Most farmers are yet to achieve best standards in the production and processing of beniseed for foreign markets despite being ranked among the leading producers of the crop in Nigeria. Beniseed from Benue State are devalued in foreign markets due to the presence of external bodies like stones, shaft and discoloration as a result of improper drying, threshing and storage system (Shabu, *et al*., 2020). The aforementioned circumstances compelled numerous farmers in Benue to sell their beniseed at a reduced price, resulting to a diminished income and a significant effect on their livelihood (Umar, *et al*., 2021). These losses at each level, if not minimize could have individual subjective effect on famers' income.

While previous studies have explored postharvest losses in various crops, such as maize (Abass, *et al.,* 2014) and rice (Coker*, et al.,* 2015), there is limited research focusing specifically on beniseed and its postharvest challenges in Nigeria. The study builds on past research by providing a comprehensive analysis of the effects of postharvest losses at stocking, threshing, drying, storage, and marketing levels on farmers' income. Unlike previous studies that often focus on a single stage of postharvest losses, this study adopts a holistic approach to examine the cumulative effects of losses across multiple stages on income of farmers in Gwer West Local Government Area of Benue State.

The main objective of this study is to investigate the effects of postharvest losses of beniseed on income of farmers in Gwer West Local Government Area of Benue State.

The specific objectives of the study are to:

i. ascertain the effect of postharvest losses at stocking level on income of beniseed farmers in Gwer West Local Government Area.
ii. ascertain the effect of postharvest losses at threshing level on income of beniseed farmers in Gwer West Local Government Area.
iii. evaluate the effect of postharvest losses at drying level on income of beniseed farmers in Gwer West Local Government Area.
iv. investigate the effect of postharvest losses at storage level on income of beniseed farmers in Gwer West Local Government Area.
v. examine the effect of postharvest losses at marketing level on income of beniseed farmers in Gwer West Local Government Area.

2. Literature Review

Conceptual Clarifications

Postharvest Losses (PHLs) of Beniseed

Postharvest losses refer to the deterioration, in terms of both quantity and quality, that occurs in beniseed production from the point of harvest to the stage of consumption. Quality losses encompass several factors that impact the nutritional and caloric composition, as well as the acceptability and edibility of the crop. Quantity losses are defined as the reduction in the quantity of crop due to various factors such as limited knowledge of postharvest management system, inadequate drying, improper timing, lack of necessary storage system, pest and disease infestation, inefficient processing methods, unpredictable weather patterns, market inefficiencies, poor infrastructure among others (Tadesse, 2020). The prevalence of quantity loss of beniseed is higher in developing countries, because of lack of adequate infrastructure, poor postharvest management system, lack of necessary postharvest knowledge (Yeshiwas, *et al.,* 2021). According to recent research by the Food and Agricultural Organisation (FAO), it has been observed that in high-income regions, the quantities of food lost and wasted are greater at the later stages of food chain. Conversely, in low-income regions, a larger proportion of food loss and waste occurs in the earlier stages of the food chain (FAO, 2023).

Many farmers have expressed significant concern about the occurrence of postharvest losses, as these losses directly impact their income and livelihoods (Prodhan, *et al.,* 2022). The stages of beniseed production most vulnerable to postharvest losses include stocking, drying, threshing, storing, processing, and marketing (Anthony, 2019). Each of these stages presents unique challenges that contribute to the deterioration of both the quantity and quality of the crop. For instance, improper drying and inadequate storage facilities often lead to mold growth and pest infestations, which significantly reduce the market value of beniseed (Tadesse, 2019). Recent studies highlight the importance of adopting modern postharvest technologies, such as hermetic storage bags and improved drying platforms, to mitigate these losses effectively (Ukpe, *et al.,* 2023). By addressing the specific issues at each stage, farmers can reduce postharvest losses, improve the quality of their produce, and enhance their overall profitability.

Crops like beniseed are prone to potential issues such as consumption by discolouration during storage, animal-like rodents, scattering, dispersion, or crushing during the handling process. High losses might occur if beniseed is unable to dry adequately due to poor weather conditions. Inexperience of some farmers can cause improper stocking, incomplete threshing and inadequate drying that can increase losses (Addai, 2021). According to the Food and Agriculture Organization, Nigeria loses about 20%-30% of its total beniseed production annually due to poor storage facilities, pests, and inadequate transportation systems (FAO, 2021). In 2022, the FAO rated beniseed postharvest losses at Nigeria, India and Sudan as 20%, 15% and 25% respectively thereby showing the height of postharvest losses and the need to control it (FAO,2023).

In this study, postharvest losses of beniseed encompasses quantitative and qualitative losses from harvesting to the consumption of beniseed. These include the stocking, threshing, drying, storing, and marketing losses.

Farmers' Income

Farmers' income refers to the total earnings that farmers derive from their agricultural activities and other supplementary sources. It is a key indicator of economic welfare in rural communities and plays a crucial role in assessing the viability of agricultural livelihoods. The concept encompasses the revenue generated from the sale of crops, livestock, and other farm produce, as well as income from off-farm activities like seasonal labor or agribusiness ventures. For farmers in developing economies like Nigeria, income is often influenced by factors such as farm size, market access, access to credit, and the use of improved agricultural practices (Ibrahim, *et al.,* 2023). The variability of farmers' income can also depend on climatic conditions, government policies, global market trends and farmers' income (FAO, 2020). Farm revenue pertains to the financial proceeds derived from the operations of farms or agribusiness entities. The significance of income in relation to the capital investment of farmers is substantial. The financial capacity of farmers to invest in improved packaging materials or storage facilities for the purpose of decreasing postharvest losses is contingent upon the income derived from both farm and off-farm sources (Coppola, *et al.,* 2020).

Farmers' income pertains to the financial earnings acquired by persons or households involved in agricultural pursuits and associated endeavours. The income of farmers can exhibit substantial variation, contingent upon various elements such as the specific crops or livestock they engage in, the magnitude of their agricultural enterprise, prevailing market circumstances within their locality, governmental regulations, and external influences including weather patterns and global commodity prices (Haqiqi & Horeh, 2021).

One of the significant challenges faced by farmers, particularly smallholder farmers, is the instability of their income due to postharvest losses, price fluctuations, and limited access to markets. According to Bello *et al.* (2021), postharvest losses substantially affect the profitability of farming activities, often reducing farmers' overall earnings. In many cases, poor management of postharvest losses, poor infrastructure, and limited knowledge of modern farming techniques exacerbates income instability. Postharvest losses of beniseed significantly reduce farmers' income by diminishing both the quantity and quality of the crop available for sale, particularly during stocking, threshing, storage, and marketing stages (Ukpe, *et al.*, 2023). These losses lead to lower market prices and reduced profitability, exacerbating poverty among smallholder farmers in regions like Benue State (Food and Agriculture Organization [FAO], 2018).

Studies indicate that improving farmers' access to markets, better postharvest management, and provision of financial support can enhance income levels and contribute to sustainable agricultural development (World Bank, 2018). Within the context of this research, income is conceptualized as the amount of money beniseed farmers earned through the sales of beniseed.

Relationship between postharvest losses and farmers income

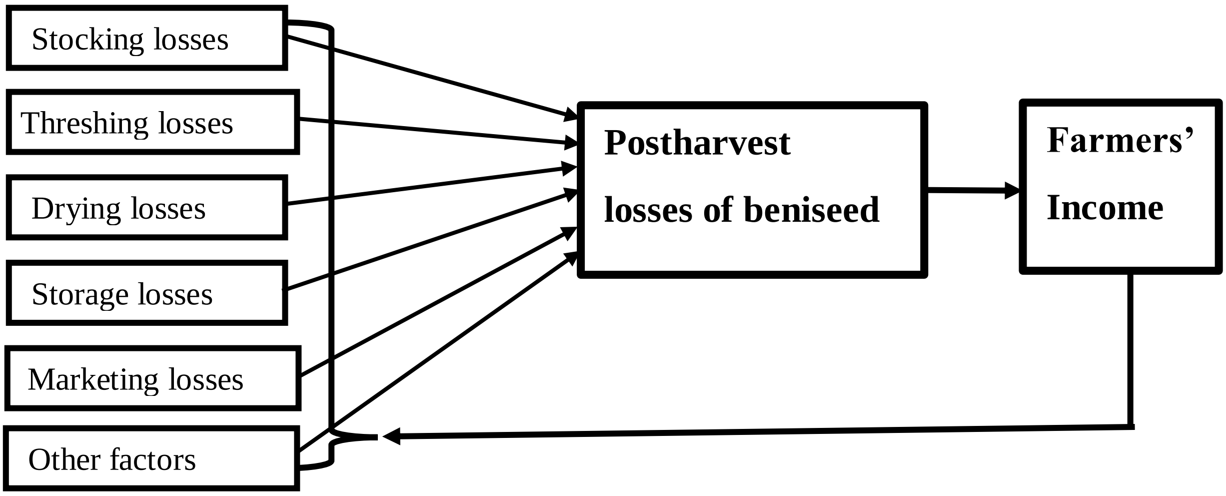
The intricate and interrelated nature of the interaction between postharvest losses and farmers' income is evident, as postharvest losses exert a substantial influence on farmers' output and subsequently impact their income. The decrease in the quality of beniseed has a negative impact on their market values. This relationship validates the Expected Utility Theory (EUT) which shows that farmers' decisions regarding postharvest management affect their income. Losses that emanate from incomplete threshing, presence of external elements like stones, chaffs and effects of pests and diseases during storage occurred as a result of postharvest management choices made farmers. Consequently, farmers are deprived of the chance to earn higher profits due to such losses (Savary, *et al.,* 2012). According to a report by USAID in 2013, smallholder output is characterized by limited quantities and substandard quality due to ineffective postharvest management practices and crude threshing method as well as inadequate storage facilities.

Significant postharvest losses have a detrimental impact on the quantity of beniseed that farmers are able to bring to the market or utilize for personal consumption, resulting in a decrease in their agricultural revenue. The inadequate implementation of postharvest practices such as stocking, threshing, drying, shelling, treatment, and storage contributes to a decrease in both the quality and quantity of beniseed grain. This, in turn, negatively impacts the income and living standards of farmers, resulting to another cycle of postharvest losses (Asea, *et al.,* 2014; Okoruwo, *et al.,* 2012:56). Inadequate postharvest handling practices, such as sub-optimal drying techniques and unsuitable storage conditions, have been identified as significant contributors to losses resulting from storage pest infestation and aflatoxin contamination (Maina, *et al*., 2016). If the postharvest activities are effectively managed, farmers are likely to have the opportunity to enhance their income. For example, the utilization of modern threshing machine and modern storage facility is a potential avenue for enhancing farmers' incomes. In order to enhance agricultural earnings and provide food security for small scale farmers, it is imperative to use efficient storage practices (Adiaha, 2017). The inadequate management of postharvest practices results in a decline in both the amount and quality of beniseed. Consequently, farmers are deprived of the potential for improved incomes, thereby perpetuating their state of poverty (Stathers, *et al.*, 2020).

Dynamics of beniseed postharvest losses on farmers' income

This section examines the intricate relationship between beniseed postharvest losses at various levels of beniseed distribution chain and farmers' income. Figure 1 below demonstrates the relationship between postharvest losses of beniseed and farmers' income.

Schematic Presentation of the effects of postharvest losses on farmers income



Source: Compiled by researcher
Figure 1: The effect of postharvest losses on farmers' income

The relationship between postharvest losses at various stages such as stocking losses, threshing losses, drying losses, marketing, storage losses, marketing losses and farmers' income is depicted in Figure 1. The diagram illustrates the relationship between postharvest losses and farmers' income. Key components such as stocking, threshing, drying, storage, marketing, and other factors play a crucial role in determining how much of the harvested produce is lost before it reaches the market. Effective management of these stages can significantly reduce postharvest losses and positively impact the income of farmers.

Poor stocking practices can lead to spoilage and pest infestation, thereby increasing postharvest losses. Threshing, drying, and storage are the next phases, where crops are processed, dried, and stored to maintain quality. If these stages are mishandled, the likelihood of damage and loss increases, affecting the farmers' income. Therefore, addressing inefficiencies in postharvest management, from stocking to marketing, is essential for reducing losses and enhancing income generation for farmers. This comprehensive approach ensures that farmers maximize their output and benefit economically from their labor.

Theoretical Framework

This study is anchored on the expected utility theory presented by Daniel Bernoulli in 1713.

Expected Utility Theory (EUT)

The inception of expected utility theory can be attributed to Daniel Bernoulli as propounded in the year 1713. Expected Utility Theory (EUT) is a fundamental concept in economics and decision theory that explains how individuals make rational choices under uncertainty. According to EUT, when faced with multiple options that have uncertain outcomes, individuals make decisions by evaluating the potential outcomes of each option based on their probabilities and the utility (satisfaction or value) associated with each outcome. The theory posits that individuals aim to maximize their expected utility, which is the weighted sum of utilities for each possible outcome, with the weights being the probabilities of those outcomes. EUT is based on several assumptions about individual behavior. First, it assumes that individuals are rational and consistent in their decision-making, meaning they have a clear set of preferences that guide their choices. Second, individuals are assumed to be risk-averse, risk-neutral, or risk-seeking, depending on how they perceive the trade-off between risk and reward. A risk-averse person, for example, would prefer a guaranteed, lower reward over a higher, uncertain reward, while a risk-seeking person might choose the riskier option in pursuit of higher gains.

Expected Utility Theory can be applied to understand farmers' decision-making processes concerning postharvest losses and its impact on their income. Farmers are often faced with uncertain outcomes regarding the quantity of beniseed they will successfully harvest and sell due to potential losses during the postharvest stage (Kadjo, *et al.,* (2018). According to EUT, farmers assess the potential outcomes of various decisions, such as the stocking and threshing method, whether to invest in better storage facilities or risk using cheaper, less effective methods. Each option comes with its own set of risks and benefits. The expected utility is calculated by weighing the possible outcomes like reduced losses, increased income, or even crop rejection against the likelihood of those outcomes occurring. Farmers seek to maximize their expected utility, which means they aim for the decision that provides the greatest balance of risk and reward, given their preferences and tolerance for uncertainty. EUT helps explain varying behaviors by suggesting that farmers weigh their potential earnings and losses based on their subjective perception of risk, with the ultimate goal of maximizing their utility, whether it is in the form of financial stability or maximizing profit under uncertainty (Olayemi, *et al.*, 2020).

Empirical Review

Kyei, *et al.,* (2025) investigated the effects of post-harvest losses on smallholder farmers' profitability: the case of fruit and vegetable farmers in the Ashanti Region of Ghana. The study sampled 100 vegetable farmers and 70 fruit farmers from five communities in the Sekyere-Kumawu District, using a structured questionnaire to collect data on socio-demographic variables, post-harvest loss estimates, and production costs. Descriptive statistics and multiple regression analysis were employed to analyze the data. The findings revealed that vegetable farmers lost approximately 6.9% of their total harvest, while fruit farmers lost about 6.5%, with significant losses occurring during harvest, storage, and due to pest infestations. The study also found that education, household size, and land size positively influenced farmers' profits, whereas losses during harvest and storage negatively impacted profitability. While the study provides valuable insights into post-harvest losses and their economic impact, it could be criticized for its limited geographical scope and reliance on self-reported data, which may introduce biases. Additionally, the study does not extensively explore potential interventions or policy recommendations to mitigate these losses, which could have provided a more comprehensive understanding of the issue.

Ibrahim *et al.* (2023) conducted a study to evaluate the economic viability of sesame production among small-scale farmers in Kano State, Nigeria, focusing on reducing postharvest losses and increasing income and profitability. The study sampled 116 farmers across four agricultural blocks using a multi-stage selection method. Data were collected using standardized questionnaires and analyzed using gross margin and regression techniques. The study identified several factors impacting the farmers' income and profitability, including household size, farm size, stocking inexperience, incomplete threshing, open drying, and access to credit. These factors contributed to significant postharvest losses, which in turn affected the profitability of sesame farming. While factors such as age and cooperative membership negatively influenced income, the study highlighted the importance of addressing these challenges to improve the farmers' financial outcomes. Despite its valuable findings, the study was criticized that it emphasized on the state's extension services as a solution for postharvest losses neglecting other important interventions such as investments in modern storage technologies or enhanced market access, which could significantly improve farmer profitability and reduce losses. Addressing these gaps would have made the study more robust and impactful.

Lukurugu *et al.*, (2023) conducted a study focusing on sesame production constraints, variety traits preference in the Southeastern Tanzania: Implication for genetic improvement. By employing a semi-structured questionnaire and interview checklist, the researchers gathered data from 240 sesame cultivators to identify the challenges faced in sesame production, the study used qualitative data analysis The findings revealed several significant postharvest factors, including a high prevalence of insect pests, illnesses, drought, weed infestation, inadequate capital to buy modern postharvest equipment, and a scarcity of improved seeds. Additionally, the study highlighted the key traits farmers prioritize when selecting sesame varieties, such as high production potential, resistance to pests and diseases, early maturation, desirable seed color, and drought tolerance. The research also noted that the market values sesame cultivars with white grain color, large seed size, clean seeds, and high oil content, indicating a strong demand for these traits among consumers. As a result, the authors suggested that farmers and post-farm operators should focus on improved breeding practices to develop sesame varieties that meet both production and market requirements. However, the study faced criticism regarding its applicability to other regions, particularly Nigeria, as the findings are geographically limited to Tanzania. This raises concerns about the generalizability of the results and their relevance to sesame farmers operating in different environmental and socioeconomic contexts.

The study conducted by Bello, *et al*., (2021) focused on analyzing the income and profitability of beniseed production in the Lafia Local Government Area of Nasarawa State, Nigeria. Using basic descriptive statistics such as mean, frequency count, percentage, and gross margin analysis, the research aimed to evaluate the profitability of beniseed farming. The findings indicated that a substantial majority of the respondents involved in sesame production were male, with many being married and relying on beniseed cultivation to support their families financially. However, access to credit facilities was limited for most respondents, which hindered their ability to invest in better postharvest management practices. As a result, insufficient funds contributed to lower income and profitability from beniseed farming. Overall, while the study offers valuable insights into the beniseed farming landscape, it could benefit from a broader analysis that includes qualitative data and a more robust examination of the factors affecting income and profitability.

laigwu *et al.,* (2021) investigated the impact of storage systems on the income of sesame seed farmers in Benue State, Nigeria, with a particular focus on fungal contamination. The study employed the direct plating approach to identify fungal species present in sesame seeds stored across various locations in the region. The findings revealed twelve distinct fungal species responsible for postharvest losses, with Aspergillus flavus and A. niger being the most prevalent across all sampled areas. The study highlighted that the contamination rates varied significantly, with samples from Otukpo Local Government Area (LGA) showing the highest contamination level, while samples from Gboko had the lowest. Importantly, the results indicated a significant negative effect of fungal contamination on farmers' income, underscoring the economic implications of inadequate storage practices. However, the study faced criticism for endorsing chemical treatments as a solution to fungal contamination, raising concerns about potential health risks associated with such substances for both farmers and consumers. This critique emphasizes the need for more sustainable and safer postharvest management practices in the agricultural sector.

Gebremichael (2017) evaluated farmers' income and storage losses in sesame indicum caused by the Indian meal moth Plodia interpunctella (*Lepidoptera*), focusing on small-scale farmers in the Western Zone of Tigray, Ethiopia. The research aimed to quantify the extent of grain loss attributed to this pest and its subsequent effect on farmers' income. A representative sample of 1 kilogram of sesame grain was collected from ten storage facilities in each district, and the data was analyzed using one-way analysis of variance (ANOVA). The findings revealed a mean weight reduction in sesame grain, with an overall percentage decrease, indicating significant losses due to *P. interpunctella*, particularly when sesame was stored for over a year. The study highlighted the role of insect pests in negatively affecting the quality and quantity of stored sesame grain, which directly reduced farmers' income. However, the study faced criticism for not fully employing control measures against the Indian meal moth, suggesting that the recommendations for pest management were insufficient and limiting the practical applicability of the research findings.

Ssebaggala *et al*., (2017) conducted a study examining the impact of postharvest losses (PHLs) on the revenue of beniseed farmers in Eastern Uganda. Utilizing a cross-sectional survey method, the researchers engaged 83 farmers through focus group discussions and conducted 150 individual interviews. The analysis employed principal component analysis and logistic regression to identify factors influencing farmers' perceived capacity to mitigate PHLs and improve their income. The study revealed that a significant portion of postharvest losses, occurred during field-based activities such as harvesting and drying, primarily due to spillage. The remaining losses were linked to home-based activities, with a notable perception of quality deterioration observed during harvesting and drying stages. Farmers expressed a lack of confidence in their ability to reduce PHLs, particularly during these critical stages. Factors impacting their perceptions included farm size, knowledge of loss mitigation strategies, the proportion of beniseed sold, and household characteristics. Additionally, the study highlighted disruptions in the income of beniseed producers due to PHLs. However, the study faced criticism for not employing a robust model to substantiate its claims, which raises concerns about the validity of the findings and their applicability in addressing the issue of postharvest losses in the beniseed industry.

Coker *et al.,* (2015) examined the impact of post-harvest losses on the income of farmers in Sub-Saharan Africa, with a specific focus on Niger State, Nigeria. The study sampled 120 smallholder rice farmers in the region using the multi-stage sampling technique. Well-structured questionnaires were used to collect data on post-harvest losses, production costs, and farmers' income. Data analysis was conducted using descriptive statistics and regression models to assess the relationship between postharvest losses and farmers' income. The findings revealed that postharvest losses significantly reduced farmers' income, with household size and access to storage facilities being key determinants of profitability. The study does not extensively explore potential interventions or policy measures to mitigate post-harvest losses, leaving room for further research in this area.

3. Methodology

The study was conducted in Gwer West Local Government Area of Benue State. The selection of the study area was based on its prominence as a significant beniseed producer in Benue State, as well as the substantial and concerning postharvest losses documented throughout the distribution process. The population of the study comprised of 24,615 beniseed farmers in Gwer West Local Government (BNARDA, 2023). Given this population, the research considered 394 as the sampled respondents.

Cluster and purposive sampling procedures were used in the selection of the beniseed farmers for the study. Since the study area, Gwer West Local Government Area is a large region with a significant number of beniseed farmers spread across various communities, cluster sampling allows the researchers to divide the population into council wards. This ensures that the sample is representative of the entire region without the need to survey every individual farmer. Purposive sampling was also used to ensure that the selected participants were directly involved in beniseed farming and have relevant experiences and insights related to postharvest losses.

The primary data was collected through structured questionnaires, which were administered to beniseed farmers in the study area. Secondary data relevant to the study was sourced from relevant publications. The simple descriptive statistics used were tables while the inferential statistics involved were Ordinary Least Squares (OLS) regression model.

The justification for using OLS in this study is based on its effectiveness in estimating the relationship between postharvest losses and farmers' income. The use of OLS regression in the study is validated since it allows for the estimation of how various independent variables like postharvest losses at stocking, threshing, drying, storage, and marketing influence the dependent variable which is farmers' income. This is essential in understanding the relative impact of each loss stage on income.

Model Specification

The model specification employed for farmers' income in this study is adapted from the empirical review used by Coker and Ninalowo (2015) in Minna, Nigeria using ordinary least square. The dependent variables used in his work include harvest losses, threshing losses, winnowing losses, transportation losses, storage losses, parboiling losses, drying losses, milling losses, household size, educational status of farmer and age of farmer.

In this study, the variables under consideration include the age of the farmer, farmers' farm size, years of farming experience, postharvest losses during stocking, postharvest losses during threshing, postharvest losses during drying, postharvest losses during storage and postharvest losses during marketing. The model to determine the effect of the postharvest losses on farmers' income was expressed thus:

Y = f (AGE, FASIZ, FAEXP, STLO, THLO, DRYLO, STOLO, MARLO) …………………1

Where:
Y = Income from beniseed (naira value)
AGE = Age of farmer (years)
FASIZ = Farm size (number of hectar)
FAEXP = Years of farming experience (number of years)
STLO = Postharvest losses during stocking (naira value)
THLO = Postharvest losses during threshing (naira value)
DRYLO = Postharvest losses during drying (naira value)
STOLO = Postharvest losses during storage (naira value)
MARLO = Postharvest losses during marketing (naira value)

The explicit form of the model is as shown follows:
$Y_t = \beta_0 + \beta_1\text{AGE} + \beta_2\text{FASIZ} + \beta_3\text{FAEXP} + \beta_4\text{STLO} + \beta_5 THLO + \beta_6 DRYLO_t + \beta_7 STOLO + \beta_8 MARLO_t + U_t$ ...2

Where,
β_0 = Constant
β_1-β_8 = Regression coefficients
U_t = Stochastic error term
It is expected that $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 > 0$, $\beta_4 < 0$, $\beta_5 < 0$, $\beta_6 < 0$, $\beta_7 < 0$.

4. Results and Discussion

Tables 1- 4 present a descriptive analysis of the data used for the study. Factors responsible for postharvest losses at various levels of beniseed distribution chain were presented. Table 5 shows the result of the estimation of the ordinary least squares.

Table 1: Determinants of Beniseed Postharvest Losses at Stocking Level

Determinants	Frequency	Percentages (%)
Stocking on an unclean platform	64	16.2
Effect of moisture, flood, rain and wind	140	35.5
Activities of rodents, birds and other animals	57	14.5
Falling of stocked beniseed due to the farmer's inexperience	40	10.2
Stocking beyond the normal time	30	7.6
Splashing away from the stocking platform	25	6.3
Other human activities such as bush burning	38	9.6

Source: *Field survey, 2024*

Data presented in Table 1 shows the various factors responsible for postharvest losses at stocking level. Majority of the sampled respondents (35.5%) identified that effect of moisture, flood, rain and wind are responsible for postharvest losses at stocking level. Other factors identified by other respondents include stocking on an unclean platform (16.2%), the activities of rodents, birds and other animals (14.5%), falling of stocked beniseed due to the farmers' inexperience (10.2%), stocking beyond the normal time (7.6%), splashing away from the stocking platform (6.3%) and other human activities such as bush burning (9.6%) as the factors responsible for postharvest losses of beniseed at the stocking level in Gwer West Local Government Area. This implies that most of the postharvest losses at the stocking level can be controlled if a conscious and a rational effort is directed at managing the losses.

Table 2: Determinants of Beniseed Postharvest Losses at Threshing Level

Determinants	Frequency	Percentages (%)
Not threshing on a clean platform such as mat, trampoline or leather	123	31.2
Not observing wind movement before threshing	77	19.5
Threshing on mat, leather or trampoline with holes	24	6.1
Exposure to activities of pests, rodents, birds and other animals during threshing	46	11.7
Uncontrolled splashing of seed from the stocking platform	24	6.1
Incomplete/inefficient threshing due to inexperience	55	13.9
Threshing while the beniseed is still drenched	29	7.3
Splashing away due to the crude and traditional method of threshing	16	4.1

Source: *Field survey, 2024*

Table 2 reveals that not threshing on a clean platform such as mat, trampoline or leather is the major determinants of postharvest losses of beniseed at the threshing level. Other factors include not observing wind movement before threshing (19.5%), exposure to activities of pests, rodents, birds and other animals during threshing (11.7%), uncontrolled splashing of seed from the stocking platform (6.1%), incomplete/inefficient threshing due to inexperience (13.9%), threshing while the beniseed is still drenched (7.3%) and splashing away due to the crude and traditional method of threshing (4.1%).

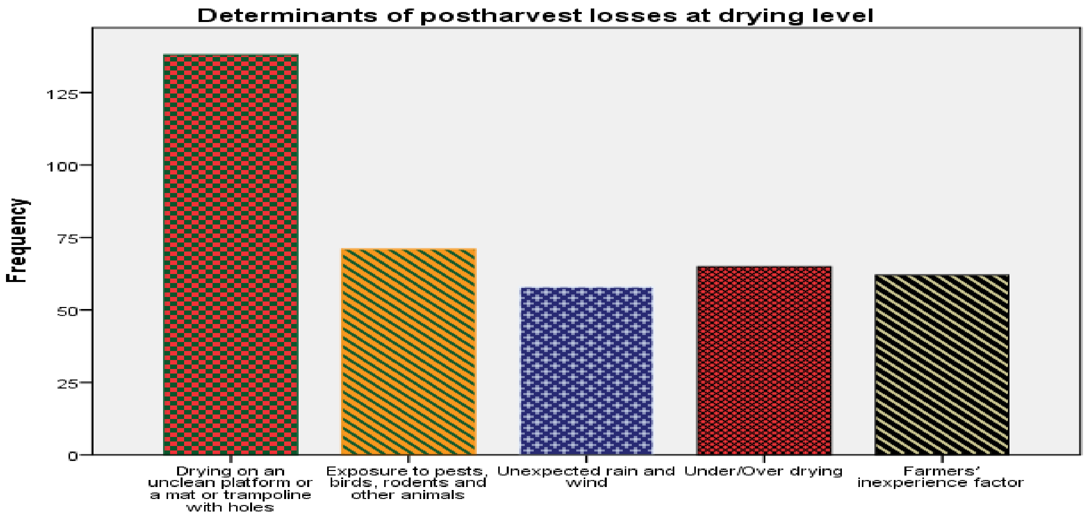


Figure 2: Bar Chart Showing the Determinants of Postharvest Losses at the Drying Level

Figure 1 shows that drying on an unclean platform or a mat or trampoline with holes is the main factor responsible for postharvest losses of beniseed at the drying level in Gwer West Local Government Area. Closely followed by exposure to pests, birds, rodents and other animals (18.0%), under/over drying (14.7%), farmers' inexperience factor (15.7%) and unexpected rain and wind (14.7%). This implies that most of the postharvest of beniseed at the drying level is due to lack of the use of a clean platform or mat/trampoline without a hole in Gwer West Local Government Area.

Table 3: Determinants of Beniseed Postharvest Losses at Storage Level

Determinants	Frequency	Percentages (%)
Exposure to pest, rat, rodents and birds	119	30.2
Stored in a torn and uncleaned bag, sack, a broken pot or use of warm out storage system	71	18.0
Stored in a wet environment	54	13.7
Storing of under drying beniseed	72	18.3
Abandoning of stored beniseed beyond the reasonable time of storge	44	11.2
Lack of modern storage facilities	34	8.6

Source: *Field survey, 2024*

Table 3 shows that exposure to pest, rat, rodents and birds pose the main challenge at the storage level. Whereas, factors such as storing of under dried beniseed, storing of beniseed in a torn and uncleaned bag, sack, storing of beniseed in a wet environment and lack of modern storage facilities among others were the other factors responsible for postharvest losses at the storage level in Gwer West Local Government Area in Benue State. This implies that if beniseed farmers can prevent their beniseed from been exposed to pest, rat, rodent and birds, postharvest losses at storage level will be partly taking care of.

Table 4: Determinants of Beniseed Postharvest Losses at Market Level

Determinants	Frequency	Percentages (%)
Discoloration/mouldy due to improper storage	86	21.8
Presence of an external elements like stones, shaft, sticks and many more due to poor winnowing	108	27.4
Losses due to improper packaging	49	12.4
Mixture different species together after harvest thereby making it attract lower price	97	24.6
Splashing on the ground or not measuring on a clean platform or mat	22	5.6
Exposing of beniseed to rain, wind and birds in the market	10	2.5
Careless handling or human accident in the market	22	5.6

Source: *Field survey, 2024*

Table 4 shows that the major factor responsible for beniseed postharvest loses at market level is the presence of an external elements like stones, shaft, sticks and many more due to poor winnowing. Other identified factors include mixture of different species together after harvest thereby making it attract lower price, discolouration/mouldy due to improper storage, splashing on the ground or not measuring on a clean platform or mat, exposure of beniseed to rain, wind and birds in the market and careless handling or human accident in the market were the prominent factors responsible for postharvest losses at the market level. This implies that if the beniseed farmers can be more careful to prevent discolouration and prevent the presence of external bodies, postharvest losses will be mitigated to the barest minimum level.

Effects of Postharvest Losses of Beniseed on farmers' Income

Table 5: Ordinary Least Squares (OLS) Regression Analysis

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.53966	0.314565	33.50549	0.0000
LNAGE	0.060534	0.051398	1.177759	0.2396
LNFASIZ	1.109867	0.039964	27.77203	0.0000
LNFAEXP	0.019454	0.022292	0.872699	0.3834
LNSTLO	-0.051789	0.018988	-2.727485	0.0067
LNTHLO	-0.036673	0.021223	-1.727982	0.0048
LNDRYLO	-0.011678	0.019667	-0.593771	0.5530
LNSTOLO	-0.021511	0.016368	-1.314200	0.0196
LNMARLO	-0.068408	0.015387	-4.445826	0.0000
R-squared	0.784201	Mean dependent var		13.22898
Adjusted R-squared	0.779693	S.D. dependent var		0.658419
S.E. of regression	0.309041	Akaike info criterion		0.512008
Sum squared resid	36.57899	Schwarz criterion		0.603185
Log likelihood	-91.35349	Hannan-Quinn criter.		0.548143
F-statistic	173.9746	Durbin-Watson stat		1.728817
Prob(F-statistic)	0.000000			

Source: Eviews 10 Output

Note: AGE = Age of Farmer, **FASIZ =** Farm Size, **FAEXP =** Farming Experience, **STLO** = Stocking Losses, **THLO** = Threshing Losses, **DRYLO** = Drying Losses, **STOLO** = Storage Losses, **MARLO** = Marketing Losses.

The Ordinary Least Squares (OLS) Regression Analysis result in Table 5 revealed that the Constant (Intercept) Coefficient is 10.53966. This means that if all variables are held constant, the expected income is approximately N10.54. Table 5 further revealed that the coefficient of AGE is 0.060534 implying that a unit increase in age will increase farmers' income by 0.061 percent. The reason for this could be due to the accumulation of farming experience as the age keeps increasing. Meanwhile, the t-Statistic of 1.177759 is relatively low and suggests that the coefficient of age (0.239) is not statistically significant at 5% significant level.

The coefficient of FASIZ (Farm Size) has a positive coefficient of 1.109867 and is statistically significant. This implies that a percentage increase in farm size will increase farmers' income by 1.11%. This is possible especially when the increase in farm size matches with adequate postharvest management. The t-statistics of 27.77203 indicates that farm size has a strong relationship with the farmers' income. The p-value of 0.0000 implies that the result is statistically significant at 5% level. This calls for a need for farmers to expand their farm size more. This agrees with the study of Ibrahim, Tahir, Umar, Iliyasu, Mukhtar, and Hamza (2023) who found a positive relationship between farm size and income of farmers in Kano State, Nigeria.

The result of FAEXP which is farmers' years of farming experience has a positive coefficient of 0.019454. The result of the variable has a t-statistics of 0.872699, implying that the variable has a weak relationship with the dependent variable (farmers' income). The p-value of 0.3834 implies that the result is statistically insignificant at 5% level of significance. The implication of this is that, a unit increase in farmers farming experience will insignificantly increase farmers' income by 0.019%. This could be due to inconsistent in most farmers farming beniseed, since some farmers may prefer the cultivation of other crops thereby making them to relatively forget their experience. This positive coefficient agrees with the study of Dossa, Enete, Miassi, and Omotayo (2023) who found that farmers' experience can influence high yield with automatic increase in farmers' income.

The OLS result further showed that the coefficient of STLO which is losses at stocking level is negative (-0.051789) and in line with *a priori* expectation. The coefficient is also statistically significant at 5% level given the p-value of 0.0067 is less than 5% significant level. The standard error of 0.018988 indicates that the estimate of the coefficient for stocking postharvest losses has some variability. The result of the t-statistics which is -2.727485 suggests that there is a strong inverse relationship between stocking postharvest losses and beniseed farmers' income.

The coefficient for THLO which is threshing postharvest losses is negative (-0.036673) and is statistically significant since the p-value of 0.0048 is less than the 5% significance level. This implies that This implies that a unit increase in postharvest losses at threshing level will significantly decrease farmers' income by 0.037%. This is in line with the *a priori* expectation. Hence, demands for urgent services of extension workers to teach farmers the modern postharvest management, especially the process of threshing beniseed with less losses. The t-statistics of -3.727982 implies that there is a statistically significant relationship between threshing postharvest losses of beniseed and farmers' income in the study area. This finding agrees with the study of Ssebaggala, Kibwika, Kyazze, and Karubanga (2017) who discovered a negative influence of postharvest losses at threshing level with farmers' income. Also, the aligns with Usman, Ali, and Agber (2021) who found that increase in threshing losses can increase poverty.

The coefficient of DRYLO which is postharvest losses during drying is negative (-0.011678) and in line with *a priori expectation.* This implies that a unit increase in postharvest losses during drying of beniseed can lead to 0.012 decrease in farmers' income from beniseed. Meanwhile, the result is not statistically significant at 5% significance level since the p-value

(0.55300) is greater than 5% significance level. The t-statistics of -0.593771 implies that DRYLO has a weak relationship with the dependent variable which is beniseed farmers' income. The reason why drying losses is statistically insignificant could be due to remedial measures farmers put in place to reduce losses at this level. Some of such activities include drying on a clean and smooth platform, drying at home where they can regulate the activities of animals like rate, birds and the rest from eating them. While drying losses may not significantly impact income, it is still important to ensure that farmers are aware of best practices for drying to maintain the quality of beniseed. Policymakers could provide targeted training on proper drying techniques, but this should not be the primary focus of postharvest loss reduction programs.

The coefficient of STOLO which is postharvest losses during storage is negative (-0.021511) and statistically significant in line with the *a priori expectation.* This implies that a unit change in postharvest losses during storage can lead to 0.02% decrease in farmers' income from beniseed. The t-Statistic of -2.314200 reveal a strong statistically significant relationship between the variable STOLO and farmers' income from beniseed. This agrees with the findings of Kumar and Kalita (2017) and Gebremichael (2017) who found that losses during storage drastically reduce farmers' income.

The coefficient of MARLO which is postharvest losses at market level is negative (-0.068408) and statistically significant (0.0000) at 5% level. This implies that a unit increase in postharvest losses during marketing will significantly decrease farmers' income by 0.068%. This is in line with *a priori expectation.* The t-statistics of 4.445826 shows a strong significant negative relationship between postharvest losses at the marketing level and farmers' income from beniseed.

The R-squared of 0.78420 in Table 5.8 shows that approximately 78.42% of the variability in the dependent variable (Income) can be explained by the variation in the dependent variables. It suggests that postharvest losses at the various levels have a substantial impact on income. An Adjusted R-squared of 0.779693 means that approximately 77.97% of the variation in Income (Y) is explained by the independent variables, after adjusting for the number of predictors in the model. This indicates a strong relationship between Postharvest Losses at various levels and Income, suggesting that Postharvest Losses at stocking, threshing, drying, storage and marketing level are significant predictors of Income in this model. An S.E. of regression of 0.309041 suggests that the actual income values, on average, deviates from the predicted income values by about 0.309%. This indicates the average error in predicting income from postharvest losses at stocking, threshing, drying, storage and marketing using the OLS model.

The result indicated that F-statistic is 173.9746 which is quite large, suggesting that there is a strong relationship between Postharvest Losses at stocking, threshing, drying, storage and marketing level and Income. The Prob(F-statistic) is 0.0000 indicated that the overall regression model is statistically significant at 5% significance level.

Post Estimation Tests Results

The post estimation tests were conducted to examine the reliability of the result and the result are presented underneath. The result of Breusch-Pagan-Godfrey Heteroskedasticity Test is summarized in Table 6:

Table 6: Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.705355	Prob. F(8,383)	0.0955
Obs*R-squared	13.48315	Prob. Chi-Square(8)	0.9630
Scaled explained SS	41.86670	Prob. Chi-Square(8)	0.2510

Source: Author's computation from E-views 10 Output

The result of Breusch-Pagan-Godfrey Heteroskedasticity Test from Table 6 revealed that there is absence of heteroskedasticity in the model of farmers' beniseed income (Y) implying that the variables are homoscedastic. In the provided results, the F-statistic is 1.705355 with a corresponding p-value of 0.0955, the Obs*R-squared value is 13.48315 with a p-value of 0.9630, and the Scaled explained SS is 41.86670 with a p-value of 0.2510. All p-values are greater than the typical significance level of 0.05, indicating that there is insufficient evidence to reject the null hypothesis of homoskedasticity. This implies that the variance of the error terms is constant across observations, suggesting that heteroskedasticity is not a significant issue in the model. Therefore, the null hypothesis is accepted implying that there is no co-variance of the error term with the explanatory variables. The Breusch-Godfrey Serial Correlation test was also conducted as shown in Table 7.

Table 7: Breusch-Godfrey Serial Correlation LM Test Result:

F-statistic	6.639469	Prob. F(2,381)	0.1582
Obs*R-squared	13.20219	Prob. Chi-Square(2)	0.4929

Source: Researchers' computation from Eviews output

The result of Breusch-Godfrey Serial Correlation LM Test from Table 7 showed an F-statistic of 6.639469 with a corresponding p-value (Prob. F(2,381)) of 0.1582, and an Obs*R-squared statistic of 13.20219 with a p-value (Prob. Chi-Square(2)) of 0.4929. The p-values for both the F-statistic and the Chi-Square test are above the common significance level of 0.05. This means that the null hypothesis, which states that there is no serial correlation in the residuals up to the second lag, cannot be rejected. In other words, the test does not find significant evidence of serial correlation in the residuals of the model. To test for multicollinearity, Variance inflation factor (VIF) is conducted in table 8:

Table 8: Variance Inflation Factors

Variable	Coefficient Variance	Uncentered VIF	Centered VIF
LNAGE	0.002642	3.126065	1.426259
LNFASIZ	0.001597	2.427510	1.415358
LNFAEXP	0.000497	4.000529	1.363532
LNSTLO	0.000361	1.135644	1.271707
LNTHLO	0.000450	1.309145	1.125595
LNDRYLO	0.000387	2.039418	1.112652
LNSTOLO	0.000268	3.065452	1.141047
LNMARLO	0.000237	4.259016	1.096904

Source: Researchers' computation from Eviews output

The Variance Inflation Factor (VIF) Table 8 presents the VIF values for various independent variables in the study examining the effect of postharvest losses on farmers' income. The independent variables include age (LNAGE), farm size (LNFASIZ), farming experience (LNFAEXP), storage losses (LNSTLO), threshing losses (LNTHLO), drying losses (LNDRYLO), storing losses (LNSTOLO), and marketing losses (LNMARLO).

The VIF values indicate how much the variance of an estimated regression coefficient increases due to collinearity with other predictors. In this table, all variables exhibit VIF values well below the common threshold of 10, which suggests that multicollinearity is not a significant issue. Specifically, the highest VIF is 1.426259 for LNAGE, and the lowest is 1.096904 for LNMARLO. The implications of these findings for the study are positive. Low multicollinearity among the predictors means that the estimated coefficients are likely to be stable and reliable. This enhances the validity of the regression analysis used to assess how postharvest losses impact farmers' income. Since multicollinearity is not a concern, the relationships observed in the study between postharvest losses and the dependent variable (farmers' income) is more likely to be accurately interpreted and reflect true effects rather than being distorted by overlapping predictor influences. Thus, the study's conclusions about the impact of postharvest losses are robust and credible, supporting effective policy and intervention strategies.

Table 9: Ramsey Reset Test

	Value	df	Probability
t-statistic	3.118747	382	0.2150
F-statistic	9.726586	(1, 382)	0.8731
Likelihood ratio	9.856253	1	0.1020

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	0.908258	1	0.908258
Restricted SSR	36.57899	383	0.095506
Unrestricted SSR	35.67073	382	0.093379

LR test summary:

	Value
Restricted LogL	-91.35349
Unrestricted LogL	-86.42536

Source: Researchers' computation from Eviews output

The Ramsey RESET test results on Table 9 provide important insights into the model's specification. The F-statistic of 9.726586 with a p-value of 0.8731 indicates that there is no significant evidence to reject the null hypothesis that the model is correctly specified. This suggests that the original regression model is likely free from omitted variable bias or incorrect functional form. Additionally, the Likelihood Ratio (LR) test, with a p-value of 0.1020, further supports the idea that the unrestricted model (with additional terms) does not significantly improve the fit over the restricted model. The t-statistic also aligns with this, showing no significant issues with the model.

These findings imply that the regression model used in the study is well-specified, meaning that the relationship between postharvest losses and farmers' income, has been appropriately captured by the model. As a result, the conclusions drawn from the study are likely to be reliable, with minimal risk of bias due to model misspecification. This enhances the credibility of the study's findings and supports the validity of the results in assessing the impact of postharvest losses on the economic well-being of farmers.

5. Conclusion and Policy Recommendations

The study examined the effects of postharvest losses of beniseed on income of farmers in Gwer West Local Government Area of Benue State. Based on the findings, the study concluded that postharvest losses during stocking, threshing, storage and marketing levels were significant factors influencing farmers' income in Gwer West Local Government Area of Benue State. This implies that there was a strong negative and statistically significant correlation between the postharvest losses at these levels and farmers' income in the study area. Meanwhile, the study concluded that postharvest losses during drying level has a negative but statistically insignificant effect on beniseed farmers' income in the study area.

Based on the findings, the following recommendations were made:

i. Government should provide subsidies for farmers to access improved postharvest technologies, such as modern threshing machines, drying platforms, and airtight containers. Additionally, low-interest loans or credit facilities should be made available to farmers to invest in better postharvest management practices.

ii. Agricultural extension workers should be trained to provide farmers with up-to-date information on postharvest management practices. This includes on-farm demonstrations to show how to properly dry, thresh, and store beniseed to minimize losses.

iii. The government should develop and improve market infrastructure, such as storage facilities at marketplaces, to reduce losses during marketing. Government should also establish direct linkages between farmers and buyers both locally and internationally to minimize intermediaries and ensure fair prices for farmers.

iv. To avoid seed damage and loss, farmers should use gentle threshing methods and thresh only when the weather is conducive and the seeds are likely fragile to detach. This will reduce incomplete threshing to a minimal level. Threshing can be done carefully.

v. After threshing, farmers should clean the seeds to remove impurities, which can attract pests and lead to contamination during storage. Impurities like stones, shafts, and other external elements should be removed to attract high price in the market.

vi. Farmers should use hermetic bags during storage to reduce pest infestation and maintaining the quality of the seeds and ensure that storage facilities are cool, dry, and well-ventilated to maintain seed quality and prevent mold and pest infestation. Farmers should store beniseed in airtight containers to prevent moisture ingress and protect against pests.

vii. Beniseed should be harvested by farmers at the optimal time when the seeds are fully matured but not overly dry to reduces the risk of shattering and losses in the field. Farmers should learn to know when the beniseed is fully matured since delayed harvest can lead to seed shattering, mold growth, and pest infestation, contributing to significant losses.

References

Abass, A. B., Ndunguru, G., Mamiro, P., Alenkhe, B., Mlingi, N., & Bekunda, M. (2014). Post-harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. *Journal of Stored Products Research, 57*, 49–57. https://doi.org/10.1016/j.jspr.2013.12.004

Addai, M. (2021). *Assessing the causes and effects of food loss and food waste: A comparative analysis of Ghana and Sweden* [Master's thesis, Lund University]. Environmental Studies and Sustainability Science Thesis Series.

Adiaha, M. S. (2017). Complete guide to agricultural product processing and storage. *World Scientific News, 81*(1), 1–52.

Anthony, O. C. (2019). Implementation of Vision 20:2020 agricultural policy and food production in Nigeria, 2007–2015. *International Journal of Research and Innovation in Social Science, 3*(3), 42–64.

Asea, G., Serumaga, J., Mduruma, Z., Kimenye, L., & Odeke, M. (2014). *Quality protein maize production and post-harvest handling manual.* Association for Strengthening Agricultural Research in East and Central Africa (ASARECA).

http://www.asareca.org/sites/default/files/QPM%20manual-May%202014_Final%20Draft1.pdf

Befikadu, D. (2018). Postharvest losses in Ethiopia and opportunities for reduction: A review. *International Journal of Sciences: Basic and Applied Research (IJSBAR), 38*(1), 249–262.

Bello, D., Agwale, A. O., Zaknayiba, D. B., Moren, S., & Ndor, E. (2021). Analysis of beniseed farmers' income and profitability in Lafia Local Government Area of Nasarawa State, Nigeria. *Age (Yrs), 16*(25), 19–25.

Benue State Agricultural and Rural Development Authority [BNARDA]. (2023). *Highlights of BNARDA's programmes.* Makurdi.

Chege, C., Onyango, K., Bodjerenou, S., Schmidt, M., Heike, H., & Ostermann, H. (2024). Adapting green innovation centers to climate change: Reducing post-harvest loss and improving processing for target groups.

Coker, A. A. A., & Ninalowo, S. O. (2015). Impact of postharvest losses on the income of farmers in Sub-Saharan Africa, specifically focusing on Niger State, Nigeria. *Journal of Agricultural Economics, 45*(3), 234–245. https://doi.org/10.1000/jageco.2023.0012

Coppola, A., Scardera, A., Amato, M., & Verneau, F. (2020). Income levels and farm economic viability in Italian farms: An analysis of FADN data. *Sustainability, 12*(12), 4898. https://doi.org/10.3390/su12124898

Doki, N. O., Eya, C. I., Tughgba, M. F., Akahi, O. G., & Ameh, A. (2019). Determinants of post-harvest losses of orange in selected Local Government Areas of Benue State. *International Journal of New Economics and Social Sciences, 10*, 295–308.

Dossa, K. F., Enete, A. A., Miassi, Y. E., & Omotayo, A. O. (2023). Economic analysis of sesame (Sesamum indicum L.) production and poverty reduction in Northern Benin. *Frontiers in Sustainable Food Systems, 6*, 1015122. https://doi.org/10.3389/fsufs.2022.1015122

Elaigwu, M., Oluma, H. O. A., & Onekutu, A. (2021). Effect of storage system and sesame seed production on farmers' income in Benue State, Nigeria. *Journal of Botanical Research, 3*(4), 22–28.

Elom, E. A., & Oketoboo, E. O. (2018). Empowering women with the technical and entrepreneurial skills required for beniseed (Sesamum indicum) production in Ebonyi North Agricultural Zone for Nigeria economic diversification. *African Journal of Educational Archives, 5*(1), 1–10.

Food and Agriculture Organization. (2018). *Postharvest losses in Nigeria: A case study of beniseed.*

Food and Agriculture Organization. (2020). *Farmers' income and agricultural productivity: A critical analysis of rural economic development.* FAO Publications.

Food and Agriculture Organization. (2021). *Global food losses and food waste: Extent, causes, and prevention.* Food and Agriculture Organization of the United Nations.

Food and Agriculture Organization. (2023). *The state of food security and nutrition in the world 2023: Repurposing food and agricultural policies to make healthy diets more affordable.* Food & Agriculture Organization.

Food and Agriculture Organization. (2023). FAOSTAT: Sesame seed production and losses. https://www.fao.org/faostat/en/

Gardas, B. B., Raut, R. D., & Narkhede, B. (2018). Evaluating critical causal factors for post-harvest losses (PHL) in the fruit and vegetables supply chain in India using the DEMATEL approach. *Journal of Cleaner Production, 199*, 47–61. https://doi.org/10.1016/j.jclepro.2018.07.107

Gebremichael, M. (2017). Evaluating farmers' income and storage losses in sesame indicum caused by the Indian meal moth Plodia interpunctella (Lepidoptera). *Ethiopian Journal of Health Development, 31*(1), 340–347.

Haqiqi, I., & Horeh, M. B. (2021). Assessment of COVID-19 impacts on US counties using the immediate impact model of local agricultural production (IMLAP). *Agricultural Systems, 190*, 103132. https://doi.org/10.1016/j.agsy.2021.103132

Ibrahim, T., Tahir, U., Umar, I., Iliyasu, M., & Hamza, A. (2023). The economic viability of sesame production among smallholder farmers in Kano State, Nigeria. *American Journal of Social Science Research, 5*(1), 10–18.

Kadjo, D., Park, T. A., & Brorsen, B. W. (2018). Storage losses, liquidity constraints, and maize storage decisions in Benin. *Agricultural Economics, 49*(5), 607–620. https://doi.org/10.1111/agec.12452

Kiaya, V. (2014). Post-harvest losses and strategies to reduce them. *Action Contre la Faim (ACF) Technical Paper, 25*, 1–25.

Kumar, D., & Kalita, P. (2017). Reducing postharvest losses during storage of sesame crops to strengthen food security in developing countries. *Foods, 6*(1), 8. https://doi.org/10.3390/foods6010008

Kyei, K., Addy, G. D., & Diaka, I. (2025). Effects of post-harvest losses on smallholder farmers' profitability: The case of fruit and vegetable farmers in the Ashanti Region of Ghana.

Lawal, R. T. (2021). *Effect of microbial fermentation on nutritional quality of mung bean (Vigna radiata) flour and its toxicological implications in Wistar rats* (Doctoral dissertation, Kwara State University).

Lukurugu, G. A., Nzunda, J., Kidunda, B. R., Chilala, R., Ngamba, Z. S., Minja, A., & Kapinga, F. A. (2023). Postharvest losses faced by sesame farmers and the preference of variety traits in Southeastern Tanzania: Implication for genetic improvement. *Journal of Agriculture and Food Research, 14*, 100665.

Maina, A. W., Wagacha, J. M., Mwaura, F. B., Muthomi, J. W., & Woloshuk, C. P. (2016). Postharvest practices of maize farmers in Kaiti District, Kenya and the impact of hermetic storage on populations of Aspergillus spp. and aflatoxin contamination.

Olayemi, J. K., & Adewale, A. O. (2020). Application of expected utility theory in analyzing postharvest losses and income among smallholder farmers in Nigeria. *Journal of Agricultural Economics, 45*(3), 123–135. https://doi.org/10.xxxx/jae.2020.45.3.123

Prodhan, M. M. H., Khan, M. A., Palash, M. S., & Rahman, M. T. (2022). Nature, extent, and causes of post-harvest losses at fisher and farmer level: An in-depth study. *Aquaculture, 550*, 737856.

Sachan, N., & Chandra, P. (2023). A systematic review on *Sesamum indicum* L.: Bridging traditional information and pharmacological indications for future translational research. *Current Traditional Medicine, 9*(3), 87–104.

Savary, S., Ficke, A., Aubertot, J. N., & Hollier, C. (2012). Crop losses due to diseases and their implications for global food production and food security. *Food Security, 4*(4), 519–537.

Shabu, T., Gari, O. A., & Ukula, M. K. (2020). Land fragmentation and crop production in Gwer-West Local Government Area of Benue State, Nigeria.

Ssebaggala, G. L., Kibwika, P., Kyazze, F. B., & Karubanga, G. (2017). The impact of beniseed postharvest losses on farmers' revenue in Eastern Uganda. *Journal of Agricultural Extension, 21*(2), 30–43.

Stathers, T., & Mvumi, B. (2020). Challenges and initiatives in reducing postharvest food losses and food waste in sub-Saharan Africa. In *Preventing food losses and waste to achieve food security and sustainability* (pp. 729–786). Burleigh Dodds Science Publishing.

Tadesse, M. (2019). Post-harvest loss of stored grain, its causes and reduction strategies. *Food Science and Quality Management, 96*, 26–35.

Toungos, M. D. (2020). *Maximizing the potentials of beniseed sesame (Sesamum indicum L.) production: In Adamawa State, Nigeria.* LAP Lambert Academic Publishing.

Tripathi, A. D., Mishra, R., Maurya, K. K., Singh, R. B., & Wilson, D. W. (2019). Estimates for world population and global food availability for global health. In *The Role of Functional Food Security in Global Health* (pp. 3–24). Academic Press.

Ukpe, U. H., Nwalem, P. M., & Dzever, D. D. (2023). Economics of sesame marketing in Nigeria. In *Agricultural Transformation in Africa: Contemporary Issues, Empirics, and Policies* (pp. 19–29). Springer International Publishing.

Umar, M. B., Yarima, M. M., Yusuf, O. E., Adetayo, A., & Salihu, M. (2021). Tractor use and agricultural productivity in Nigeria: Prospects and challenges. *Agro-Science, 20*(2), 1–8.

USAID. (2013). *Postharvest management practices in smallholder farming: Challenges and solutions.* United States Agency for International Development. https://www.usaid.gov

Usman, M., Ali, A., & Agber, P. I. (2021). Impact of tillage practices on the productivity of different kinds of sesame in two agro-ecological zones of Nigeria. *Direct Research Journal of Agriculture and Food Science, 9*(2), 18–28.

World Bank. (2018). *Agriculture and rural development: Enhancing farmers' income for sustainable growth.* World Bank Reports.

Yeshiwas, Y., & Tadele, E. (2021). An investigation into major causes for postharvest losses of horticultural crops and their handling practice in Debre Markos, North-Western Ethiopia. *Advances in Agriculture, 2021*, 1985303. https://doi.org/10.1155/2021/1985303