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MITIGATING POSTHARVEST LOSSES IN CUCUMBER PRODUCTION: X-RAYING THE CAUSES, DRIVERS, AND COPING MECHANISMS AMONG SMALLHOLDERS

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ABSTRACT

Food losses resulting from poor post-harvest management hamper achieving the sustainable development goal of zero hunger and improved food security in most developing countries. There is thus a need to understand the underlying causes and factors influencing postharvest losses among farmers to reduce postharvest losses. The study examined the primary and secondary causes of postharvest losses, the extent of postharvest losses, the drivers, and the mitigation strategies. A multistage sampling procedure was used in the selection of 200 respondents. Primary data was collected with the aid of a structured questionnaire. The data was analyzed using descriptive statistics and Ordinary Least Square regression. The results of the socioeconomic characteristics of the farmers indicated that the majority (54.0%) were female, with mean age, education, household size, and monthly income of 45.15 years, 11.88 years, six persons, and ₦129,400 ($180.57), respectively. The major primary and secondary causes of postharvest losses were pathogens and pests (89%) and poor road networks ($\bar{x}$ = 4.5), respectively. About 41% reported a postharvest loss of between 21% and 50% of cucumber. The drivers of postharvest losses were off-farm income, harvest time after maturity, household size, the quantity of cucumber produced, and market distance. The major mitigation strategies devised by the respondents to reduce postharvest losses include timely harvesting, improved handling and transportation techniques, and adopting improved pest and disease management practices. The findings of this study suggest that improving road networks, especially those connecting farmers to the markets, would significantly reduce post-harvest losses.

INTRODUCTION

Cucumber is an edible fruit produced and consumed globally for its nutritional, health, and economic benefits (Adeoye & Balogun, 2016; Onuwa et al., 2023). Nutritionally, cucumbers are rich in fiber, potassium, manganese, magnesium, and vitamins A, C, and K (Chakraborty & Rayalu, 2021). It supports antimicrobial and antifungal activities, aids detoxification, hydration, and anti-inflammatory effects on the skin (Akhtar et al., 2020; Chakraborty & Rayalu, 2021). It is also instrumental in treating diabetes, reducing cancer risk (Tuama & Mohammed, 2019), and other health benefits such as aiding digestion, wound healing, weight loss, and reducing blood pressure and eye puffiness. Economically, studies on cucumber production have shown that the crop has high economic significance; it is a profitable venture for small-scale farmers with the highest benefit-cost ratio (Adeoye & Balogun, 2016; Onuwa et al., 2023). Similarly, Onuwa et al. (2023) and Adeoye and Balogun (2016) posited that cucumber production in areas where the soil is suitable and favourable climatic conditions can support farmers' earnings at regular intervals. Hence, increased cucumber production can catalyze farmers' income and welfare, enhance food security, and achieve zero hunger in Sub-Saharan Africa (SSA). However, the realization of zero hunger, the second goal of the United Nations Sustainable Goals, and food security are under threat in SSA due to the high level of waste resulting from postharvest losses. While improvements at the farm level to increase on-farm yields are

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generally effective and contribute to higher supply (Sheahan & Barrett, 2017), they do little to improve profitability as a result of postharvest losses. Consequently, an increase in yields has not translated to significant benefits for smallholder farmers, mainly due to postharvest losses. Thus, to end global hunger and food insecurity, especially in developing countries, it has become imperative to significantly reduce the ugly trend and ensure that food wastage is reduced to the barest minimum.

Globally, food waste and loss are estimated at around one-third of all the food produced in the world (FAO, 2019), with most losses happening by far in developing countries. It is estimated that over 40% of annual perishable crops, such as fruits and vegetables produced in the region, are lost before they reach the final consumers due to poor handling and storage (Sheahan & Barrett, 2017). These losses are costly and have essential implications economically, socially, and environmentally, such as loss of farmer income resulting in poverty in some cases, intensified food insecurity, and environmental externalities, which, combined with others, ultimately lead to economic stagnation (Ogundele, 2022). Postharvest losses can thus be defined as quantitative or qualitative measurable food loss occurring shortly after harvest until it reaches the final consumer or any other utilizable points (Hodges et al., 2011). Quantitative losses are assessed by evaluating the reduction in the physical quantity of food commodities over some time and space. Conversely, qualitative losses are assessed regarding the decline in nutritional content, aesthetic attributes, viability, and overall nutritional properties of food commodities (Falola et al., 2023; Sheahan & Barrett, 2017). According to Ishangulyyev et al. (2019) and Ogundele (2022), such losses can occur due to environmental, technological, social, economic, or managerial causes; they can happen anywhere in the food supply chain – from production, processing, and storage to marketing/distribution. However, the cost of post-harvest losses is higher for perishable crops like fruits and vegetables like tomatoes, mangoes, and cucumbers. Empirical studies estimated that postharvest losses for fruits and vegetables could exceed 40% in Nigeria, leading to enormous financial losses among farmers and the country (Obanubi et al., 2021).

Postharvest losses have a more severe and far-reaching effect than just waste of farm produce, especially in developing countries that have yet to attain self-sufficiency in food production. Postharvest losses indicate an inefficient food-functioning system (Chikez et al., 2023**),** and the causes of these losses could be classified into primary, secondary, or tertiary factors (Sugri et al., 2021). Globally, integrated and innovative approaches have been established to facilitate the efforts to ensure sustainable food production and consumption. In Nigeria, the Nigerian Stored Products Research Institute (NSPRI) was established, and one of the targets was to research and enhance postharvest management of farm produce to meet appropriate standards of local consumption and export. Despite these efforts, the problems of postharvest losses continue to persist and worsen. The perishable nature of most agricultural produce, especially vegetables and fruits, makes it prone to high post-harvest losses.

Cucumber is one of the highly perishable crops characterized by its high moisture content and lack of refrigeration capability. This predisposes the crop to rapid deterioration, leading to significant potential for losses if not managed properly. Thus, in transporting harvested cucumbers from places of production to consumption, a significant proportion of the farm produce is lost. In Nigeria, cucumber is consumed in all regions but is produced mainly in the northern region. The southern regions, including Enugu state, have recorded increased cucumber production. Cucumber productivity in Nigeria is relatively low and unranked compared to other vegetables like tomatoes and citrus. Thus, little attention is paid to the crop, especially its postharvest management. Along the cucumber value chain, freshly harvested cucumbers encounter qualitative and quantitative losses, which have implications for marketing and price, especially given the perfectly competitive nature of the agricultural market. Since over 60% of Nigerians are engaged in agriculture, devising practical solutions to mitigate post-harvest losses is crucial for advancing sustainable development in this sector. The output of this study is an indication of the primary causes and drivers of post-harvest losses among small-scale cucumber farmers, and this will serve as a guide to policymakers in devising effective measures to reduce postharvest losses among farmers and boost overall food security

The main result from this study shows the primary and secondary causes of post-harvest losses and the factors that drive post-harvest losses among small-scale cucumber farmers. It further highlights the coping strategies adopted by cucumber farmers to mitigate post-harvest losses.

The article is presented in various sections. It follows with a brief review of related literature that have conducted various studies on post-harvest losses globally. The next section presents the methodology adopted for achieving the study objectives which includes a description of the study area, method of sampling survey participants, and statistical tools employed for analyzing data. The results are presented tabularly and extensively discussed in subsequent sections. This is finally followed by the concluding section and appropriate recommendations based on the research findings.

LITERATURE REVIEW

Across the globe, several studies have been done on postharvest management and the effect and intensity of postharvest losses of various crops. Studies by Akaagerger et al. (2023) examined the effect of X-rays and charcoal cooler bins on shelf-life extension for cucumbers. In other studies, Hodges et al. (2011) and Aidoo et al. (2014) found that postharvest losses negatively impacted farmers, consumers, and the economy in diverse ways. These studies emphasized the need to reduce postharvest losses as it would enhance the pathway to food security and sustainable development. This is supported by other research reiterating that minimizing postharvest losses translates to increased levels of farmers' income and savings (Mlambo et al., 2017; Shee et al., 2019). The irregular patterns of post-harvest losses also negatively affect food security (Balana et al., 2022; Kikulwe et al., 2018), reducing the income for farmers, increasing prices for consumers, and declining food security level (Ibrahim et al., 2022; Okadonye et al., 2022). With the tremendous adverse effects of postharvest losses on economic and food security, SSA must spend an estimated $940 billion by 2050 to end hunger (Porciello et al., 2020). This

is 47% of the designated money for forming functional postharvest technologies (Sugri et al., 2021). Despite the efforts from governments to increase farmers' profit margins and food security by drastically reducing postharvest losses, there is a need for policies that focus on understanding the determinants of postharvest losses (Falola et al., 2023). To bridge this gap, this study identified the causes and extent of postharvest losses, assessed drivers of these postharvest losses, and investigated the coping mechanisms adopted by smallholder cucumber farmers. The findings are expected to inform policies that will help to improve the understanding of the postharvest challenges faced by smallholder farmers in the region and enable the promulgation and adoption of measures that will minimize postharvest losses, increase the economic viability of cucumber production, alleviate the poverty of farmers, and increase the income levels of small-scale farmers in Enugu state.

Based on this premise, the study intends to assess the primary and secondary causes, determine the drivers of post-harvest losses among small-scale cucumber farmers and identify the coping strategies adopted by cucumber farmers to mitigate post-harvest losses.

MATERIALS AND METHODS

Study Area

The study was conducted in Enugu State, one of Nigeria's five states in the southeastern region. It has a total land area of 8,022.95 Km^2 and an estimated population of over three million (National Population Commission, 2006). Enugu state has a high production potential for cucumbers (Okafor & Yaduma, 2021). However, postharvest losses remain a significant challenge in the area, threatening food security and reducing farmers' income and sustainability of the enterprise (Ozioko et al., 2019)

Sampling Procedure

The study adopted a multistage sampling procedure in the selection of respondents. In the first stage, five out of the six Agricultural Zones (AZs) in the state were purposively selected based on their agrarian nature. In the second stage, one Local Government Area was also purposively selected from each of the selected AZs due to the concentration of cucumber farmers. Similarly, in stage three, two communities with high cucumber production were purposively selected, giving ten communities. In the final stage, 20 cucumber farmers were randomly selected from the list of cucumber farmers in each of the ten communities, giving 200 respondents for the study.

Data Collection

Data was collected using structured questionnaires. The questionnaires were designed to capture information on the farmers' socio-economic characteristics, postharvest losses, drivers of postharvest losses, and mitigation strategies. Data on their socioeconomic characteristics such as age, sex, farming experience, level of education, and number of agricultural extension visits per annum. We also collected information on the quantity of cucumber harvested, the quantity sold, and the quantity lost. Data on the possible socioeconomic and institutional drivers and the various mitigation strategies employed to reduce the magnitude of postharvest losses were also obtained.

Econometric Estimation

The collected data were analysed using descriptive statistical tools such as frequency, percentage, mean, Likert scale rating, and inferential statistical tools like the ordinary least square regression model.

Ordinary least square regression model

The ordinary least square regression (OLS) model was used to determine the drivers of postharvest losses among cucumber farmers. The model is specified as follows:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \ldots + \beta_{14}X_{14} + \varepsilon \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:
Y = Postharvest losses (kg)
X_1 = Sex (male=1, female=0)
X_2 = Age (Years)
X_3 = Farming experience (Years)
X_4 = Extension contacts (No of contacts in a year)
X_5 = Household size (No of persons living in a household)
X_6 = Access to credit (Access =1, No = 0)
X_7 = Distance to Market (km)
X_8 = Cooperative Membership (Yes =1, No = 0)
X_9 = Quantity produced (kg)
X_{10} = Farm size (Ha)
X_{11} = Monthly Income (Naira)
X_{12} = Time of harvest after maturity (days)
X_{13} = Off-farm Income (Yes =1, No = 0)
X_{14} = Ownership of Transport facility (Yes =1, No = 0)

β_0 = Intercept
β_1-β_{14} = Coefficients
ε = Error term

Likert scale rating model

A 5-point Likert scale was employed to determine the causes of postharvest losses. The causal items were designated as very high, high, moderate, low, and very low, corresponding to 5, 4, 3, 2, and 1, respectively. This was ranked using a weighted mean (x). The mean score (MS) of the respondents based on the four 5-point scale was obtained thus:

$$\frac{\Sigma fx}{n} = \frac{5+4+3+2+1x}{5} = 3.0. \ldots\ldots (2)$$

A 3.0 cut-off point using the interval scale of 0.05 was adopted. Therefore, any item with a mean score (MS) less than 3.05 (i.e., MS < 3.05) was considered as a weak factor and thus not significant, while mean values above 3.05 (i.e., MS > 3.05) were regarded significant and thus was rated as major causes of post-harvest losses.

RESULTS

Table 1. Socioeconomic characteristics of small-scale cucumber farmers

Socio-economic characteristics	Freq.	Per. (%)	Mean
Sex			
Female	108	54.0	
Male	92	46.0	
Age			
20-40	72	36.0	
41-60	114	57.0	45.45
61-100	14	7.0	
Household size			
3-5	92	46.0	
6-8	86	43.0	6.21
9-12	33	11.0	
Years in formal education			
Primary school	16	8.0	
Secondary school	148	74.0	11.88
Tertiary education	54	18.0	
Years of farming experience			
2-10	126	63.0	
11-19	38	23.0	
20-28	10	5.0	10.43
29-37	33	11.0	
Monthly income from cucumber farming (₦)			
≤ 50000	98	49.0	
51000-150000	58	29.0	
151000-250000	14	7.0	
251000-350000	14	7.0	
≥351000-	16	8.0	129,400
Source of Farm Labor			
Family	81	27.0	
Hired	88	44.0	
Both	58	29.0	
Cooperative membership			
No	130	65.0	
Yes	70	35.0	
Source of credit			
None	130	65.0	
Commercial banks	8	4.0	
Cooperative society	36	18.0	
Microfinance bank	4	2.0	
Friends	8	4.0	
Personal savings	14	7.0	
Extension visits			
Never	152	76.0	
Once	16	8.0	0.4
Twice	32	16.0	

Table 2. Primary causes of post-harvest losses in cucumber production

Variables	Frequency	Percent (%)
Have you experienced post-harvest losses?		
Yes	200	100.0
No		
Causes of post-harvest losses		

Harvesting at incorrect maturity	144	72.0
Poor handling and storage	72	86.0
Pathogens and pest	178	89.0
Ethylene sensitivity	56	28.0
Temperature and humidity (water loss)	132	66.0
Mechanical damage	152	76.0

Table 3. Psychometric scale of the secondary causes of postharvest losses in cucumber production

Variables	Mean	Standard Deviation
Secondary causes		
Poor road network	4.5200	0.75852
Lack of proper storage facilities	3.3900	1.36252
Market-related issues (lack of demand due to high prices)	3.3500	1.29002
Financial constraints	3.9100	1.34911
Inadequate knowledge of post-harvest management	3.2300	1.21319
Climate-related factors	4.0800	1.06059
Insufficient market info and opportunities	3.0000	1.26331
Poor extension services	2.7400	1.26826
Long distance to markets	3.2700	1.34731
Cucumber variety cultivated	2.1400	1.03494

Table 4. Extent of post-harvest losses among small-scale cucumber farmers

Postharvest Loss	Frequency	Percentage (%)
≤ 20 %		
Yes	132	66.0
No	68	34.0
21-50 %		
Yes	81	40.5
No	119	59.5
≥50 %		
Yes	54	27.0
No	146	73.0

Table 5. OLS regression on the drivers of post-harvest losses

Variables	Coefficient	t-value	Sig.
(Constant)	1.136	0.339	0.735
Age	-.033	-0.717	0.475
Sex	1.046	1.368	0.175
Household Size	0.690	2.880	0.005***
Years In Formal Education	0.094	0.363	0.717
Farming Experience	-0.042	-0.502	0.617
Farm Size	-3.457	-1.373	0.173
Monthly Income	-8.203e-6	-1.311	0.193
Off Farm Income	5.055e-5	2.647	0.010***
Quantity Of Cucumber produced	0.002	2.420	0.018**
Market Distance	14.522	-3.539	0.001***
Cooperative Membership	-3.716	2.204	0.030**
Credit Access	-1.132	-0.710	0.480
Extension Service	-0.726	-0.597	0.552
Time Of Harvest After Maturity	0.991	3.069	0.003***
R^2	**0.424**		
Adj. R^2	**0.330**		
F-value	**4.477**		0.001***

Table 6. Strategies for mitigating post-harvest losses

Variables	Frequency	Percentage (%)
Timely Harvesting	200	100.0
Improved handling and suitable transportation	196	98.0
Use of appropriate storage facilities	126	63.0
Pest and disease management practices	196	98.0
Market diversification	134	67.0
Postharvest management training	58	29.0
Value addition and processing	54	27.0
Contract farming	48	24.0
Sorting and grading	178	89.0
Regular inspections and monitoring of harvested cucumbers	192	96.0
Timely marketing and distribution	192	96.0

DISCUSSIONS

Table 1 shows the socioeconomic characteristics distribution of respondents. The table shows that the majority (54.0%) of the respondents were females, underscoring women's significant role in cucumber production. This suggests that both genders actively participate in agricultural activities, contributing to potential gender equality and economic empowerment in cucumber farming. This study contradicts that of Okwuokenye and Petu-Ibikunle (2021), which reported that 82.98% of the cucumber farmers were males. The result on age indicates that the majority of the farmers fell within the age range of 41-60 years (57%), with the mean age of the respondents as 45.45 years. Similar findings were made by Okwuokenye and Petu-Ibikunle (2021), who observed that the cucumber farmers had an average age of 44.56 years. This indicates that most farmers in the study area are young and active, thus possessing the energy needed for efficient production and management after harvest. The mean household size was about six persons, indicating readily available household labor for cucumber farming, thus reducing production and post-production costs (Achoja & Obadaya, 2019). A higher level of formal education has been linked with higher technology adoption (Onuwa et al., 2023; Ukwuaba & Ileka, 2024); thus, the result on education level, which shows that the majority (74%) obtained secondary education, indicates a high literate level. This contrasts with the findings of Adepoju (2014) but agrees with the findings of Ukwuaba et al. (2018). Thus, given the literacy level, the respondents will be more inclined to adopt modern farming techniques, technological advancements, and sustainable practices to reduce postharvest losses. The average farming experience of respondents was 10.43 years. Thus, it can be deduced that the farmers have accumulated a substantial amount of practical knowledge and skills related to cucumber farming that could enable them to reduce the number of losses incurred after harvest.

Cucumber farming is highly lucrative (Onuwa et al., 2023) and substantially contributes to household income and improved welfare. Findings from this study revealed that the average income from cucumber farming was ₦129,400 ($180.57). Sources of labor were majorly hired labor (44%). This contrasted with the finding of Abdullah et al. (2019), which asserts that smallholder farmers predominantly rely on family labor for their farming activities. Additionally, the majority (65%) of farmers were not members of cooperatives, and only about 35% of respondents had access to credit. The significant sources of credit were cooperative societies (36%) and personal savings (14%). Only about 12% of respondents had access to credit from formal financial institutions like commercial and microfinance banks. This could significantly affect production activities as credit is essential to any business. Lack of access to credit could limit farming activities and expansion to increase farm output (Falola et al., 2023). Concerning extension visits, the result shows that the majority (76%) of the respondents had no contact with extension agents, with an average number of visits of 0.4. This aligns with the findings of Asadu et al. (2018) and is strong evidence that extension service delivery in the state of Enugu is weak. The lack of extension visits indicates a gap in knowledge dissemination and technology transfer, which could be addressed to enhance productivity and reduce postharvest losses.

Table 2 presents the results of the primary causes of post-harvest losses in cucumber production among the respondents. Before identifying the primary causes, the farmers' experience of postharvest losses indicates that all (100%) have experienced postharvest losses. Postharvest losses' major causes were pest and pathogens infestation (89%) and poor handling and storage (86%). Mechanical damage (76%), harvesting at pre-maturity (72%), and water loss (66%) were also identified as primary causes by a significant proportion of respondents. In comparison, only about 28% of respondents attributed the losses to ethylene sensitivity. Similarly, Anyoha et al. (2023), Elik et al. (2019), and Kitinoja et al. (2019a) highlighted proper handling and storage, pest and pathogen infestation, and untimely harvesting as significant causes of postharvest losses of different agricultural produce. Pest and disease infestation could occur during or after production. Cucumber insect pest's because direct damage and could be vectors for various viral diseases. Thus, it is crucial to identify them before infestation to reduce yield losses. Most pathogens of vegetable crops like cucumber occur before harvest but continue to wreak havoc on the crop until harvest. Cucumbers are perishable and require special handling and storage attention. However, most small-scale farmers lack adequate storage and processing facilities and thus encounter significant losses after harvest due to their unavailability (Falola et al., 2023; Sugri et al., 2021). This study also identified mechanical damage to cucumbers as a significant cause of losses. This damage often manifests through external and internal mal-handling of cell tissue structure. In a related study, Adewoyin et al. (2022) also agreed that mechanical damage is one of the major causes of postharvest loss in fruit. This suggests that careful handling and transportation are required to prevent physical damage to crops, and investing in appropriate transportation methods to reduce the risk of mechanical damage is imperative. Pre-maturity harvest was also identified as a primary cause of losses. This reason for pre-maturity harvest may include poor timing, lack of proper training, and inadequate extension services with the farmers. In some areas, farmers who encounter conflicts, sit-at-home protests, and theft often harvest produce before full maturity for fear of losing all produce. This contrasts with the findings of Falola et al. (2023), as untimely harvest was adjudged to have minimal impact on postharvest losses. The majority (66%) of respondents agreed that increased temperature and humidity contribute significantly to postharvest losses of cucumber and the impact of this factor on water loss and overall cucumber quality. This was also reported to be one of the causes of postharvest losses highlighted in a study by Al-Amin et al. (2021). When fruits are exposed to hot weather conditions and subsequently stored, they lose their water content, resulting in a loss of turgidity and subsequent shrinkage. A lower percentage (28%) of respondents identified ethylene sensitivity as a cause of losses. Ethylene accelerates the ripening process of cucumbers, and it is essential to avoid storing cucumbers with other crops that emit ethylene gas (Adewoyin et al., 2022). Most cucumber farmers are knowledgeable about this, and thus, it is unlikely that they would store cucumbers under such circumstances. Consequently, it has a limited effect on causing post-harvest cucumber losses.

Table 3 presents the secondary causes of postharvest losses in cucumber production. Most of these secondary causes are related to logistic or technical issues and are often beyond farmers' control. The poor road transportation network was the most significant secondary cause of postharvest losses ($\bar{x}$ = 4.5). This indicates that farmers recognize the impact of inadequate road infrastructure on timely transportation to markets, which can lead to reduced market access. This is in agreement with the study by Sourav et al. (2024) and Sule (2019), which highlights the importance of adequate road networks (from areas of production to consumption) and the detrimental effect it has on the quality and quantity of crop output if not adequately addressed. Climate-related factors ($\bar{x}$ = 4.0), such as temperature, rainfall, and humidity, were also significant causes of postharvest losses. This suggests that these climatic variables reduce the quality and shelf life of harvested cucumbers. This aligns with a study by Akanwa and Okoli (2021), which reports that climate change has resulted in warmer temperatures, contributing to heightened high-temperature levels, more prevalent pests, and increased disease occurrences. Financial constraint ($\bar{x}$ =3.9) also significantly contributed to postharvest losses. This is in line with the study by Anyoha et al. (2023), which also showed that inadequate finance is a significant cause of postharvest loss. This suggests that financing is critical in preserving the shelf life of agricultural produce. Adequate financing increases their capacity to adopt improved postharvest management practices and invest in necessary infrastructure, innovations, and technologies to reduce postharvest losses. Market-related issues ($\bar{x}$ =3.3), deficient demand for cucumber due to increased prices, were identified as one of the secondary causes of postharvest losses. This is in line with the findings by Aminu et al. (2020), which revealed that customer's low demand was perceived as a highly severe cause of postharvest loss. In addition to pricing, other factors, such as poor quality, poor accessibility, and unfavorable market dynamics, were other market factors that could also influence postharvest losses negatively. Inadequate knowledge of postharvest management ($\bar{x}$ =3.2) and inadequate storage facilities ($\bar{x}$ =3.30) were also perceived by the producers as secondary causes of postharvest losses in Nigeria. These results align with those of Sugri et al. (2021), Adewoyin et al. (2022), and Falola et al. (2023). In contrast, insufficient market information ($\bar{x}$ =3.0) and cucumber variety cultivated ($\bar{x}$ =2.14) were identified as insignificant secondary causal agents of postharvest losses. This suggests that producers are beginning to close the gap in information regarding cucumber market information, opportunities, and varieties. The results are in contradiction to the findings of Egwuonwu (2020) and Falola et al. (2023).

The result in Table 4 provides insights into the extent of post-harvest losses experienced by respondents in the study. The responses are categorised based on the level of losses experienced by the respondents. The Table reveals that most respondents (66%) reported post-harvest losses ranging between 1-20%, 40.5% lost 21-50%, and 27% lost over 50% of cucumbers after harvest. The high level of PHL could be linked to pests and diseases, poor handling, mechanical damage, and poor infrastructure to preserve the shelf life. This suggests that postharvest loss has negatively impacted the farmers' income and welfare and contributed to food insecurity in the study area. This supports the conclusions drawn by Aysel et al. (2019), which indicated that fruit and vegetable loss could reach as high as 50% and signifies huge income loss to the farmers.

Table 5 shows the drivers of postharvest loss of cucumber. The coefficient of determination (R^2) value of 0.424 implies that the independent variables explain about 42 % of the variability in the postharvest losses. The regression result showed that off-farm income, the quantity of cucumber produced, harvest time after maturity, household size, and market distance positively and significantly influenced postharvest losses. In contrast, cooperative membership negatively and significantly influenced postharvest losses. The coefficient of the household size, which was statistically significant at 1% ($p<0.01$) indicated that a high household size experienced higher levels of postharvest losses. This could result from resource competition, inefficient allocation of resources, and poor handling practices. For instance, household needs are higher in large households, and this may involve the diversion of resources, such as money needed to improve postharvest management, to other household needs. This contradicts the findings of Falola et al. (2023), who reported that the household size of the farmers negatively affected postharvest losses in onion production. Off-farm income was positive and significant at 5 % ($p<0.05$) indicating that off-farm income results in higher postharvest losses. This could result from diverting attention to off-farm activities, leading to less attention to effective postharvest management. The quantity of cucumber produced was positively significant at 5% ($p<0.05$). This implies that an increase in production leads to an increase in postharvest losses. Increased production is expected to lead to an increased output, which, if not managed effectively, would lead to significant postharvest losses. This agrees with the findings of Kulwijila (2021) and, lately, Aidoo et al. (2014), who found that post-harvest losses increase as production increases. The result further shows that distance to market was significantly positive at 1% ($p<0.001$), suggesting that reducing market distance would significantly reduce postharvest losses. Cucumbers are highly perishable and susceptible to mechanical damage, especially during transportation. The inadequate access road to the farm settlements where cucumber is produced makes its translocation very challenging and causes unnecessary delays in the market. This could predispose the cucumbers to more significant losses. This aligns with the findings of Sani et al. (2023), who stated that congestion and build-up of heat during transportation could worsen as a result of poor road networks and long distances travelled, thereby leading to mechanical damage like bruising and softening. Cooperative membership was negatively significant at 5% ($p<0.05$). This implies that membership of cooperatives reduces postharvest losses. This could result from benefits from membership, such as access to credit, improved information on postharvest management practices, and pooled resources to collectively invest in infrastructures targeted at reducing postharvest losses. The harvest time after maturity was positively significant at 1% ($p<0.01>$), thus implying that the longer the harvest after maturity, the greater the postharvest losses. Cucumbers not harvested long after maturity could be more vulnerable to infestations by pests and pathogens. Since cucumber is best consumed fresh, delayed harvesting after maturity would lead to over-ripening,

loss of taste, loss of nutrients, and generally, reduced quality. As a result, the crop becomes more fragile and may quickly lose its morphological value during postharvest handlings.

The findings presented in Table 6 highlight the multifaceted strategies adopted by the producers to mitigate postharvest losses. The result indicates that all respondents (100%) have good knowledge of the imports of cucumbers harvested at the right stage of maturity. Supporting this, Adeola (2020) identified delay in harvesting as one of the causes of post-harvest losses. Harvesting cucumber at the optimal stage leads to maximum quality, taste, and nutritional value while extending its shelf life. This practice aligns with the principle that timely harvest reduces post-harvest losses. Proper postharvest handling and transportation techniques were adopted by 98% of the respondents to minimize physical damage and bruising, prevent spoilage, and extend its marketable life. In line with these techniques, Elik et al. (2019) emphasized the need for proper postharvest handling due to its vulnerability to mechanical damage, especially during transportation. The result also showed that 63% of respondents used appropriate and suitable storage facilities to mitigate postharvest losses. Storage facilities with controlled temperature and humidity conditions help slow down the deterioration process of cucumbers, thereby preventing spoilage and preserving their market value. This finding is supported by Ibrahim et al. (2022), who reported modern storage facilities as an effective strategy to reduce post-harvest losses. This also agrees with the study that adequate transportation would reduce congestion and heat build-up that could facilitate spoiling, which is also essential in the postharvest process. This study identified that 98% of respondents recognized the importance of pest and disease management practices as an effective strategy for reducing postharvest losses. This means that appropriate prevention and control measures can significantly reduce spoilage. This aligns with Urugo et al. (2024) that farmers adopted a diversification strategy to cope with the challenges of postharvest losses on perishable crops. Sixty-seven percent of the respondents also adopted a market diversification strategy to mitigate postharvest losses. This is in line with the study by Aminu et al. (2020), which reported diversification as the most employed mitigation strategy for dealing with postharvest issues. Diversifying the market outlets allows farmers to spread their risk and ensure that even if one market experiences oversupply or unfavorable conditions, others may still provide an avenue for selling cucumbers at a reasonable price. However, traversing different markets may have severe cost implications. Capacity building in the form of training on postharvest management was adopted by 29% of respondents. According to Sule (2019), training programs in post-harvest loss management are essential and significant elements in efforts to combat food insecurity by reducing postharvest losses. However, adopting this strategy by a smaller group suggests a potential gap in the extension agents' knowledge dissemination and outreach efforts. Value-addition and transformation of farm produce can reduce waste and extend the shelf-life of the produce, leading to higher economic returns for farmers. This would, however, involve financial investment in processing and packaging infrastructures, which may not be available for small-scale farmers. To this effect, only about 27% of the farmers adopted this strategy. This shows that very few respondents see this as a viable strategy or that other challenges, such as lack of access roads to other markets, further constrain the strategy. Contract farming was adopted as a coping strategy by 24% of respondents. Contract farming arrangements provide a degree of market predictability, which may contribute to reduced losses by ensuring a market for the produce before harvest. The reason for the adoption by a few respondents could be that not all farmers have access to such arrangements or may prefer more independent strategies. Also, 89% of the respondents adopted the practice of sorting and grading cucumbers. This ensures that the best quality is not mixed up with spoilt products, helps separate cucumbers based on quality, size, and appearance, and reduces the likelihood of spoilage. This aligns with Kitinoja et al.'s (2019b) findings, which also identified sorting and grading as a veritable strategy to mitigate post-harvest loss. Similarly, 96% adopted regular inspections and monitoring of harvested cucumbers to ensure prompt identification of potential issues, enabling corrective actions to be taken before losses escalate. Also, most (96%) farmers adopted timely marketing and distribution as a crucial strategy. Similarly, Yusuf (2020) identified the importance of adequate market access and transportation to ensure effective and timely marketing to significantly reduce the risk of over-ripening, spoilage, and quality deterioration.

CONCLUSIONS

The cucumber farmers in Enugu state, Nigeria, are losing a large chunk of their potential revenue due to high postharvest losses. This study thus evaluates the causes of post-harvest losses among cucumber farmers and the factors contributing to these losses. Findings from this study revealed that post-harvest losses could result from primary and secondary causes such as pest and disease infestation, mechanical damages, poor road networks, and unfavorable climate conditions. This suggests that while farmers could control most primary factors through mitigation strategies adopted, most secondary factors are beyond the farmer’s control. Household size, off-farm income, quantity of cucumber produced, cooperative membership, harvest time after maturity, and market distance were the significant factors influencing postharvest losses in cucumber production. To significantly reduce the adverse effect on their income, the farmers employed diverse coping strategies such as timely harvesting and marketing, improved handling and suitable transportation means, suitable storage facilities, and proper pest and disease management to manage and mitigate the impact of postharvest losses on their livelihood.

Based on these findings, farmers are encouraged to form and join cooperatives to easily access the benefits that could accrue from membership, such as access to information, training, and acquisition of technologies that enhance postharvest management of farm produce. The government must allocate funds to improve road transportation systems and networks connecting farming areas to markets to reduce the distance to market and improve market access. This would facilitate the movement of fresh crop produce from rural production areas to numerous areas of consumption. Finally, farmers are encouraged to ensure that farm produce is harvested at maturity. This is especially important for perishable crops like cucumber, which may overripe and lose quality as they mature.

Overall, the study has identified the extent of post-harvest losses among small-scale farmers and the factors that drive these losses. This information would facilitate the enactment of policies that would curb this menace affecting farmers' income and food security. The study is not without limitations as challenges were encountered in collecting data from various cucumber farmers around the state. However, this was overcome by mobilizing enumerators to facilitate data collection, especially in rural areas. Due to budget constraints, the study could only cover a limited geographic concentration, further studies can adopt a larger concentration from different geographic regions across the country. Additionally, further studies could also consider analyzing the disaggregated postharvest losses among male and female cucumber farmers given the relatively lower access to resources by females which could lead to higher losses.

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