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EXAMINING THE ECONOMIC CONSEQUENCES OF POST-HARVEST LOSSES IN SMALLHOLDER ONION FARMING IN KANO STATE, NIGERIA

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ABSTRACT

Post-harvest losses posed a formidable challenge in the onion supply chain, affecting farmers, marketers, and consumers. This study aimed to analyse the extent of post-harvest losses and identify the key factors that contributed to these losses in the onion supply chain. Employing a multi-stage sampling technique, specific Local Government Areas (LGAs) in Kano State were selected based on their high concentration of onion production activities - Kura, Bunkure, and Garun Malam. Descriptive statistics and the Post-Harvest Loss Estimation model (PHLE) were utilized to analyse the collected data. Data were obtained from a sample of 195 onion producers, 54 wholesalers, and 127 retailers in the study area. The findings underscored that post-harvest losses occurred at various stages of the onion supply chain, including harvesting, transportation, and marketing. The study highlighted the strategies employed by producers and marketers to mitigate these losses, such as adopting careful harvesting techniques, utilizing appropriate transportation vehicles, and implementing effective storage practices. However, it was worth noting that the adoption of post-harvest technologies and strategies remained relatively low. Market-related factors, including pricing dynamics and market infrastructure, also exerted influence on post-harvest losses. The study employed a conceptual framework that emphasized the interplay between pre-harvest factors, harvest and post-harvest activities, and market-related factors in determining the extent of losses. This study highlighted the imperative for a comprehensive and integrated approach to address post-harvest losses in the onion supply chain. Implementing targeted interventions and enhancing awareness among stakeholders can significantly reduce post-harvest losses and improve the overall efficiency of the onion supply chain, ensuring sustainable production and food security.

Keywords: Post-harvest losses; economic impact; cost analysis; loss reduction strategies

INTRODUCTION

Efficient management of post-harvest losses is crucial for global food security and sustainable agricultural systems. Unfortunately, a significant amount of food is lost in the global supply chain, posing a serious challenge to meeting the nutritional needs of the

growing global population (Osabohien, 2022). Studies estimate that approximately one third of all food produced is lost before reaching the final consumer (Gustavsson *et al.,* 2011). This equates to a staggering 1.3 billion tonnes of wasted food, with fruits and vegetables accounting for a substantial portion of these losses (Kasso and Bekele, 2018).

Addressing post-harvest losses is particularly critical in regions with high food needs, such as Africa. In African countries, post-harvest losses range from 20% to 40%, significantly impacting regions already struggling with low agricultural productivity (Osabohien, 2022). These losses not only affect food availability but also contribute to increased prices, limiting access to nutritious produce for a large portion of the population (Dos Santos, *et al.,* 2020).

Nigeria, with its diverse climate and agricultural potential, faces substantial post-harvest losses, including those of onions—a vital vegetable crop. Onions are a significant agricultural commodity in Nigeria, particularly in Kano state, where they are grown extensively (NASS 2012; NBS, 2017). However, the post-harvest losses of onions in the region are alarmingly high, impacting the economy, food availability, and farmer livelihoods (Ibeawuchi, *et al.,* 2015)

Post-harvest losses of fruits and vegetables in Nigeria amount to a significant portion of the annual production (Kasso and Bekele, 2018). These losses not only deprive communities of nutritious food but also lead to increased prices, making the produce less accessible to a large segment of the population. Moreover, the economic implications are substantial, as the efforts and investments made in cultivating onions are undermined by the losses incurred during post-harvest handling and processing. Similarly, reducing post-harvest losses is not only imperative for food security and economic sustainability but also for minimizing the environmental impact associated with food waste. By curbing these losses, we can optimize resource use, reduce greenhouse gas emissions, and alleviate the pressure to intensify agricultural production to meet future demands (Al-Amin *et al.,* 2021).

Therefore, this study aims to explore the underlying factors contributing to post-harvest losses in the onion supply chain; examine the socioeconomic characteristics of stakeholders involved in onion production and marketing; identify the causes of post-harvest losses in onion production and marketing; evaluate the costs and returns associated with onion production and marketing; describe strategies for reducing post-harvest losses in the onion supply chain.

By addressing the problem of post-harvest losses and focusing specifically on onions in Kano state, this study will contribute to the broader understanding of the challenges faced in managing post-harvest losses in agricultural systems. The findings will inform policymakers, researchers, extension workers, and farmers about the necessary strategies and interventions to reduce losses, enhance food security, and promote sustainable agricultural practices. Ultimately, by mitigating post-harvest losses, we can work towards a more resilient and efficient food supply chain, benefiting both producers and consumers while ensuring a more sustainable future for agriculture.

The conceptual framework of this study is based on the relationship between post-harvest losses and the various factors that contribute to these losses in the onion supply chain. The framework illustrates the key elements that influence post-harvest losses, including pre-harvest factors, harvest and post-harvest activities, and market-related factors. These elements are interconnected and collectively contribute to the overall extent of post-harvest losses experienced by onion producers and marketers (Dos Santos *et al.,* 2020)

The pre-harvest factors encompass variables such as varietal characteristics, pests and diseases, and environmental conditions. These factors affect the quality and condition of the

onions at the time of harvest, subsequently influencing the extent of losses during post-harvest activities (Al-Amin *et al.,* 2021). Harvest and post-harvest activities include harvesting techniques, sorting, packaging, storage, transportation, and marketing. The efficiency and effectiveness of these activities directly impact the preservation of onion quality and the magnitude of losses incurred (Babalola *et al.,* 2010; Kumar *et al.,* 2020).

Market-related factors play a crucial role in post-harvest losses as well. These factors involve aspects such as market demand, pricing, market infrastructure, and post-harvest management practices. The conditions and dynamics of the market influence the duration of storage and the time it takes for the onions to reach consumers, which can significantly impact the level of post-harvest losses (Ajayi, 2023). The conceptual framework highlights the complex nature of post-harvest losses and emphasizes the need to consider multiple factors and their interrelationships to develop effective strategies for minimizing losses throughout the onion supply chain.

The theoretical framework employed in this study is the Systems Approach to post-harvest management. The Systems Approach recognizes that post-harvest losses are influenced by a series of interconnected factors and activities that form a system. This approach emphasizes the need to understand the entire onion supply chain as a system, considering the interactions between different components and their impact on post-harvest losses (Gómez-Limón & Riesgo, 2010; Sharda & Sirohi, 2018).

The Systems Approach provides a holistic perspective, considering not only the individual activities and processes within the supply chain but also the linkages and feedback mechanisms between them. It recognizes that addressing post-harvest losses requires a comprehensive and integrated approach, considering both technical and managerial aspects (Gardas, Raut, & Narkhede, 2018). By adopting this approach, our study considers the various stages of the onion supply chain, from pre-harvest to post-consumption, and examines the interactions between different actors, activities, and variables. This approach enables the identification of critical points and bottlenecks within the system where losses are likely to occur. It also allows for the exploration of potential interventions and strategies that can be implemented at different stages to minimize losses and improve the overall efficiency of the onion supply chain (Ajayi, 2023).

Overall, the Systems Approach provides a theoretical foundation for understanding the complexity of post-harvest losses in the onion supply chain and guides the investigation of interconnected factors and activities to develop effective management strategies.

METHODOLOGY

Description of the Study Area

The study was conducted in Kano State, Nigeria, which served as the commercial hub of the Northern states. Kano State has a total land area of 20,760 km^2, with 1,754,200 hectares of fertile agricultural land, including 86,500 hectares of exclusive Fadama land (Olofin *et al.,* 2008). Additionally, the state had around 75,000 hectares of grazing land. Administratively, Kano State was divided into 44 Local Government Areas (LGAs) and was classified into three Agricultural Development Programme (ADP) zones by the Kano State Agricultural and Rural Development Authority (KNARDA, 2011) for effective extension service delivery. The zones were Zone I, Zone II, and Zone III, each comprising multiple LGAs. With a projected population of 13,076,892 in 2016, Kano State was the most populous state in

Nigeria (NPC, 2020). The state's predominant occupation was agriculture, and the population was predominantly Hausa/Fulani. The major crops cultivated in the state included rice, millet, maize, cowpea, vegetables, and groundnut (NAERLS, 2012). Agriculture was a significant source of livelihood in the study area, with onion production, marketing, and consumption being particularly important.

Sampling Technique and Data Collection

A multi-stage sampling technique was employed to select three LGAs in Kano State based on their high concentration of onion production activities. The selected LGAs were Kura, Bunkure, and Garun Malam. From these LGAs, a total of 195 onion producers were randomly selected. Additionally, four markets—Gundutse, Kura Yan Alabasa, Zaria Road, and Yankaba markets—were selected based on their high concentration of onion marketers. A total of 54 wholesalers and 127 retailers were randomly selected from these markets.

Primary data for the study were collected using structured questionnaires administered to the selected onion producers and marketers. The collected data encompassed socio-economic characteristics of the onion producers and marketers, quantities and values of onion post-harvest losses, the relationship between total post-harvest losses and activities at different stages of the onion value chain, causes of post-harvest losses, costs, and returns of onion production and marketing, as well as the strategies adopted by producers and marketers to reduce post-harvest losses.

Analytical Tools

The collected data were analysed using various analytical tools, including descriptive statistics, the Post-Harvest Loss Estimation (PHLE) model, Ordinary Least Square (OLS) regression analysis, and gross margin and marketing margin analysis.

Descriptive Statistics

Descriptive statistics, such as mean, frequency distribution, percentages, minimum, maximum, variance, and standard deviation, were employed to describe the socio-economic characteristics of various actors along the onion value chain, the causes of onion post-harvest losses along the chain, and the strategies adopted to reduce losses along the value chain in the study area.

Table 1: Summary of location and sample size for producers

LGA	Villages selected	Estimated population of farmers	Percentage of the population	Sample size
Kura	Rigar doka	80	20.51	40
	Butalawa	60	15.38	30
Garun malam	Yadakwari	70	17.94	35
	Dakasoye	60	15.38	30
Bunkure	Bunkure	70	17.94	35
	Bono	50	12.82	25
Total		390	100	195

Table 2: Summary of sample size and location for marketers (wholesalers)

Market	Estimated population of wholesalers	Percentage of population	Sample size
Gundutse	30	50	27
Kura Yan Albasa	20	33.34	18
Yankaba	10	16.66	9
Total	60	100	54

Table 3: Summary of sample size and location for marketers (retailers)

Market	Estimated population of retailers	Percentage of population	Sample size
Gundutse	60	31.91	41
Kura Yan Albasa	50	26.59	34
Zaria Road	48	25.54	32
Yankaba	30	15.96	20
Total	188	100	127

Post-harvest Loss Estimation (PHLE) Model

The PHLE model, developed by Suleiman (2015), was utilized to quantify the post-harvest losses of onions. This model enabled the determination of the quantity and value of onion losses at different stages of the producer, wholesale, and retail levels of the marketing chain. The major post-harvest activities considered in the model were harvesting, sorting, packaging, storage, haulage and transportation, and marketing (selling). According to Suleiman (2015), the PHLE model is expressed as:

$$TPHL = \sum (\sum S_i + \sum P_i + \sum R_i + \sum T_i + \sum M_i) \qquad (1)$$

Where:
TPHL = Total post-harvest losses (kg)
$\sum$ = Summation
Hi, Si, Pi, Ri, Ti, and M_i are losses during harvesting, sorting, packaging, storage, transportation and marketing respectively.

Total Post-Harvest Loss Index is given by:

$$TPHLI = \frac{TPHL}{TH} \qquad (2)$$

Where:
TPHLI = Total Post-harvest loss index,
TPHL = Total post-harvest loss (kg)
TH = Total harvest (kg)

Ordinary Least Square (OLS) Regression Model

OLS was conducted to establish the relationship between total post-harvest losses and the activities carried out at different stages of the onion value chain. This analysis helped

identify significant factors contributing to post-harvest losses. Following Suleiman (2015), the model is specified as:

$Y = f(X_1, X_2, X_3, X_4, X_5, X_6)$…… (3)

Where:
Y = dependent variable representing total post-harvest loss (kg)
X_1= quantity lost during harvesting (kg)
X_2 = quantity lost during sorting (kg)
X_3 = quantity lost during packaging (kg)
X_4 = quantity lost during storage (kg)
X_5 = quantity lost during haulage and transportation (kg)
X_6= quantity lost during marketing (kg)

$Y = f(X_1, X_2, X_3, X_4, X_5, X_6)$…… (4)

Where:
Y = dependent variable representing total value lost (₦)
X_1= value lost during harvesting (₦)
X_2 = value lost during sorting (₦)
X_3 = value lost during packaging (₦)
X_4 = value lost during storage (₦)
X_5 = value lost during haulage and transportation (₦)
X_6= value lost during marketing (₦)

Gross Margin and Marketing Margin Analysis

Adopted from Bada *et al.,* (2021), the gross margin and marketing margin analyses were performed to evaluate the costs and returns associated with onion production and marketing. These analyses provided insights into the profitability and efficiency of the onion value chain in the study area. It is the difference between gross income (GI) and the total variable cost (TVC).

GM = GI-TVC……. (5)

Where:
GM = Gross Margin
GI = Gross Income (N/ha)
And TVC = Total Variable Cost (N/ha)

$$Marketing\ Margin = Selling\ Price - Purchasing\ Price \quad \text{……} \quad (6)$$

$$Percentage\ Marketing\ Margin = \frac{Selling\ Price - Purchase\ Price}{Selling\ Price} \times 100 \quad \text{…...……..} \quad (7)$$

By employing these analytical tools, this study aimed to gain a comprehensive understanding of the post-harvest losses in the onion value chain in Kano State, Nigeria. The

findings contribute to the development of effective strategies and interventions for reducing post-harvest losses and improving the overall efficiency and sustainability of the onion industry in the region.

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Onion Producers, Wholesalers, and Retailers

Table 4 presents the socio-economic characteristics of onion producers, wholesalers, and retailers. Most of the producers (62%), wholesalers (50%), and retailers (62.9%) fell within the economically active age range, with mean ages of 40, 41, and 36 years, respectively. This dominance of individuals in their active and productive age has significant implications for the sustainability of the onion enterprise, as knowledge and experience are passed on from one generation to another. This finding aligns with the results of Grema and Gashua (2014), who reported that farmers in this age group are physically strong, capable of making informed production decisions, and have the potential for higher productivity compared to older farmers.

The mean household sizes were 11, 12, and 8 for onion producers, wholesalers, and retailers, respectively, with a range of 1 to 30. The larger household sizes observed in the study have implications for onion production and marketing. They contribute to the availability of free family labour, which reduces the cost of labour and increases production, thereby enhancing profit generation. This finding is consistent with the results of Bada *et al.*, (2021), who reported similar mean household sizes for producers, wholesalers, and retailers.

The average years of experience in the studied location were 16, 16, and 13 years for producers, wholesalers, and retailers, respectively. This indicates that onion producers and marketers in the area have considerable experience, which is expected to enhance their efficiency in performing marketing activities.

Table 5 reveals that all the producers and marketers in the study were males. This can be attributed to the nature of the activities involved in onion production and marketing, as well as the cultural setting of the area where land allocation is primarily done for men. This finding is in line with the observations of Shu'aib (2009), who noted that gender segregation in the region leads to the division and assignment of responsibilities, with men undertaking more physically demanding and outdoor tasks, while women are engaged in simpler and indoor activities.

The study also found that the majority (92.3%) of onion producers, 87% of wholesalers, and 81.1% of retailers were married. This implies that onion production and marketing serve as a source of livelihood, thereby attracting married individuals who are responsible for supporting their families. This result is consistent with the findings of Kaka *et al.,* (2021), who reported a high proportion of married onion producers and marketers in Kebbi State.

A large proportion of the producers (39%) and wholesalers (44.4%) had Islamic education, while a significant proportion of the retailers (44.4%) had primary education. This indicates that all respondents had attained some form of education, which is expected to enhance the adoption and assimilation of modern agricultural innovations. This finding aligns with the results of Illo *et al.,* (2016) and Kaka *et al.,* (2021), who reported a similar trend of education among onion producers and marketers in Kebbi State.

Table 4: Age, household size and years of experience of onion farmers and marketers

Class Interval	Producers		Wholesalers		Retailers	
	Frequency	%	Frequency	%	Frequency	%
Age						
18-26	8	4.1	6	11.1	19	15.0
27-35	59	30.2	15	27.8	52	40.9
36-44	62	31.8	12	22.2	28	22.0
45-53	53	27.2	13	24.1	19	15.0
54-62	13	6.7	8	14.8	9	7.1
Total	195	100	54	100	127	100
Minimum	20		23		18	
Maximum	62		60		62	
Mean	40		41		36	
Std. Deviation	8.677		10.815		10.191	
Household size						
1-6	47	24.1	17	31.5	63	49.6
7-12	88	45.1	15	27.8	42	33.1
13-18	34	17.4	12	22.2	16	12.6
19-24	20	10.4	6	11.1	4	3.1
25-30	6	3.1	4	7.4	2	1.6
Total	195	100	54	100	127	100
Minimum	1		1		1	
Maximum	30		30		30	
Mean	11		12		8	
Std. Deviation	6.409		7.948		5.872	
Experience						
2-9	36	18.4	11	20.4	48	37.8
10-17	82	42.1	19	35.2	43	33.9
18-25	57	29.2	17	31.4	24	18.9
26-33	14	7.2	5	9.3	8	6.3
34-41	6	3.1	2	3.7	4	3.1
Total	195	100	54	100	127	100
Minimum	3		4		2	
Maximum	40		40		40	
Mean	16		16		13	
Std. Deviation	8.077		8.724		8.671	

Regarding association membership, most producers (65.6%) were not members of any production or marketing association. In contrast, many wholesalers (70.4%) were members of marketing associations, while most retailers (60.6%) were not members. These findings contrast with the results of Kaka *et al.* (2021), who reported a high proportion of onion retailers belonging to marketing associations in Kebbi State. The result implies that a significant number of producers and retailers in the study area are deprived of the benefits associated with membership in production and marketing associations. These benefits include improved access to information, knowledge, and credit facilities, among others.

Table 5: Sex, marital status, level of education and membership to production/marketing association of onion farmers and marketers

Variables	Producers		Wholesalers		Retailers	
	Frequency	%	Frequency	%	Frequency	%
Sex						
Male	195	100	54	100	127	100
Total	195	100	54	100	127	100
Marital status						
Single	15	7.7	7	13.0	24	18.9
Married	180	92.3	47	87.0	103	81.1
Total	195	100	54	100	127	100
Level of education						
Primary	39	20.0	8	14.8	58	45.7
Secondary	58	29.7	15	27.8	26	20.5
Tertiary	22	11.3	7	13.0	15	11.8
Islamic Literacy	76	39.0	24	44.4	28	22.0
Total	195	100	54	100	127	100
Membership to Production/Marketing association						
Members	67	34.4	38	70.4	50	39.4
Non members	128	65.6	16	29.6	77	60.6
Total	195	100	54	100	127	100

Source: Field Survey, 2019

Quantities and Values of Onion Losses

Table 6 presents the quantities and values of onion losses at different stages. The study found that the maximum quantity and value of losses at the farm level occurred during storage, with an estimated loss of 7,500 kg/ha and a corresponding value of N350,000. This finding is consistent with the observations of Sharma (2016), who noted that maximum losses in onions in the Jaipur district of Rajasthan were incurred during the storage stage. Similarly, at the wholesale market level, the maximum quantity and corresponding value of losses were recorded during storage, with a maximum quantity of 52,500 kg and a value of N3,300,000. At the retail level, the maximum loss and corresponding value were also during storage, with a maximum quantity of 52,500 kg and a value of N2,450,000. This finding contradicts the findings of Sharma and Singh (2011), who reported maximum losses in tomato, onion, pea, potato, radish, capsicum, and cabbage in Uttarakhand during the marketing (selling) stage.

The results highlight the critical role of proper storage practices in reducing post-harvest losses in the onion value chain. Attention should be given to improving storage facilities, adopting appropriate storage technologies, planting of improve varieties, and implementing effective post-harvest management strategies to minimize losses and enhance the profitability of onion production and marketing.

Volume and Losses of Onion Harvested or Purchased

The study assessed the volume and losses of onions at different stages of the value chain, including production, wholesale markets, and retail markets. The findings shed light on the extent of post-harvest losses and their implications for onion producers and marketers.

At the farm level, the minimum and maximum total post-harvest loss indices were 0.012 and 0.70, respectively. The mean loss index value was 0.19, indicating that 19% of the total onion harvested was lost due to harvest and post-harvest activities. This highlights the significant losses incurred by farmers and emphasizes the need for improved practices and technologies to minimize these losses.

The OLS results revealed that the quantity of post-harvest loss during harvesting, sorting, and storage had a positive and significant impact on the total quantity of onion post-harvest loss. This suggests that increasing losses in these stages contribute to overall loss. On the other hand, the quantity of post-harvest loss during transportation showed an inverse relationship with the dependent variable, indicating that higher transportation losses were associated with lower total losses. The losses during packaging, transportation, and marketing (selling) were not found to be significant.

At the wholesale market level, the minimum and maximum total post-harvest loss indices were 0.003 and 0.30, respectively. The mean loss index value was 0.07, indicating that 7% of the onions purchased at the wholesale market were lost due to post-harvest activities. This suggests that post-harvest losses continue to occur even after the onions leaves the farm gate.

The regression analysis showed that the estimated coefficients of value of post-harvest loss during harvesting and storage were positive and significant, indicating that an increase in these variables leads to a corresponding increase in the total value of onion post-harvest losses. However, the value of post-harvest loss at packaging and transportation had an inverse relationship with the dependent variable. Losses during sorting, packaging, transportation, and marketing were not significant.

At the retail market level, the minimum and maximum total post-harvest loss indices were 0.007 and 0.58, respectively. The mean loss index value was 0.11, indicating that 11% of the onions purchased at the retail level were lost due to post-harvest activities.

Table 6: Quantities and values of post-harvest losses

Actors	Stage	Quantity of Onion lost (kg/ha)					Value of loss (₦/ha)				
		Min	Max	Mean	SD	Var	Min	Max	Mean	SD	Var
	Harvest	75	3150	566.3	493.1	2.43E5	2000	100000	20635.0	18303.9	3.35E8
	Sorting	50	3000	459.5	596.3	3.56E5	2000	120000	17886.2	23900.3	5.71E8
	Packaging	50	2500	373.9	474.5	2.25E5	1166.7	100000	15427.7	18506.5	3.42E8
Producers	Storage	93.8	7500	1841.6	1513.9	2.29E6	4062.5	350000	68754.2	62145.3	3.86E9
	Transportation	75	2500	387.5	419.3	1.76E5	2000	100000	15277.2	17315.9	3.00E8
	Marketing	75	3375	607.5	692.7	4.80E5	3000	100000	21020.3	21575.4	4.65E8
	Total	418.8	22025	4236.3			14229.2	870000	159000.6		
	Sorting	300	6000	2310	1991.5	3.97E6	9200	245000	108120	82528.9	6.81E9
	Packaging	750	15000	3057.7	3997.6	1.60E7	25000	700000	168846.2	188371.9	3.55E10
Wholesalers	Storage	450	52500	12529.8	12812.6	1.64E8	13800	3300000	720825.5	792258	6.28E11
*per annum	Transportation	300	15000	4309.6	3526.4	1.24E7	22500	1200000	264500	264511.5	7.00E10
	Marketing	750	30000	7346.2	8443.6	7.13E7	22500	2400000	426923.1	518378.5	2.69E11
	Total	2550	118500	29553.3			93000	7845000	1689215		
	Sorting	150	5250	1125	1531.7	2.35E6	5000	245000	67220	74720.5	5.58E9
	Packaging	150	7500	1200	2102.1	4.42E6	7000	400000	67772.7	111896.7	1.25E+10
Retailers	Storage	75	52500	3727.9	8051.7	6.48E7	5500	2450000	194998.1	421057.8	1.77E11
*per annum	Transportation	150	300	250	72.1	5.19E3	5500	34000	15870.4	6040.9	3.65E7
	Marketing	150	30000	2288.8	4622.2	2.14E7	5200	1050000	115937.6	220779.7	4.87E10
	Total	675	95550	8591.7			28200	4179000	461798.8		

Table 7: Total post-harvest loss indices of producers, wholesalers and retailers

Total Post-harvest Loss Index	Minimum	Maximum	Mean
Producers	0.012	0.70	0.19
Wholesalers	0.003	0.30	0.07
Retailers	0.007	0.58	0.11

The regression analysis revealed that the coefficients of value of post-harvest loss at storage and transportation were positive and significant, while the coefficient of loss at packaging was negative. This implies that an increase in losses during storage and transportation leads to a corresponding increase in the total value of onion post-harvest losses. Losses during sorting, packaging, and marketing were not found to be significant.

Table 8: Relationship between total quantity of post-harvest loss and activities carried out at farm level

Quantity of PHL at Farmer Level	Coefficient	Std. Error	t-value	Sig.
Constant (X_0)	0.312	0.378	0.824	0.411
Harvesting (X_1)	0.199	0.094	2.118	0.036**
Sorting (X_2)	0.264	0.124	2.130	0.035**
Packaging (X_3)	0.006	0.142	0.039	0.969^{NS}
Storage (X_4)	0.485	0.054	8.899	0.000***
Transportation (X_5)	-0.048	0.138	-0.348	0.728^{NS}
Marketing (X_6)	0.133	0.131	1.013	0.312^{NS}
R^2	0.47			
R^2 adjusted	0.46			
F. value	27.329***			

*** = significant at 1%, ** = significant at 5%, NS = not significant

Table 9: Relationship between total value of post-harvest loss and activities carried out at farm level

Value of PHL at Farmer Level	Coefficient	Std. error	t-value	Sig.
Constant (X_0)	0.306	0.587	0.521	0.603
Harvest (X_1)	0.355	0.096	3.706	0.000***
Sorting (X_2)	0.150	0.126	1.194	0.234^{NS}
Packaging(X_3)	-0.023	0.140	-0.163	0.871^{NS}
Storage (X_4)	0.503	0.058	8.726	0.000***
Transportation(X_5)	-0.054	0.142	-0.383	0.703^{NS}
Marketing(X_6)	0.083	0.145	0.573	0.567^{NS}
R^2	0.48			
R^2 adjusted	0.47			
F. value	28.321***			

*** = significant at 1%, NS = not significant

Table 10: Relationship between quantity of post-harvest loss and activities carried out by wholesalers

Quantity of PHL at Wholesaler Level	Coefficient	Std. Error	t-value	Sig.
Constant (X_0)	0.068	0.763	0.089	0.929
Sorting (X_1)	-0.003	0.175	-0.017	0.987^{NS}
Packaging(X_2)	-0.144	0.190	-0.755	0.454^{NS}
Storage (X_3)	0.704	0.086	8.196	0.000***
Transportation(X_4)	0.253	0.142	1.776	0.082*
Marketing(X_5)	0.245	0.108	2.268	0.028**
R^2	0.796			
R^2 adjusted	0.774			
F. value	37.376***			

*** = significant at 1%, ** = significant at 5%, * = significant at 10%, NS = not significant

Table 11: Relationship between value of post-harvest loss and activities carried out at wholesale level

Value of PHL at Wholesaler Level	Coefficient	Std. Error	t-value	Sig.
Constant (X_0)	-0.387	1.095	-0.353	0.725
Sorting (X_1)	0.026	0.166	0.155	0.878^{NS}
Packaging(X_2)	-0.170	0.178	-0.954	0.345^{NS}
Storage (X_3)	0.722	0.086	8.396	0.000***
Transportation(X_4)	0.376	0.136	2.770	0.008***
Marketing(X_5)	0.170	0.112	1.518	0.135^{NS}
R^2	0.824			
R^2 adjusted	0.806			
F. value	44.925 sig. at 1%			

*** = significant at 1%, NS = not significant

Table 12: Relationship between quantity of post-harvest loss and activities carried out at retail level

Quantity of PHL at Retailer Level	Coefficient	Std. Error	t-value	Sig.
Constant (X_0)	-1.048	1.042	-1.006	0.317
Sorting (X_1)	0.193	0.172	1.123	0.264^{NS}
Packaging(X_2)	0.170	0.197	0.860	0.392^{NS}
Storage (X_3)	0.706	0.057	12.316	0.000***
Transportation(X_4)	-0.144	0.351	-0.410	0.682^{NS}
Marketing(X_5)	0.479	0.070	6.886	0.000***
R^2	0.766			
R^2 adjusted	0.756			
F. value	76.558***			

*** = significant at 1%, NS = not significant

Table 13: Relationship between total value of post-harvest loss and activities carried out at retail level

Value of PHL at Retailer Level	Coefficient	Std. error	t-value	Sig.
Constant (X_0)	-2.837	1.560	-1.819	0.072
Sorting (X_1)	0.155	0.147	1.052	0.295^{NS}
Packaging(X_2)	0.409	0.187	2.188	0.031**
Storage (X_3)	0.689	0.059	11.702	0.000***
Transportation(X_4)	-0.136	0.320	-0.424	0.673^{NS}
Marketing(X_5)	0.525	0.073	7.208	0.000***
R^2	0.771			
R^2 adjusted	0.761			
F. value	78.671***			

*** = significant at 1%, ** = significant at 5%, NS = not significant

Causes of Post-Harvest Loss

Table 14 presented the major causes of post-harvest losses as reported by producers, wholesalers, and retailers. At the farm level, physical bulb damage during harvesting and pests and diseases were identified as major causes of onion post-harvest loss. At the market level, physical bulb damage during haulage and transportation, as well as during marketing transactions, were reported as major causes. These findings align with previous (Gardas, Raut, & Narkhede, 2018) studies that highlighted mechanical damage, pathological damage, and physiological deterioration as the principal causes of post-harvest losses.

Table 14: Causes of onion post-harvest losses

Causes of Post-harvest Losses	Producers		Wholesalers		Retailers	
	Frequency	%	Frequency	%	Frequency	%
Physical bulb damage during harvesting						
Is a cause	153	78.5	5	9.3	5	3.9
Not a cause	42	21.5	49	90.7	122	96.1
Total	195	100	54	100	127	100
Physical bulb damage during haulage and transportation						
Is a cause	66	33.8	27	50.0	58	45.7
Not a cause	129	66.2	27	50.0	69	54.3
Total	195	100	54	100	127	100
Physical bulb damage during marketing transaction						
Is a cause	51	26.2	45	83.3	103	81.1
Not a cause	144	73.8	9	16.7	24	18.9
Total	195	100	54	100	127	100
Pests and diseases						
Is a cause	138	70.8	16	29.6	18	14.2
Not a cause	57	29.2	38	70.4	109	85.8
Total	195	100	54	100	127	100
Varietal characteristics						
Is a cause	72	36.9	11	20.4	16	12.6
Not a cause	123	63.1	43	79.6	111	87.4
Total	195	100	54	100	127	100
Watering after ripening						
Is a cause	55	28.2	6	11.1	5	3.9
Not a cause	140	71.8	48	88.9	122	96.1
Total	195	100	54	100	127	100
Time of harvest						
Is a cause	61	33.3	5	9.3	4	3.1
Not a cause	134	66.7	49	90.7	123	96.9
Total	195	100	54	100	127	100

Economic Implications of Post-Harvest Losses

The analysis of gross margin and marketing margin demonstrated the economic implications of post-harvest losses for onion producers and marketers. The gross margin analysis showed a 49.4% reduction in gross margin due to post-harvest losses, indicating the

significant impact on farmers' income and welfare. Similarly, the marketing margin analysis revealed a reduction of 97.02% for wholesalers and 96.7% for retailers, highlighting the substantial loss in profitability at the marketing stage.

Table 15: Gross margin analysis of onion production/ha

Cost Items	Cost(₦)	Percentage
Total variable cost	308651.7	
Total revenue	392156.3	
Gross margin	83504.6	50.6
Total revenue without PHLs	473633.2	
Reduction in gross margin due to loss	81476.9	49.4
Gross margin without PHLs	164981.5	100

These findings underscore the urgent need for interventions and strategies to address post-harvest losses in the onion value chain. Improved harvesting techniques, storage facilities, transportation methods, and market infrastructure can help minimize losses and enhance the income and livelihoods of onion producers and marketers.

Table 46: Marketing margin analysis of onion/kg

Cost Items	Wholesalers Cost	%	Retailers Cost	%
Purchasing cost	34.90		31.84	
Selling price/kg	53.35		50.95	
Marketing margin	18.50	2.98	19.11	3.3
Total revenue without PHLs	655.4		609.4	
Reduction in marketing margin due to loss	602.03	97.02	558.4	96.7
Marketing margin without PHL(s)	620.5	100	577.6	100

Strategies Employed by Producers and Marketers to Reduce Post-Harvest Losses

The study examined the strategies adopted by onion producers and marketers in the study area to mitigate post-harvest losses. The findings indicate that the use of post-harvest technologies or strategies to reduce losses is minimal. However, there are a few strategies that have been adopted by producers and marketers, which are discussed below.

Physical Bulb Damage during Harvesting: Out of the 195 producers interviewed, only 63.7% of them adopted strategies to prevent physical bulb damage during harvesting. Among these farmers, 22.6% practiced careful pulling to avoid bulb injury, 19% pulled the bulb on time, and 22.1% pulled the bulb when the soil was soft/wet. Physical Bulb Damage during Haulage and Transportation: Around 23.6% of the producers employed strategies to prevent physical bulb damage during haulage and transportation. Among them, 14.9% adopted careful loading and offloading techniques, 4.1% used suitable vehicles for transportation, and 4.6% avoided exposure to the sun during transit by covering the onions and transporting them early in the morning or late in the evening.

Physical Bulb Damage during Marketing Transactions: Approximately 19% of the producers employed strategies to prevent physical bulb damage during marketing transactions. Among them, 3.6% utilized adequate storage space to avoid overstocking, 3.1% avoided displaying onions in the sun, and 12.3% sold the onions on time at a lower price. This finding conforms with results reported by Babalola *et al.*, (2010).

Table 17: Strategies adopted by producers to reduce post-harvest losses

Causes of PHLs	Strategies	Frequency	%
Physical bulb damage during harvesting	Careful Pulling to avoid bulb injury	44	22.6
	Pulling on time	37	19.0
	Harvesting when the soil is soft/wet	43	22.1
Physical bulb damage during haulage and transportation	Careful loading and offloading	29	14.9
	Use of good vehicle	8	4.1
	Transporting early in the morning or late in the evening	9	4.6
Physical bulb damage during marketing transaction	Adequate storage space to avoid overstocking	7	3.6
	Avoid display of onion in the sun/marketing under shade	6	3.1
	By selling on time at cheaper price	24	12.3
Pest and diseases	Spraying	125	64.1
Varietal Characteristics	Planting of good seed variety that produced many layered non stalked onion	56	28.7
Watering after ripening	Avoid watering after ripening	35	17.9
Time of harvest	Pulling early in the morning or late in the evening	34	17.4
	Separating good onions form damaged or injured ones	5	2.6

Pests and Diseases: The primary measure employed by producers to address pests and diseases was spraying chemicals before harvest, which was practiced by 64.1% of the farmers. Varietal Characteristics: Around 28.7% of the farmers selected good onion seed varieties that produced multi-layered, non-stalked onions. Time of Harvest: To reduce post-harvest losses resulting from the time of harvest, 17.4% of the producers pulled their onions early in the morning or late in the evening and stored them under shade in well-ventilated places. Additionally, 2.6% separated the damaged onions from the good ones, a strategy similar to the findings of Babalola *et al.*, (2010).

The strategies adopted by wholesalers and retailers to reduce post-harvest losses were similar. These are included: Physical Bulb Damage during Haulage and Transportation: Among the wholesalers, 27.8% used good vehicles for transportation, while among the retailers, 7.9% employed this strategy. Furthermore, 18.5% of the wholesalers and 21.3% of the retailers adopted careful loading and offloading techniques to minimize physical bulb damage during haulage and transportation. Physical Bulb Damage during Marketing Transactions: Both wholesalers and retailers implemented strategies to reduce physical bulb damage during marketing transactions. This included selling onions at cheaper prices (31.5% of wholesalers and 37% of retailers), covering onions with grasses/tarpaulin and conducting

marketing transactions under shade (46.3% of wholesalers and 72.4% of retailers), and using good storage facilities (14.8% of wholesalers and 21.3% of retailers).

Table 18: Strategies adopted by wholesalers to reduce post-harvest losses

Causes of PHLs	Strategies	Frequency	%
Physical bulb damage during haulage and transportation	Use of good vehicle for transportation	15	27.8
	Careful loading and offloading	10	18.5
Physical bulb damage during marketing transaction	Using good storage facility	8	14.8
	Selling at cheaper price	17	31.5
	Covering the onion/Marketing under shade	25	46.3
Pest and diseases	Removing the infected ones from the good ones	14	25.9
Varietal Characteristics	Buying of good onion seed variety	9	16.7
Watering after ripening	Avoid watering when it ripened	5	9.3
Time of harvest	Store in cool dry place after pulling	4	7.4

Pests and Diseases: To address post-harvest losses caused by pests and diseases, 25.9% of the wholesalers and 10.2% of the retailers separated damaged onions from the good ones. Additionally, 16.7% of wholesalers and 12.6% of retailers purchased dried, pests and diseases resistant varieties, and 7.4% of wholesalers and 3.1% of retailers stored onions in cool, dry places.

Table 19: Strategies adopted by retailers to reduce post-harvest losses

Causes of PHLs	Strategies	Frequency	Percentages
Physical bulb damage during haulage and transportation	Transport in the morning/evening and covering with straws/tarpaulin.	19	15.0
	Careful loading and offloading	29	21.3
	Use of good vehicle	10	7.9
Physical bulb damage during marketing transaction	Selling on time at cheaper price	47	37.0
	Covering the onion/Marketing under shade	92	72.4
	Using good storage facility	27	21.3
Pest and diseases	Separating the infected ones from the good ones	13	10.2
Varietal Characteristics	Buying of good variety	16	12.6
Watering after ripening	Avoid watering when it ripened	4	3.1
Time of harvest	Keep in cool dry place after pulling	4	3.1

CONCLUSION

The findings of this study indicate that the adoption of post-harvest technologies and strategies to reduce losses among onion producers and marketers in the study area is limited. However, some measures have been employed to address specific causes of post-harvest losses, such as physical bulb damage during harvesting, haulage and transportation, and marketing transactions. The strategies include careful pulling during harvesting, timely harvesting, use of suitable vehicles, storage space management, and proper loading and offloading techniques.

Regarding pests and diseases, the use of chemical spraying before harvest was the primary approach adopted by farmers. Additionally, some farmers selected good onion seed varieties and adjusted watering frequency to mitigate losses caused by varietal characteristics. Producers also took measures to address losses associated with the time of harvest, such as storing onions under shade and separating damaged onions from the good ones.

Wholesalers and retailers exhibited similar strategies to reduce post-harvest losses, including the use of good transportation vehicles, careful loading, and offloading, and adopting practices to prevent physical bulb damage during marketing transactions. They also employed measures like selling at lower prices, covering onions during transportation and marketing, and utilizing appropriate storage facilities. Some wholesalers and retailers separated damaged onions, purchased resistant varieties, and stored onions in cool and dry conditions to mitigate losses caused by pests and diseases.

Based on the study findings, it is evident that there is a need to enhance the adoption of post-harvest technologies and strategies (e.g., awareness and training, access to information, collaboration and networking, infrastructure improvement, varietal improvement, and policy support among others) to minimize losses in the onion supply chain. The following recommendations are proposed:

REFERENCES

Abass, A.B., Ndunguru, G., Mamiro, P., Alenkhe, B., Mlingi, N. and Bekunda, M. (2014). Post-harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. *J. Stored Prod. Res*., 57: 49–57.

Ajayi, A.P. (2023). Lean and circular economy relevance in post-harvest loss prevention: Nigerian retailers' perceptions. *International Journal of Integrated Supply Management*, 16(1): 82-105.

Al-Amin, J.A., Suleiman, A.I. & Collins, E.E. (2021). Accelerating post-harvest food loss reduction in Nigeria through the development of a pilot-scale vacuum cooling and storage System. *Assessment*, 11(20).

AUC (2018). African Union Commission. Inaugural Biennial Review Report of the African Union Commission on the Implementation of the Malabo Declaration on Post harvest loss management strategy for Shared Prosperity and Improved Livelihoods, Assembly Decision (Assembly/AU/2(XXIII) of June 2014, published August 2018

Babalola, D.A., Makinde, Y.O., Omonona, B.T. & Oyekanmi. M.O. (2010). Determinants of post-harvest losses in tomato production: a case study of Imeko-Afon Local government area of Ogun state. *Journal of Life and Physical Science*, 3 (2): 14-18.

Bada, M.M., Suleiman, A. Mustapha, A., Sambo, A.S. and Abdulaziz, K. (2021). Effects of post-harvest losses on profitability of fresh tomato (*Solanum lycopersicum*)

production and marketing in Kano State, Nigeria. *American Journal of Marketing Research*, 7(3): 35-43

Dos Santos, S.F., Cardoso, R.D.C.V., Borges, Í.M.P., e Almeida, A.C., Andrade, E.S., Ferreira, I.O., & do Carmo Ramos, L. (2020). Post-harvest losses of fruits and vegetables in supply centers in Salvador, Brazil: Analysis of determinants, volumes, and reduction strategies. *Waste Management*, 101: 161-170.

FAO (2011). Global food losses and waste. Food and Agriculture Organization of the United Nations, Rome 32pp.

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.

Grema, I.J., and Gashua, A.G., (2015). Economic analysis of onion production along River Komadugu area of Yobe State, Nigeria. *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, 7(10): 5-11.

Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., Meybeck, A. (2011). Global Food Losses and Food Waste; Food and Agriculture Organization of the United Nations: Rome, Italy.

Kader, A.A., and Rolle R.S., (2004). The role of post-harvest management in assuring the quality and safety of horticultural crops. Food and Agriculture Organization. Agricultural services bulletin 152.

Kaka, Y., Gindi, A.A. and Magaji, U. (2021) Evaluation of onion value chain actors in Kebbi State, Nigeria: A Case study of producers and retailers. *Asian Journal of Agricultural Extension, Economics & Sociology*, 39(2): 12-22

Kasso, M., and Bekele, A. (2018) Post-harvest loss and quality deterioration of horticultural crops in Dire Dawa region, Ethiopia. *Journal of the Saudi Society of Agricultural Sciences*, 17(1): 88-96.

KNARDA (2011). Media Newsletter, Kano State Agricultural and Rural Development Authority. Media Press. Kano.Pp.2-15.

llo, A.I., Kaka, Y., Hassan, U., Umar, S and Bamidele, A. A. (2016). Marketing of onion in Aliero central market, Aliero Local Government Area of Kebbi State. *Journal of Humanity and Social Science*, 21 (1): 42-49.

NAERLS (2012). Agricultural Performance Survey, Kano State. National Agricultural Extension Research and Liaison Services, ABU-Zaria.

NASS (2012). A Collaborative Survey by National Agriculture Sample Survey 2011/2012 and National Bureau of Statistics.

NPC (2020). National and State population projection based on 2006 Population and Housing Census (PHC). National Population Commission.

Olofin E.A., (2008). The Physical Setting. *In*: Olofin E.A., Nabegu, A.B. and Dambazau, A.M., (Eds.), *Wudil within Kano Region: A Geographical Synthesis*. Adamu Joji Publishers, Kano City, 5-34.

Osabohien, R. (2022). Soil technology and post-harvest losses in Nigeria. *Journal of Agribusiness in Developing and Emerging Economies*.

Sharma, G. and Singh, S.P. (2011). Economic analysis of post-harvest losses in marketing of vegetables in Uttarakhand. *Agricultural Economics Research Review*, 24: 309-315.

Sharma, S. (2016). Economic analysis of post-harvest losses in onion in Jaipur District of Rajasthan. *The Asian Journal of Horticulture*, 11:124-128.

Shu'aib, A.U. (2009). Economic Analysis of Bee Keeping in Selected Local Government Areas of Kano State, Nigeria. An M.Sc. Dissertation, Submitted to the Department of Agricultural Economics and Extension, Usman Danfodio University, Sokoto. Pp.57.

Suleiman, A. (2015). Post-Harvest Losses Estimation Model. A model developed by Aminu Suleiman, Department of Agricultural Economics and Extension, Bayero University, Kano. An Unpublished Article, March 2015.