KIJHUS KIU Interdisciplinary Journal of Humanities and Social Sciences

IMPACT OF STORAGE MANAGEMENT STRATEGIES ON OPERATIONAL EFFICIENCY AND PROFITABILITY AMONG SMALLHOLDER ONION FARMERS IN SHINKAFI LGA, ZAMFARA STATE, NIGERIA

Tijjani Salihu Shinkafi[1, 2, 4], Andrew Nyakundi[1], Tukur Muhammad[1] & Eric Mabonga[1]

[1] Department of Business Administration, Faculty of Business and Management, Kampala International University, Uganda
[2] Department of Public Health and Nutrition, Faculty of Health Sciences, Victoria University Uganda
[3] Department of Science Education & Educational Foundations, Faculty of Education Kampala International University Western Campus, Uganda
[4] Department of Biochemistry, Faculty of Chemical and Life Sciences, Usmanu Danfodiyo University Sokoto, Nigeria

Corresponding Author: tjshinkee@gmail.com

Citation: Shinkafi et al (2024). Impact of storage management strategies on operational efficiency and profitability among smallholder onion farmers in Shinkafi lga, Zamfara state, Nigeria. *KIU Interdisciplinary Journal of Humanities and Social Sciences, 5*(2), 325-355.

ABSTRACT

This study explores how different storage methods affect efficiency and profitability among smallholder onion farmers in Shinkafi LGA, Zamfara State, Nigeria. It assesses traditional, hybrid, and ventilated storage methods to reduce post-harvest losses and enhance profitability by preserving onion quality. Using the Technology Acceptance Model, the research highlights farmers' challenges in adopting innovative storage techniques. Data were collected from 381 farmers via a Likert-scale questionnaire in May- June 2023. Most respondents were male (98.4%), aged 19-30, married, Muslim, and had secondary education. The findings revealed that the traditional and ventilated storage methods significantly decrease post-harvest losses, as indicated by their respective t statistics and p-values (traditional method: t=3.607, P=.000, P<.05; ventilated method: t=2.461, P=0.007, P<.05). In contrast, the hybrid method, which combines features of both the traditional and ventilated methods, showed no significant impact on decreasing post-harvest losses (t=1.716, P=.0.071, P>.05). The study shows that, whereas both traditional and ventilated approaches greatly reduce post-harvest losses (27% and 22%, respectively), the hybrid method does not significantly reduce onion post-harvest losses (11.5%) during storage. Adopting both traditional and vented storage methods allows farmers to reduce postharvest losses, maintain quality, and increase profits

Keywords: Onion, Post-harvest management, Food security, Profit

INTRODUCTION

Post-harvest losses quickly become a major concern, costing farmers and many countries heavily. Numerous initiatives have been undertaken to reduce losses as a result of this problem. Crop production is essential for food security and nutrition, thus post-harvest losses are undesirable because they risk lives and reduce farmer revenue (Ogedengbe, Malomo, Akanji, Extension, & Systems, 2022). Losses incurred after harvest have a significant influence on smallholder farmers' income and food security (Amjad et al., 2023). In addition to the economic consequences, these losses lead to food waste and undercut efforts to develop sustainable farming practices (Kusumowardani et al., 2022).

Historically, many communities around the world have devised various storage strategies to decrease postharvest loss. These methods range from traditional to ventilation-based. Nowadays, hybrid approaches that mix traditional and ventilation concepts are utilized in the United States, India, and Brazil (Cramer et al., 2021; Gulati et al., 2021). Farmers in Africa do not employ this technology to preserve onions, most likely because electricity remains a problem in most of the world's largest onion growers, such as Nigeria. Because onions are perishable, they cannot be stored for an extended amount of time without being protected from sunshine, pests, moisture, or heat (Chávez-Mendoza & Guevara-Aguilar, 2025). To maximize profitability, farmers must store onions for as least two to six months after harvest. Efficient storage strategies can help farmers increase their profits because onions are cheap at harvest time. Inefficient practices can reduce the amount of onion kept, increasing farmers' post-harvest losses (Yeshiwas, Alemayehu, & Adgo, 2023)

With global food demand increasing due to population increase, more than one-third of food is lost or squandered during post-harvest agricultural procedures. Effective storage methods allow farmers to preserve onions after harvest, during periods of high supply (when prices are low), and sell them at a higher price during periods of low supply, enhancing income and profitability. The difficulty is that onions rot easily during storage, resulting in a huge loss for producers. Smallholder farmers in Shinkafi Local Government in Zamfara State face considerable post-harvest losses as a result of inadequate onion storage methods. The lack of suitable storage methods and infrastructure, combined with extreme weather conditions in the region, resulted in significant levels of spoiling and decreased market value of onions, hurting smallholder farmers' revenue. (Peterson, 2009).

According to annual estimates, Nigeria's onion crop is worth more than N700 billion, but post-harvest losses account for 40 to 50 percent of that total, or more than N300 billion (OFAN, 2023). The northern states of Sokoto, Zamfara, and Kebbi are Nigeria's leading onion producers. Shinkafi Local Government is in Zamfara State. Nigeria produces around 2 million metric tons of onions per year, with approximately 40% lost owing to post-harvest losses (OFAN, 2023). It is possible to enhance onion storage and handling habits through research and implementation, which will help smallholder farmers and the larger community alike.

The absence of cost-effective storage solutions available to onion producers will continue to result in onion rotting and post-harvest losses in the long run. This will have an impact on both farmers' living standards and Nigeria's overall economy. Research to find and adopt the most effective technique of onion storage would represent a management opportunity to boost smallholder farmers' income and reduce post-harvest losses.

1.2 Objectives of the Study

1.2.1 General Objective

This study aims to evaluate the impact of storage management strategies on operational efficiency and profitability among smallholder onion farmers in Shinkafi LGA, Zamfara State, Nigeria

1.2.2 Specific Objectives

1. To examine the traditional methods of onion storage on post-harvest losses of smallholder farmers in Shinkafi Local Government Area of Zamfara State.
2. To assess the hybrid methods of onion storage on post-harvest losses of smallholder farmers in Shinkafi Local Government Area of Zamfara State.
3. To analyze the ventilated methods of onion storage on post-harvest losses of smallholder farmers in Shinkafi Local Government Area of Zamfara State.

1.3 Hypotheses

Ho 1: Traditional onion storage methods significantly cause post-harvest losses to smallholder farmers in Shinkafi Local Government Area of Zamfara State when using traditional methods of onion storage

Ho 2: Hybrid onion storage methods significantly cause post-harvest losses to smallholder farmers in Shinkafi Local Government Area of Zamfara State when using traditional methods of onion storage

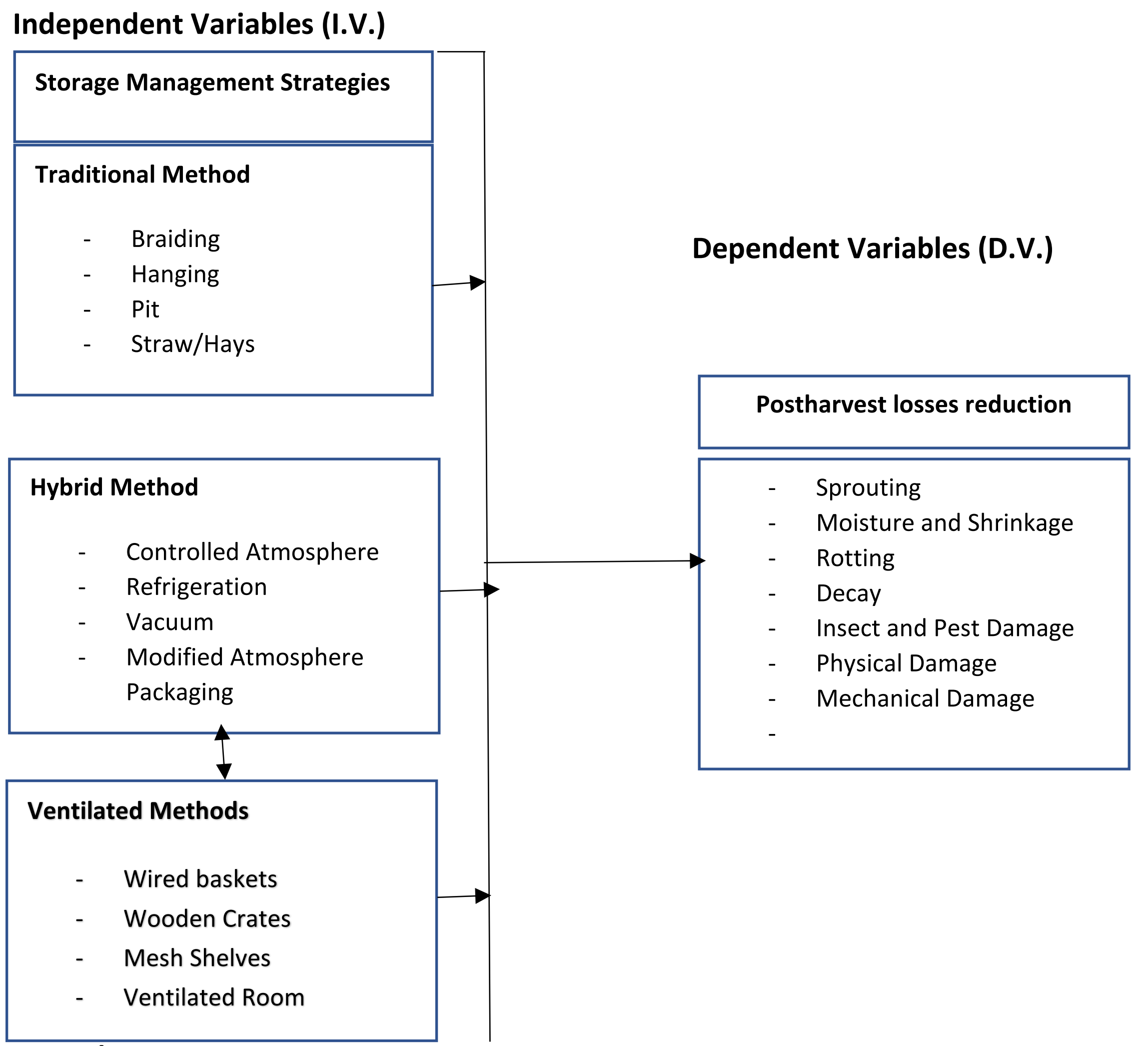
Ho 3: Ventilated onion storage methods significantly cause post-harvest losses to smallholder farmers in Shinkafi Local Government Area of Zamfara State when using traditional methods of onion storage

1.4 Conceptual Framework

The research will be based on post-harvest handling, agricultural extension, and marketing theories. These theories will serve as a foundation for understanding the factors that influence onion storage methods, onion quality, post-harvest losses, and smallholder farmer profitability. The relationship between independent and dependent variables has been provided in **Figure 1**

Independent Variable: Storage Management Strategies (e.g., traditional, hybrid, ventilated methods).

Dependent Variable: Operational Efficiency and Profitability (e.g., reduction in post-harvest losses, increased revenue, reduced costs, improved storage life).



Source: Researcher, 2024

FIGURE 1: RELATIONSHIP BETWEEN INDEPENDENT AND DEPENDENT VARIABLES

3.0 Methodology

3.1 Research Approaches

The study used a cross-sectional and quantitative design, with a standardized Likert questionnaire used to collect data from interested participants. The questionnaire was translated into Hausa, the major local language used in the study area, to verify that the respondents understood it well.

3.2 Research Design

The study used a stratified random sampling research design. The Shinkafi Local Government Area is divided into ten political wards. Data was collected in each of the ten wards, excluding Kware and Kurya for security purposes.

3.3 Target Population

The target population are the onion farmers within Shinkafi Local Government Area of Zamfara State. Shinkafi Local Government Area (LGA) has a population of about 135,649 according to census 2006. The number of onion farmers in the LGA is 8000

3.4 Sample Size

The sample size of 381 smallholder farmers was calculated using the sample size formula for a limited population. Shinkafi LGA has an estimated 8,000 smallholder farmers. Yamane (1967) created the formula for calculating sample size.

The calculation is as follows:

$n = N / (1 + N(e^2))$

Where:

n = sample size

N = population size (8000)

e = margin of error (5%)

$n = 8,000 / (1 + 8,000(0.05^2)$

n = 381

Therefore, a sample size of 381 smallholder farmers was selected for the study.

3.5 Sampling Technique

A simple random sampling was carried out. A total of 381 questionnaires were printed in the Hausa language (local language) and 381 were administered to the willing respondents in the eight wards out of the 10 wards of Shinkafi LGA. Shinkafi local government area is divided into 10 local government wards

3.5 Data Collection Methods

Data was collected using a structured Likert questionnaire, which was administered to the willing smallholder farmers.

3.5.1 Quality Control

This section describes the validity and reliability of the research instrument.

3.7.1 Validity of Research Instrument

The instrument used in this study to collect data on the evaluation of onion storage methods and their impact on post-harvest losses of smallholder farmers in Shinkafi Local Government Area of Zamfara State, Nigeria, underwent a rigorous validation process to ensure its validity, including literature review and construct validity. The supervisors and Research Ethics Committee examined the instrument to verify that it covered all important topics and that the questions were clear and understandable. Similarly, the components were validated in a pilot study that included 10% of farmers with prior experience with onion storage and post-harvest losses. The responses from the pilot study were examined, and the questionnaire was found to be appropriate for measuring the concept.

3.5.2 Reliability of Research Instrument

To assess the reliability of the instrument employed in this study, the Cronbach Alphar was used to collect data on onion storage practices used by smallholder farmers in Shinkafi Local Government Area and their impact on post-harvest losses. It works well with Likert scales or similar items that require respondents to assess agreement, frequency, or importance, with the responses treated as continuous variables.

3.6 Data Analysis

3.6.1 Quantitative Data

Descriptive statistics such as frequency distribution, percentages, mean, and standard deviation were used to describe respondents' demographics, onion production, onion storage techniques, post-harvest losses, income, and food security.
Using the Statistical Package for the Social Sciences (SPSS) Software version 20.0, regression analysis was used to evaluate the research hypotheses and determine the impact of various onion storage strategies on reducing post-harvest losses.

3.6.2 Multiple Regression Equation

The regression model is presented below.

$Y = Bo + B1X1 + B2X2 + B3X3 + e$

Where:

Y = Post-harvest losses of smallholder farmers

X1 = Traditional methods

X2 = Hybrid methods

X3 = Ventilated methods

Bs = Coefficients

e = Margin error (5%)

All statistical tests were set to $p < 0.05$, with a 95% confidence level. The analysis results were presented in tables, graphs, and charts, and were discussed in relation to the study questions and hypotheses.

3.6.3 Assumptions of the Multiple Linear Regression Model

3.6.3.1 Test for Normality

The residuals of variables are thought to be normally distributed. That is, errors in forecasting the value of Y (the dependent variable) are distributed in a way similar to the normal curve. When defining reference intervals for variables, the assumption of normalcy is critical; if this assumption is broken, it is difficult to draw accurate and reliable conclusions about reality (O'Farrell, et al., 1971). Normality can be evaluated using skewness and kurtosis, however this test must be performed on the residuals themselves. The statements in this variable showed an approximation of a normal distribution (Osborne, Waters, & evaluation, 2002). The results will reveal if the skewness values are within the permissible range of < 3 and the kurtosis values are fewer than the suggested range (< 10).

3.6.3.2 Test for Linearity

Only linear relationships between dependent and independent variables can be effectively estimated using standard multiple regression. If the connection between the independent variables (IV) and the dependent variable (DV) is not linear, the results of the regression analysis will undervalue the underlying relationship (Osborne et al., 2002). Linearity can be tested using PP plot which shows if data points were not seriously deviated from the fitted line (Osborne et al., 2002).

3.6.3.3 Test for Homoscedasticity

According to the homoscedasticity assumption, mistakes have the same variance across all levels of independent variables (Osborne et al., 2002). To test for homoscedasticity, a plot of the standardized residuals versus the regression standardized projected value was utilized. The findings will show whether standardized residuals follow a rectangular distribution and are concentrated in the center (around 0).

3.6.3.4 Test for Multicollinearity

Multicollinearity occurs when a large number of independent variables have a strong connection with one another, or when one independent variable is a near-linear combination of other independent variables. The Variable Inflation Factor (VIF) data were utilized to administer the exam. VIF=1 is used to express minor inter-correlations between independent variables. VIF > 10, on the other hand, indicates that collinearity is an issue. Low tolerance levels and high VIF values indicate multicollinearity (Oswald, 2013).

3.7 Ethical Considerations

Ethical considerations were taken into account during the investigation. All individuals provided informed consent, and their confidentiality was guaranteed. The study also followed all applicable ethical criteria. The inquiry was conducted solely for research purposes, and all information was kept totally confidential.

4.0 Results, Discussion, Conclusion and Recommendations

4.1 Results

Data collected are presented in frequency tables and percentages measured on a five-point Likert scale (**Table 1**)

Table 4.1: Demographics of the Respondents

		Frequency	Percent
	Female	6	1.6
Gender	Male	375	98.4
	Total	381	100.0
Age	51 and above	12	3.2
	41 – 50	44	11.6
	31 – 40	103	27.0
	19 – 30	199	52.2
	Below 18yrs	23	6.0
	Total	381	100.0
Marital status	Widowed	4	1.0
	Divorce	17	4.4
	Single	111	29.2
	Married	249	65.3
	Total	381	100.0
Religion	Islam	381	100.0
Education qualification	Degree level	21	5.5
	College	44	11.5
	Secondary level	212	55.6
	Primary level	104	27.4
	Total	381	100.0
Wards	Birnin Yero	33	8.6
	Jangeru	50	13.1
	Badarawa	39	10.2
	Katuru	40	10.4
	Galadi	40	10.4
	Shanawa	40	10.4
	Shinkafi South	60	15.7
	Shinkafi North	79	20.7
	Total	381	100.0

Source: Researcher's survey, 2024

Table 4.1 shows that the majority of responders are male. The table shows that 375 respondents (98.4%) are male, while only 6 respondents (1.6%) are female. The majority of responders to the study are male, indicating that farming activity in Shinkafi LGA is predominantly male. The table shows that the majority of responders are between the ages of 19 and 30. According to the table, 103 respondents (27.0%) were between the ages of 31 and 40; 44 respondents (11.6%) were between the ages of 41 and 50; and 12 respondents (3.2%) were 51 years or older. The bulk of responses fell between the ages of 19 and 430, indicating that the majority of those who participated in the study were between the ages of 19 and 30. From the table, it can be discerned that the majority of the respondents are married. The table shows that 249 respondents representing 65.3% were married; 111 respondents representing 29.2% of the respondents are single; 4 respondents representing 1.0% are widows; and 17 respondents representing 4.4% are divorced. The data revealed that the majority of the respondents who took part in the survey are married.

From the table, it can be discerned that all the respondents are Muslims. The table shows that 381 respondents representing 100% are Muslims. This means that the respondents are from the same religious background. This is because the local government is dominated by Muslims.

The table displays the educational backgrounds of the respondents. According to the table, 212 respondents (55.6%) received O'levels, 104 respondents (27.4%) obtained primary school certificates, 44 respondents (11.5%) obtained college certificates, and 21 respondents (5.5%) obtained degrees. This demonstrates a clear understanding that the majority of respondents to the survey have an O'level or higher and would be able to understand the questions under consideration due to their level of educational attainment. However, the questionnaire was read in the local tongue to facilitate comprehension.

The table indicates the respondents' ward of residence. The majority of responders are from Shinkafi North, with 79 respondents (20.7%). Katuru, Galadi, and Shanawa wards each had 40 respondents, accounting for 10.4% of total respondents. Binin Yero has the fewest respondents, with 33, accounting for 8.6% of total respondents. Badarawa has 39 responders, or 10.2% of the total, while Shinkafi South has 60, or 15.7%. This suggests that the vast majority of survey responses came from Shinkafi North. The results also reveal that 8 of the 10 wards of Shinkafi LGA participated in the survey, as represented in the survey, and that the sample is clearly representative of the whole population.

4.2 Results of Objectives

4.2.1 Descriptive Statistics on Objective One (Traditional Methods)

Table 4.2: Descriptive Statistics on Objective One (Traditional Methods)

Statements	DS	D	NS	A	SA	Mean	SD
We store the onion using the braiding method and is effective in reducing post-harvest losses	46 12.0%	43 11.2%	29 7.6%	99 26.1%	164 43.1%	3.77	1.413
We store the onion using the clamping method and is effective in reducing post-harvest losses	21 5.5%	80 21.0%	33 8.6%	108 28.3%	139 36.5%	3.69	1.303
We sore the onion using the pyramiding method and is effective in reducing post-harvest losses	78 20.5%	44 11.5%	63 16.4%	121 31.8%	75 19.7%	3.18	1.422
We store the onion using the mesh bagging method and is effective in reducing post-harvest losses	26 6.8%	28 7.3%	34 8.9%	120 31.5%	173 45.4%	4.02	1.207
We store the onion in bins and is effective in reducing post-harvest losses	77 20.2%	52 13.6%	64 16.7%	122 32.0%	67 17.5%	3.13	1.398
We store the onion using pit storage and is effective in reducing post-harvest losses	45 11.8%	64 16.8%	52 13.7%	155 40.6%	65 17.1%	3.35	1.273
None of these methods is used	47	62	64	149	59	3.29	1.259
Overall	12.3%	16.2%	17.0%	39.1%	15.4%	24.43	9.28

Source: Primary or Field data, 2024

Key: DS, disagree strongly; D, Disagree; NS, not sure; A, agree; SA, strongly agree

The results of table 4.2 above reveal that the majority of respondents think that employing the braiding method to store onions is effective in decreasing post-harvest losses. According to the table, 164 respondents (43.1%) highly agreed and 99 respondents (26.1%) agreed that they store onions using the braiding method, which is beneficial in decreasing post-harvest losses. On the other hand, 46 respondents (12.0%) and 43 respondents (11.2%) strongly disagreed that keeping onions using the braiding method is beneficial in reducing post-harvest losses. 29 respondents, or 7.6% of the total, expressed neutrality on the question

The table above demonstrates that the majority of respondents believed that utilizing the clamping method to store onions is beneficial in decreasing post-harvest losses. According to the table, 139 respondents (36.5%) highly agreed and 108 respondents (28.3%) agreed that they store onions using the clamping method, which is beneficial in decreasing post-harvest losses. In contrast, 21 respondents representing 5.5% and 80 respondents representing 21.0% strongly disagreed and disagreed, respectively, that they store the onion using the clamping method,

which is effective in minimizing post-harvest. 33 respondents, or 8.6%, were neutral on the question.
The results of the table above demonstrate that the majority of respondents agreed that utilizing the pyramiding method to preserve onions is effective in decreasing post-harvest losses. According to the table, 75 respondents, or 19.7%, highly agreed, while 121 respondents, or 31.8%, agreed that they store onions using the pyramiding method, which is helpful in decreasing postharvest losses. On the contrary, 78 respondents (20.5%) strongly disagreed and 44 respondents (11.5%) disagreed that they store the onion using the pyramiding method, which is effective in decreasing post-harvest losses. 63 respondents, or 16.4%, were neutral on the question.
The results of Table 4.10 above demonstrate that the majority of respondents agreed that storing onions in mesh bags is effective in avoiding post-harvest losses. According to the table, 173 respondents (45.4% strongly agreed) and 120 respondents (31.5%) agreed that they store onions using the mesh bagging method, which is effective in decreasing post-harvest losses. On the contrary, 26 respondents (6.8%) and 28 respondents (7.3%) strongly disagreed that they store onions using the mesh bagging method, which is beneficial in decreasing post-harvest losses. 34 respondents, or 8.9%, expressed neutrality on the question. The results of the table above demonstrate that the majority of respondents agreed that storing onions in bins was effective in decreasing post-harvest losses. According to the table, 67 respondents (17.5%) strongly agreed and 122 respondents (32.0%) agreed that storing onions in bins reduces post-harvest losses. On the contrary, 77 respondents (20.2%) and 52 respondents (13.6%) strongly disagreed and disagreed, respectively, that storing onions in bins is effective in reducing post-harvest losses. 64 respondents, or 16.7%, expressed neutrality on the question.

The results also suggest that the majority of respondents believe that storing onions in pits is useful in avoiding post-harvest losses. According to the table, 65 respondents (17.1%) highly agreed, while 155 respondents (40.6%) agreed that they store onions in pits, which is effective in decreasing post-harvest losses. On the other hand, 45 respondents (11.8%) and 64 respondents (16.8%) strongly disagreed and disagreed, respectively, that they store onions in pits and that this method is effective in reducing post-harvest losses. The question was viewed neutrally by 52 respondents, or 13.7% of the total.
Finally, the majority of respondents agreed that neither of these strategies is used. According to the table, 59 respondents (15.4%) strongly agreed, while 149 respondents (39.1%) agreed that none of these approaches are employed. In contrast, 47 respondents (12.3%) strongly disagreed and 62 respondents (16.2%) argued that none of these strategies are used. 64 respondents, or 17.0%, expressed neutrality on the question

4.2.2 Descriptive Statistics on Objective Two (Hybrid Methods)

Table 4.3: Descriptive Statistics on Objective Two (Hybrid Methods)

Statements	DS	D	NS	A	SA	Mean	SD
We store onions using a controlled atmosphere storage	20	30	67	131	124	3.80	1.147
method and is effective in reducing post-harvest losses	5.2%	9.4%	17.6%	35.2%	32.6%		
We store onions using the dynamic atmosphere storage	31	51	82	115	102	3.54	1.242
method and is effective in reducing post-harvest losses	8.1%	13.3%	21.5%	30.2%	26.8%		
We store onions using the heat treatment storage	61	56	50	148	66	3.27	1.345
method and is effective in reducing post-harvest losses	16.0%	14.7%	13.1%	38.9%	17.3%		
We store onion using the modified humidity storage	44	34	110	103	90	3.42	1.259
method and is effective in reducing post-harvest losses	11.5%	8.9%	28.9%	27.0%	23.6%		
We store the onion using the vacuum cooling storage	65	9	87	137	83	3.43	1.325
method and is effective in reducing post-harvest losses	17.0%	2.3%	23.0%	36.0%	21.7%		
We do not use any of these methods	33	27	96	145	80	3.56	1.153
Overall	8.6%	7.0%	25.3%	36.1%	20.9%	21.06	7.47

Source: Primary or Field data, 2024

Key: DS, disagree strongly; D, Disagree; NS, not sure; A, agree; SA, strongly agree

Table 4.3 indicates that the majority of respondents feel that storing onions in a controlled climate is effective in avoiding post-harvest losses. According to the table, 124 respondents (32.6%) and 134 respondents (35.2%) strongly agree and agree that they store onion in a controlled atmosphere storage method, which is effective in decreasing post-harvest losses. In contrast, 20 respondents (5.2%) and 36 respondents (9.4%) strongly disagree and disagree that they store onions in a controlled atmosphere storage method that is beneficial in avoiding post-harvest losses. 67 respondents, or 17.6%, were ambivalent on the topic of whether they store onions in a controlled atmosphere storage method that is effective in avoiding post-harvest losses. This means that smallholder farmers store onions in a regulated atmosphere, which helps to reduce post-harvest losses.

The results in Table 4.3 reveal that the majority of respondents agree that they store onions using the dynamic environment storage method, which is effective in reducing post-harvest loss. The chart reveals that 102 respondents (26.8%) and 115 respondents (30.2%) strongly agree and agree that they store onions using the dynamic environment storage method, which is beneficial in decreasing post-harvest losses. In contrast, 31 respondents (8.1%) and 51 respondents

(13.3%), respectively, strongly disagree and disagree that storing onions in a dynamic climate is effective in reducing post-harvest losses. 82 respondents, or 21.5%, responded neutrally to the question of whether they store onions using the dynamic environment storage method, which is helpful in decreasing postharvest losses. This means that smallholder farmers store onions using the dynamic environment storage method, which is effective at lowering post-harvest losses.

The results of Table 4.3 reveal that the majority of respondents agreed that they preserve onions using heat treatment, which is beneficial in reducing post-harvest losses. According to the table, 66 respondents (17.3%) highly agree and 148 respondents (38.9%) agree that we preserve onions using heat treatment, which is effective in reducing post-harvest losses. On the contrary, 61 respondents (16.0%) and 56 respondents (14.7%) strongly disagree and disagree that they store onion using the heat treatment storage method, which is effective in reducing post-harvest losses. 50 respondents, or 13.1% of the total, responded neutrally to the question of whether they store onions using heat treatment, which is effective in decreasing postharvest losses. This indicates that smallholder farmers use heat treatment to store onions, which reduces post-harvest losses.

The results of Table 4.3 demonstrate that the majority of respondents are undecided about keeping onions using the modified humidity storage method. The chart reveals that 90 respondents (23.6%) and 103 respondents (27.0%) highly agree and agree that they store onions using the modified humidity storage method, which is beneficial in decreasing post-harvest losses. On the contrary, 44 respondents (11.5%) and 34 respondents (8.9%) strongly disagree that we store onions using the modified humidity storage method, which is beneficial in decreasing post-harvest losses. 110 respondents, or 28.9%, responded neutrally to the question about storing onions using the modified humidity storage method, which is effective in decreasing post-harvest losses. This suggests that smallholder farmers were indecisive on this particular subject, implying that the method is not employed.

Table 4.3 demonstrates that the majority of respondents agreed that vacuum cooling is an efficient way to reduce post-harvest losses when storing onions. According to the table, 83 respondents (21.7%) and 137 respondents (36.0%) highly agree and agree that they store onions utilizing vacuum chilling storage methods, which are helpful in decreasing post-harvest losses. In contrast, 65 respondents (17.0%) and 9 respondents (2.3%), respectively, strongly disagree and disagree that they store onions using the vacuum chilling storage method, which is effective in reducing post-harvest losses. 87 respondents, or 23.0%, responded neutrally to the question of whether they store onions utilizing vacuum chilling storage methods, which are beneficial in reducing postharvest losses. This means that smallholder farmers use vacuum cooling to preserve onions, which is successful at decreasing post-harvest losses.

Table 4.3 reveals that the majority of respondents agreed with the statement that they do not utilize any of these approaches. The data shows that 80 respondents (20.9%) highly agree and 145 respondents (38.1%) agree that they do not employ any of these strategies. In contrast, 33 respondents (8.6%) strongly disagree and 27 respondents (7.0%) disagree that they do not employ any of these strategies. 96 respondents, or 25.3%, responded neutrally to the question, stating that they do not employ any of these approaches. This means that we, as smallholder farmers, do not use any of these approaches.

4.2.3 Descriptive Statistics on Objective Three (Ventilated Methods)

Table 4.4: Descriptive Statistics on Objective Three (Ventilated Methods)

Statements	DS	D	NS	A	SA	Mean	SD
We store onion using an open-air method and is effective in reducing post-harvest losses	24 6.3%	22 5.8%	79 20.7%	177 46.5%	79 20.7%	3.69	1.063
We store onion using the forced-air method and is effective in reducing post-harvest losses	49 12.8%	58 15.2%	66 17.3%	148 38.9%	60 15.5%	3.29	1.263
We store onion using the mechanical method and is effective in reducing post-harvest losses	77 20.2%	54 14.2%	54 14.2%	131 34.4%	65 17.0%	3.13	1.402
We store onion using the modified atmosphere method and is effective in reducing post-harvest losses	21 5.5%	46 12.1%	115 30.7%	140 36.7%	59 15.5%	3.44	1.064
We store onion using the natural ventilation method and is effective in reducing post-harvest losses	71 18.6%	34 8.9%	62 16.3%	157 41.2%	57 15.0%	3.24	1.341
We store onion using a combination ventilation method and is effective in reducing post-harvest losses	39 10.2%	27 7.1%	51 13.4%	132 34.6	132 34.6	3.77	1.280
We do not use any of these methods	31	15	50	135	15	3.94	1.191
Overall	8.1%	3.9%	13.1%	35.5%	39.4%	24.50	8.60

Source: Primary or Field data, 2024

Key: DS, disagree strongly; D, Disagree; NS, not sure; A, agree; SA, strongly agree

The results of table 4.4 reveal that the majority of respondents felt that storing onions in the open air is effective in avoiding postharvest losses. According to the table, 79 respondents (20.7%) highly agree and 177 respondents (46.5%) agree that they store onions in the open air, which is effective in decreasing post-harvest losses. On the other hand, 24 respondents (6.3%) and 22 respondents (6.0%) strongly disagree and disagree, respectively, that they store onion in an open-air technique that is effective in preventing post-harvest loss. 79 respondents (20.7% of the total) responded neutrally to the question of whether they store onions open-air, which is effective in decreasing post-harvest losses. This means that smallholder farmers store onions in open air, which is beneficial in decreasing post-harvest losses.

Table 4.4 demonstrates that the majority of respondents agreed that they store onions using the forced-air approach, which is effective in decreasing post-harvest losses. According to the table, 60 respondents (15.7%) highly agree and 148 respondents (38.9%) agree that they store onions using the forced-air approach, which is beneficial in decreasing post-harvest losses. On the other hand, 49 respondents (12.8%) and 58 respondents (15.1%) strongly disagree that they store onions using the forced-air approach, which is beneficial in reducing post-harvest losses. 66 respondents, or 17.3%, responded neutrally to the question of whether they store onions using the forced-air approach, which is effective in reducing postharvest losses. This means that smallholder farmers store onions using forced-air methods, which are successful at reducing post-harvest losses.

The results of table 4.4 reveal that the majority of respondents stated that they store onions mechanically, which is effective in decreasing postharvest losses. According to the table, 65 respondents (17.0%) highly agree and 131 respondents (34.4%) agree that they store onions mechanically, which is effective in decreasing post-harvest losses. On the contrary, 77 respondents (20.2%) and 54 respondents (14.2%) strongly disagree that they store onions mechanically and that it is beneficial in decreasing post-harvest losses. 54 respondents, or 14.2%, responded neutrally to the question of whether they store onions mechanically, which is effective in reducing postharvest losses. This means that smallholder farmers store onions mechanically, which reduces post-harvest losses.

Table 4.4 demonstrates that the majority of respondents felt that storing onions under modified environment is useful in decreasing post-harvest losses. According to the table, 59 respondents (15.4%) highly agree and 140 respondents (36.7%) agree that they store onions using the modified environment approach, which is beneficial in reducing post-harvest losses. On the contrary, 21 respondents (5.5%) and 46 respondents (12.0%) strongly disagree and disagree that they store onions using the modified environment approach, which is effective in reducing post-harvest losses. 115 respondents, or 30.2%, responded neutrally to the question of whether they store onions using the modified environment approach, which is effective in decreasing postharvest losses. This indicates that smallholder farmers store onions using the modified environment method, which is successful at decreasing post-harvest losses.

The results of table 4.4 reveal that the majority of respondents felt that employing natural ventilation to store onions is effective in reducing post-harvest loss. The chart reveals that 57 respondents (15%) and 157 respondents (41.2%) highly agree and agree that they store onions utilizing natural ventilation, which is effective in decreasing post-harvest losses. In contrast, 71 respondents representing 18.6% and 34 respondents representing 8.9% strongly disagree and disagree, respectively, that they store onion using the natural ventilation approach and that it is effective in decreasing post-harvest losses. 62 respondents, or 16.3% of the total, responded neutrally to the question of whether they store onions using natural ventilation, which reduces post-harvest losses. This means that smallholder farmers store onions utilizing natural ventilation, which is excellent for reducing post-harvest losses.

The results of table 4.4 reveal that the majority of respondents agreed that they store onions using a combined ventilation strategy, which is effective in decreasing postharvest losses. According to the table, 132 respondents (34.6% each) strongly agree and agree that they store onions using a combination ventilation approach that is helpful in decreasing post-harvest losses. On the contrary, 39 respondents (10.2%) and 27 respondents (7.1%) strongly disagree and disagree that they store onions using a combination ventilation approach that is beneficial in reducing post-harvest losses. 51 respondents, or 13.4%, responded neutrally to the question that they store onions using a combination ventilation strategy that is effective in decreasing postharvest losses. This means that smallholder farmers store onions with a combined ventilation strategy, which is helpful in reducing post-harvest losses.

Table 4.4 reveals that the majority of respondents agreed with the statement that they do not utilize any of these approaches. According to the table, 150 respondents (39.4%) highly agree and 135 respondents (35.5%) agree that they do not employ any of these approaches. In contrast, 31 respondents (8.1%) strongly disagree and 15 respondents (3.9%) disagree that they do not employ any of these strategies. 50 respondents, or 13.1%, responded neutrally to the question, stating that they do not employ any of these approaches. This implies that smallholder farmers do not employ any of these strategies.

4.2.4 Descriptive Statistics on the Dependent Variable (Post-Harvest loses)

Table 4.5: Descriptive Statistics on the Dependent Variable (Post-Harvest Losses)

	DS	D	NS	A	SA	Mean	SD
We cure the onion before storage which reduces post-harvest losses	40 10.5%	46 12.1%	43 11.3%	125 32.8%	127 33.3%	3.67	1.330
We sort onion and remove the damaged ones before storage which reduces post-harvest losses	26 6.8%	27 7.1%	40 10.5%	133 34.9%	155 40.7%	3.96	1.189
We store onion in a cool, dried and ventilated place which reduces post-harvest losses	24 6.3%	33 8.7%	39 10.2%	124 32.5%	161 42.3%	3.96	1.201
We protect the stored onion from sunlight which reduces post-harvest losses	45 11.5%	41 10.7%	24 6.3%	98 25.7%	173 45.4%	3.82	1.410
We protect onion from moisture during rainfall which reduces post-harvest losses	37 9.7%	36 9.4%	51 13.4%	95 24.9%	162 42.5%	3.81	1.336
We regularly check the stored onion for sprouting and spoilage which reduces post-harvest losses	38 9.9%	24 6.3%	44 11.5%	96 25.3%	179 47.0%	3.93	1.317
We store the onion for up to six months	38 10.0%	67 17.6%	57 15.0%	119 3.2%	100 26.2%	3.46	1.317
We need money hence we cannot store our onion	52 13.6%	64 16.8	44 11.5%	128 33.7%	93 24.4%	3.38	1.373
We grade the onion before storage Overall	46 12.1%	52 13.6%	76 19.9%	131 34.4%	76 19.9%	3.36	1.279

Source: Primary or Field data, 2024

Key: DS, disagree strongly; D, Disagree; NS, not sure; A, agree; SA, strongly agree

The results of Table 4.5 reveal that the majority of respondents agreed that they treat the onion before storage to avoid post-harvest losses. According to the table, 127 respondents (33.3%) highly agree and 125 respondents (32.8%) agree that they treat the onion before storage to avoid post-harvest losses. On the contrary, 40 respondents (10.5%) and 46 respondents (12.1%) strongly disagree and disagree, respectively, that they cure the onion before storage to prevent post-harvest losses. 43 respondents, or 11.3% of all respondents, were neutral on the topic of whether they cure the onion before storage to prevent post-harvest losses. This means that smallholder farmers cure their onions before storage, reducing post-harvest losses.

The results of Table 4.5 demonstrate that the majority of respondents stated that they sort onions and remove damaged ones before storage to prevent post-harvest losses. According to the table, 155 respondents (40.7%) highly agree and 133 respondents (34.9%) agree that they sort onions and eliminate damaged ones before storage, hence reducing post-harvest losses. On the contrary, 26 respondents (6.8%) and 27 respondents (7.1%) strongly disagree and disagree that they sort onions and eliminate damaged ones before storage, thereby reducing post-harvest losses. 40 respondents, or 10.5% of the total, were neutral on the topic of whether they sort onions and eliminate damaged ones before storage to prevent post-harvest losses. This means that smallholder farmers sort onions and remove damaged ones before storage, hence reducing post-harvest losses.

The results of Table 4.5 reveal that the majority of respondents agreed that they store onions in a cool, dry, and ventilated area to prevent post-harvest losses. According to the table, 161 respondents (42.3%) highly agree and 124 respondents (32.5%) agree that they store onion in a cool, dry, and aired area to avoid post-harvest losses. On the contrary, 24 respondents (6.3%) and 33 respondents (8.7%) strongly disagree and disagree that they keep onion in a cool, dry, and ventilated environment to avoid post-harvest losses. 39 respondents, or 10.2% of all respondents, said they keep onion in a cold, dry, and aired area to prevent post-harvest losses. This means that smallholder farmers store onions in a cool, dry, and ventilated area to prevent post-harvest losses.

Table 4.5 demonstrates that the majority of respondents stated that they cover the stored onion from sunlight, hence reducing post-harvest losses. According to the table, 173 respondents (45.4%) highly agree and 98 respondents (25.7%) agree that they protect the stored onion from sunlight, hence reducing post-harvest losses. On the contrary, 45 respondents (11.8%) and 41 respondents (10.7%) strongly disagree and disagree that they protect the stored onion from sunlight, hence reducing post-harvest losses. 24 respondents, or 6.3% of the total, responded neutrally to the question of whether they protect stored onions from sunlight, which minimizes postharvest losses. This means that smallholder farmers shelter their stored onions from sunlight, reducing post-harvest losses.

The results of Table 4.5 reveal that the majority of respondents stated that they store onions to protect them from moisture during rainfall, hence reducing post-harvest losses. According to the table, 162 respondents (42.6%) highly agree and 95 respondents (25.1%) agree that they protect onion from moisture during rains, reducing post-harvest losses. In contrast, 37 respondents (9.7%) and 36 respondents (9.4%) strongly disagree and disagree, respectively, that they protect onion from moisture during rainfall, hence reducing post-harvest losses. 51 respondents, or 13.4% of the total, responded neutrally to the question of whether they protect onions from moisture during rains, reducing post-harvest losses. This means that smallholder farmers shield onions from moisture during rains, lowering post-harvest losses.

Table 4.5 demonstrates that the majority of respondents agreed that they regularly check their stored onions for sprouting and rotting, which decreases post-harvest losses. The table reveals that 179 respondents (47.0%) strongly agree and 96 respondents (25.3%) agree that they regularly check stored onions for sprouting and rotting, which decreases post-harvest losses. In contrast, 38 respondents (9.9%) and 24 respondents (6.3%) strongly disagree and disagree that they regularly check stored onions for sprouting and rotting, which decreases post-harvest losses. 44 respondents, or 11.5% of the total, responded neutrally to the question of whether they regularly inspect stored onions for sprouting and spoiling, which decreases postharvest losses.

This means that smallholder farmers periodically inspect stored onions for sprouting and rotting, lowering post-harvest losses.

The results of Table 4.5 demonstrate that the majority of respondents agreed that they store onions for up to six months. According to the table, 100 respondents (26.2%) highly agree and 119 respondents (31.2%) agree that they preserve onions for up to six months. In contrast, 38 respondents (10.0%) and 67 respondents (17.6%) strongly disagreed and disagreed that they kept the onion for up to six months. On the subject of storing onions for up to six months, 57 respondents, or 15.0%, were neutral. This means that smallholder farmers can preserve their onions for up to six months.

The results of Table 4.5 reveal that the majority of respondents agreed that they need money, so we can't save our onions. According to the table, 93 respondents (24.4%) highly agree and 128 respondents (33.7%) agree that they need money, thus we cannot store our onion. On the contrary, 52 respondents (13.6%) and 64 respondents (16.8%) strongly disagree and dispute that they need money, thus we cannot save our onions. 44 respondents, or 11.5%, responded neutrally to the question of whether they needed money and hence could not store their onions. This means that smallholder farmers need money, thus we can't store our onions.

The results of Table 4.5 reveal that the majority of respondents believed that onions should be graded before storage. According to the table, 76 respondents (19.9%) highly agree and 131 respondents (34.4%) agree that they grade the onion before storage. In contrast, 46 respondents (12.1%) and 52 respondents (13.6%) strongly disagree and disagree that onions should be graded before storage. In response to the question of whether they grade the onion before storage, 76 respondents, or 19.9%, expressed neutrality. This means that smallholder farmers grade their onions before storage.

4.3 Results of Hypothesis Testing

4.3.1 Assumptions of Regression Analysis

To avoid false regression, regression analysis as a parametric tool for drawing empirical results must meet specific criteria. The data must meet some of the regression assumptions, including linearity, normalcy, multicollinearity, and homoscedasticity. This section gives the relevant tests for these assumptions as they apply to the data in this investigation.

4.3.1.1 Normality Test

One of the statistical tests that must be performed prior to performing regression analysis is to ensure that the data residuals are normally distributed. The normality test result revealed that the data has a normal distribution, as proven by the histogram and P-P plots, with the histogram curve having a bell shape and the P-P plots conforming to the diagonal normality line depicted in the plot (Fig 2).

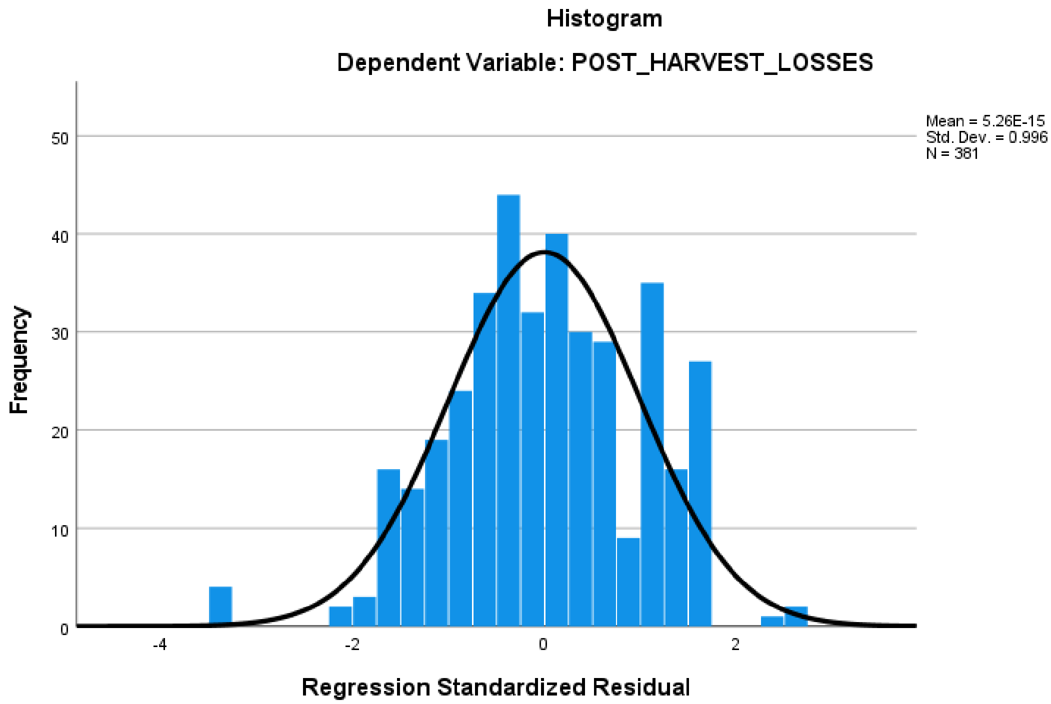


FIGURE 2: RESULTS OF THE NORMALITY TEST

4.3.1.2 Homoscedasticity Test

Another linear regression assumption is that the residuals are homoscedastic. Homoscedasticity means that the dependent variable's variances are equal at each observation of the independent variable. This can be determined using the Partial plots. When independence is assumed, it means that the samples are not dependent on each other. The assumption of homoscedasticity requires that the variance of the dependent variable be the same at all values of the independent variable, or that the error term has constant variance, and the partial plots exhibit no obvious pattern (Gupta 1999). These are fulfilled in the partial plots shown (Fig 2).

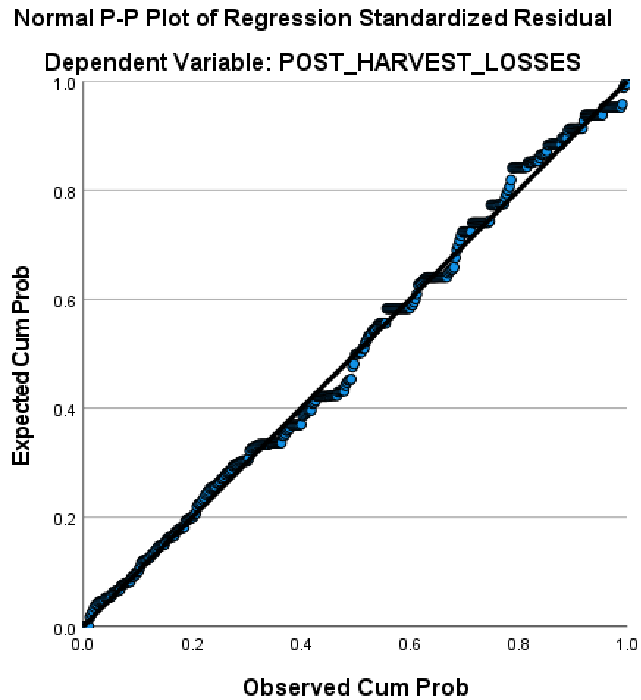


FIGURE 3: RESULTS OF HOMOSCEDASTICITY TEST

4.3.1.3 Linearity Test

Linearity means that the predictor (independent) variables in the regression have a straight-line relationship with the dependent variable. Linearity is not an issue if your residuals are consistently distributed and homoscedastic (Gupta 1999). However, Figure 4 depicts scatter plots of our regression's residuals. The graph shows that the residual scores are concentrated in the middle at the zero (0) point, indicating that the linearity requirement was not violated.

4.3.1.4 Multicollinearity Test

Another assumption in linear regression is multicollinearity. Multicollinearity raises the variance of regression coefficients, threatening the regression equation's validity. In this study, multicollinearity between the independent variables was investigated using Pearson's correlation, Variance Inflated Factor (VIF), and tolerance levels. A VIF more than 10 or a tolerance value less than 0.1 suggests the possibility of multicollinearity (Gupta, 1999). The VIF for all variables is less than 10, indicating that there is no deleterious multicollinearity among the independent variables.

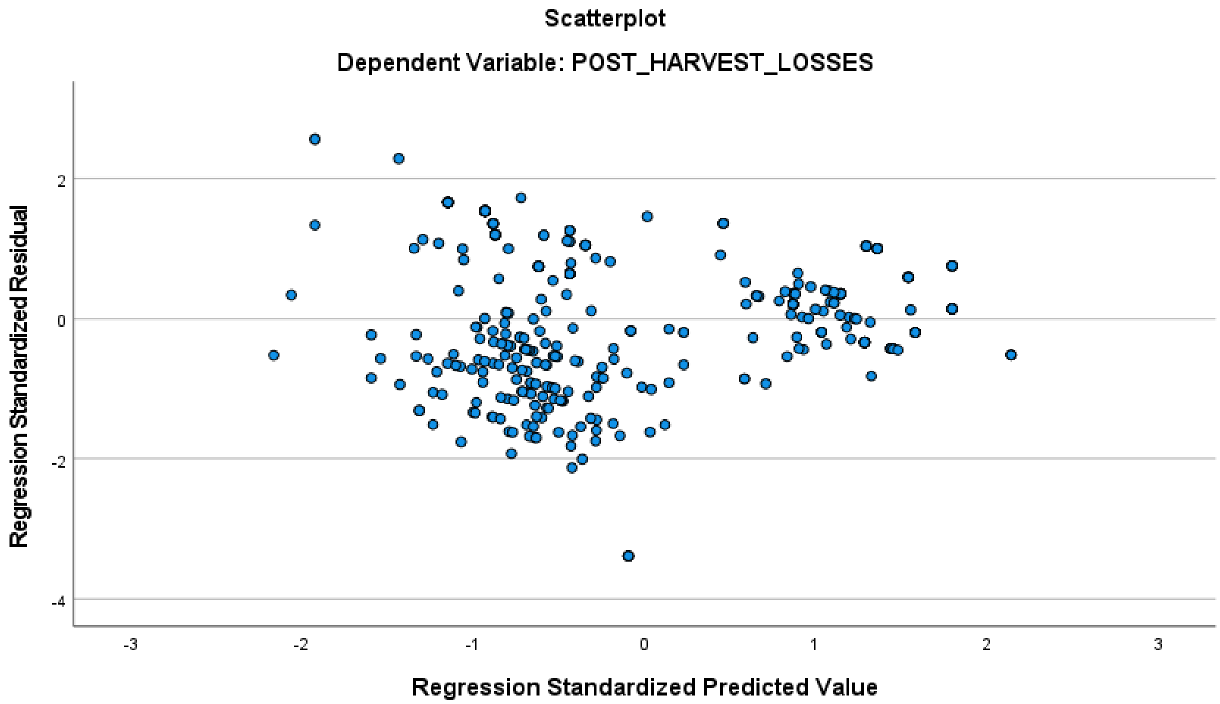


FIGURE 4: RESULTS OF THE MULTICOLLINEARITY TEST

4.4 Multiple Regression Analysis and Test of Hypotheses

To evaluate the hypotheses proposed in this study, multiple regression was used to determine the various effects of storage methods such as traditional, hybrid, and ventilated ways on post-storage losses.

All statistical tests will have a level of significance of $p < 0.05$, indicating 95% confidence. The SPSS findings are provided below.

TABLE 4.6: REGRESSION OUTPUT I

Model summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.497[a]	.247	.242	.72370

a. prediction of (constant); Ventilated Method, Hybrid Method, Traditional Method

Table 4.16 presents a summary of the multiple regression analysis. The multiple correlation coefficient was 0.497a, which suggests a correlation. R2, the multiple coefficient of determination of the variables, was 0.247, indicating that variations in the 'independent variables' (traditional method, hybrid method, and ventilated method) captured in the study account for approximately 24.7% of the total variation in post-harvest losses of smallholder farmers in Zamfara state. Thus, the remaining 75.3% of the variation in post-harvest losses can be attributed to variables not included in the study. The modified R2 of 24.2% implies that the independent variables will continue to explain the dependent variable by 24% even if additional factors are introduced. R is the measure of quality prediction, therefore a result of 0.497 indicates a decent level of prediction for the dependent variable.

Table 47: Regression output ii

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	64.384	3	21.760	41.546	.000[b]
	Residual	188.400	377	.524		
	Total	274.668	380			

a. Dependent Variable: Postharvest losses

b. Predictors: (Constant), Ventilated Method, Hybrid Method, Traditional Method

The F-ratio in the ANOVA Table (Table 4.17) assesses if the overall regression model is a good match to the data. Table 4.16 demonstrates that the independent variables statistically predict the dependent variable, F(3,377)=41.546, P <0.5, indicating that the regression model was fit to the data.

In other words, Table 4.17 above displays the findings of a multiple regression study that examines the effects of independent factors on post-harvest losses among smallholder farmers in Zamfara State, Nigeria. The F-statistic, which assesses the adequacy and goodness of fit of the model employed in the study, was 41.546 with a p-value of 0.000b, which is significant at 5%; this indicates that the model is fitted to the data.

Table 4.8: Regression output iii

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.635	.194		8.427	.000
	TRAD._METHOD	.267	.073	.251	3.602	.000
	HYBRID_METHOD	.115	.067	.123	1.716	.071
	VENT._METHOD	.219	.089	.179	2.461	.007

a. Dependent Variable: Postharvest losses

If the P value is less than 5%, the null hypothesis is rejected; if the P value is larger than 5%, the study does not reject the null hypothesis.

Regression equation to predict dependent variable from dependent variable

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + e$$

$$Y = 1.635 + .267\times1 + .115\times2 + .219\times3$$

Hypothesis testing

4.4.1 Hypothesis I

H_{01}: Traditional methods of onion storage have no significant effect on post-harvest losses of smallholder farmers in Shinkafi Local Government Area of Zamfara State

The coefficient for "traditional methods" was.267, which is positive. This means that traditional methods have a beneficial effect on smallholder farmers' post-harvest losses since smallholder farmers rely heavily on these approaches to avoid onion post-harvest losses. The significance of this, however, can be determined by the P value, denoted as "sig". The coefficient of 26.7% indicates that a percentage increase in traditional onion storage methods in the Shinkafi local government account will result in a 27 percent reduction in post-harvest losses.

The t statistic for the "traditional method" was 3.602 with a p-value of 0.000. The p-value is less than 0.05, indicating that the link represented by the model is statistically significant at the 5% level of significance. This suggests that the study contains sufficient statistical evidence to reject the null hypothesis. Based on the findings, the study rejects the null hypothesis H01, which claims that traditional onion storage methods have no significant effect on post-harvest losses for smallholder farmers in Zamfara's Shinkafi Local Government Area. The model's connection is positive, indicating that farmers in the Shinkafi local government region employ this strategy extensively to address post-harvest losses. It is understandable that smallholder farmers are better experienced with this strategy, which they frequently utilize to alleviate post-harvest losses in Shinkafi LGA. This traditional method is commonly used for braiding, hanging, pits, and hays. As a result, smallholder farmers' traditional methods have greatly contributed to their onion production in Shinkafi LGA.

4.4.2 Hypothesis II

H_{02}: Hybrid method of onion storage has no significant effect on post-harvest losses of smallholder farmers in Shinkafi Local Government Area of Zamfara State

The coefficient of the "hybrid method" was 0.115, which is positive. This means that the hybrid approach has a beneficial influence on smallholder farmers' post-harvest losses because the coefficient is positive. The significance of this, however, can be determined by the P value, denoted as "sig". The coefficient of 11.5% indicates that a percentage increase in the hybrid method of onion storage in the Shinkafi local government account will result in an 11.5% reduction in post-harvest losses.

The "hybrid method" had a t statistic of 1.716 and a p-value of 0.071. The p-value exceeds 0.05, suggesting that the link described in the model is statistically insignificant at the 5% level of significance. This indicates that the study lacks sufficient statistical evidence to reject the null hypothesis. Based on the findings, the study does not reject the null hypothesis H02, which claims that the hybrid method of onion storage has no significant influence on post-harvest losses for smallholder farmers in Zamfara State's Shinkafi LGA.

The "hybrid method"'s t statistic was 1.716, with a p-value of 0.071. The p-value is bigger than 0.05, indicating that the link represented by the model is statistically insignificant at the 5% level of significance. This suggests that the study lacks sufficient statistical evidence to reject the null hypothesis. Based on the findings, the study does not reject the null hypothesis H02, which claims that the hybrid method of onion storage has no significant influence on post-harvest losses among smallholder farmers in Zamfara State's Shinkafi Local Government Area.

4.4.3 Hypothesis III

$H0_3$: Ventilated method of onion storage has no significant effect on post-harvest losses of smallholder farmers in Shinkafi Local Government Area of Zamfara State.

The coefficient for "ventilated methods" was 0.219, which is positive. This means that the ventilated approach has a beneficial effect on smallholder farmers' post-harvest losses since smallholder farmers utilize it extensively to prevent post-harvest onion losses. The significance of this, however, can be determined by the P value, denoted as "sig". The coefficient of 21.9% indicates that a percentage increase in ventilated onion storage in the Shinkafi local government account will result in a 22-percent decrease in onion post-harvest losses.

The t statistic for the "ventilated method" was 2.461, with a p-value of 0.007. The p-value is less than 0.05, indicating that the link represented by the model is statistically significant at the 5% level of significance. This suggests that the study contains sufficient statistical evidence to reject the null hypothesis. Based on the findings, the study rejects the null hypothesis H03, which asserts that ventilated onion storage has no significant effect on post-harvest losses for smallholder farmers in Zamfara's Shinkafi Local Government Area. The model's connection is positive, indicating that farmers in the Shinkafi local government region employ this strategy extensively to address post-harvest losses. It is understandable that smallholder farmers are better experienced with this strategy, which they frequently utilize to alleviate post-harvest losses in Shinkafi LGA. The ventilated method is typically utilized with a ventilated chamber, mesh shelves, and wooden boxes. As a result, smallholder farmers' usage of ventilated methods has greatly increased onion harvests in Shinkafi LGA.

4.2 Discussion of Findings

The paper assesses the economic impact of storage methods on post-harvest losses in onion production: a case study from Shinkafi LGA, Zamfara State, Nigeria. The primary goal of the study is to assess the economic impact of onion storage methods on post-harvest losses for smallholder farmers in the Shinkafi local government area of Zamfara State, Nigeria. The specific objectives

include: to evaluate the traditional methods of onion storage on post-harvest losses to smallholder farmers in Shinkafi Local Government Area of Zamfara State; to evaluate the hybrid methods of onion storage on post-harvest losses to smallholder farmers in Shinkafi Local Government Area of Zamfara State; and to evaluate the ventilated methods of onion storage on post-harvest losses to smallholder farmers in Shinkafi Local Government Area of Zamfara State.
Three hypotheses were proposed to lead the investigation in accordance with the study objectives; the hypotheses are expressed in null form to provide direction for the study. The theories were developed to solve the issue of onion storage methods. The value of this project as an academic activity is that it will provide empirical knowledge on onion storage methods and post-harvest losses to smallholder farmers in Zamfara State's Shinkafi Local Government Area. The study lasts four months, from April to August. The study is limited in that it only includes the Shinkafi LGA of Zamfara State, therefore the results may not be universally applicable.

The literature relevant to the subject was critically evaluated. They cover both theoretical literature on storage strategies and actual investigations relevant to the study. The study used a quantitative method using a survey research design, with a questionnaire serving as the primary data collection tool. Data from the questionnaire were evaluated, and the study's hypotheses were tested using multiple regression. The investigated hypotheses demonstrated that the traditional and ventilated onion storage methods have significant influence on post-harvest losses for smallholder farmers in Shinkafi LGA, Zamfara State.
The initial goal was to assess the impact of traditional onion storage methods on post-harvest losses for smallholder farmers in the Shinkafi Local Government Area of Zamfara State. Our results were consistent with a research done by (Rodrigues, Almeida, García-Falcón, Simal-Gándara, & Pérez-Gregorio, 2010) who studied the effect of traditional methods on post-harvest losses to Portuguese cultivars. Traditional storage methods affect the quality of onion during storage leading to poor postharvest management and a reduction in the amount of onion stored. A decrease in the amount of onion stored leads to a decrease in profit (Petropoulos, Ntatsi, & Ferreira, 2017). Due to fear of postharvest losses incurred during storage, the majority of smallholder farmers prefer to sell their onions immediately after harvest even though they will make less profit. A study conducted in Ethiopia has shown that 97% of smallholder farmers sell their onions immediately after harvest. To make more profit, effective post-harvest management of the onion business is required. Ideal storage methods should preserve the onion quality during storage for a long term (3 to 6 months) to maximize the profit by reducing the damage to onions. Farmers who sell their onions after three to five months provided they use methods that reduce damage to onions make more profits (Yeshiwas et al., 2023).
The second objective was to assess the impact of hybrid onion storage methods on post-harvest losses for smallholder farmers in Zamfara State's Shinkafi Local Government Area. Because of the constraints of both traditional and ventilated techniques of onion storage to raise the revenue

(profits) for onion smallholder farmers, technologies such as modified ventilated structures, Modified Atmospheric Storage (MAS), and Controlled Atmospheric Storage (CAS) were created (Priya, Sinja, Alice, Shanmugasundaram, & Alagusundaram, 2014). These methods reflect hybrid onion storage methods, which were discussed in the theoretical study under the section technology acceptance model. When smallholder farmers accept technical advancements in onion post-harvest management and processing, their return on investment (ROI) increases. They reflect the mix of traditional storage methods and technology to reduce post-harvest losses for onions and boost farmers' income. Farmers' post-harvest losses are determined by both pre-harvest management and post-harvest handling techniques. For example, 35.3% post-harvest losses were found in Ethiopia in a study carried out by (Yeshiwas et al., 2023). Another study found that improper pre and post-harvest management procedures caused 30-40% of post-harvest losses (Tripathi & Lawande, 2019). Some authors observed 15 to 50 percent losses of fruits and vegetables due to improper pre and post-harvest management procedures (Singh, Sharma, & Kesharwani, 2021). Extending the shelf life of farm food during storage reduces post-harvest losses (and increases profit). Hybrid post-harvest management strategies of onion storage have been demonstrated to lower post-harvest losses of onion by 10% (Nath, Meena, Kumar, & Panwar, 2018). Post-harvest handling practices have been shown to cause at least 50% of fruit and vegetable losses. Smallholder farmers' returns on investment can be increased by post-harvest management practices and handling, especially if the farm produce is well preserved and stored until prices are high enough to sell for a profit (Tröger, Hensel, & Bürkert, 2007)

The third objective was to assess the impact of ventilated onion storage methods on post-harvest losses for smallholder farmers in Zamfara State's Shinkafi Local Government Area. Ventilated methods were created to solve the issues faced with standard onion preservation methods (Gupta & Demand, 2013). Findings from this study indicate that ventilated storage methods of onion do not reduce post-harvest losses to farmers. The ventilated method does not prevent pest infestation, moisture, and light exposure to the stored onion leading to deterioration in the quality of the onion which increases post-harvest losses (Nassarawa, Sulaiman, & Nutrition, 2019; Shree & Kumari, 2019). Our findings are in agreement with (Gorrepati, Murkute, Bhagat, & Gopal, 2018) where the authors highlighted that although the ventilated methods can reduce post-harvest losses when compared with the traditional it does prevent infestation of pest and temperature variability leading to spoilage and consequent increase in post-harvest losses. In general, the use of proper post-harvest management practices increases the profit of farmers by 50% (Yadav, Barman, & Dadrwal).

The choice of storage methods and management of onions during and after harvest is critical to onion profitability (economic impact) and the socioeconomic well-being of smallholder farmers in Shinkafi Local Government Area. During storage, onions that have been exposed to the sun, wounded, or maintained in a humid environment frequently deteriorate, resulting in a drop in both quality and quantity. This is the reason for the decrease in profit in onion storage management. Traditional methods that use straws or hay, as well as ventilated methods that use vented rooms or wired baskets, have been demonstrated to increase the postharvest losses of onion to smallholder farmers in Shinkafi Local Government Area, Zamfara State, Nigeria. Each method presents with various degrees of challenges, however a combination of traditional and ventilated (hybrid method) has been shown to preserve onion, and reduce postharvest losses for up to 8 months (Shagun et al., 2024)

The majority of the smallholder farmers in Shinkafi Local Government Area, Zamfara State, northwest, Nigeria are male and Muslim. This gender imbalance is common in most part of the northern Nigeria. The same was observed by (Bulama, Idi, Kyari, Abuna, & ENVIRONMENT, 2024) in Borno State, northeast, Nigeria. Women in northwestern Nigeria are not into the farming business due to cultural barriers (Okolie, Ehiobuche, Igwe, Agha-Okoro, & Onwe, 2022)

4.3 Conclusion

The study evaluates the Impact of Storage Management Strategies on Operational Efficiency and Profitability among Smallholder Onion Farmers in Shinkafi LGA, Zamfara State, Nigeria. The study concludes that traditional onion storage methods significantly impact post-harvest losses among smallholder farmers in Shinkafi LGA, Zamfara State. This finding aligns with previous research, which highlights that techniques such as pit storage and open-air drying can help preserve onion quality and reduce losses. Smallholder farmers rely heavily on traditional storage systems for post-harvest management. Improving these procedures may aid in further reducing losses and increasing storage effectiveness. The study's second goal was to determine the effect of hybrid storage methods on post-harvest onion losses among smallholder farmers in Shinkafi LGA, Zamfara State. The findings indicate that hybrid storage systems, which combine traditional and modern procedures, have no substantial effect on post-harvest losses in this location. According to the study, this outcome is due to local farmers' lack of experience with modern storage techniques such as controlled atmosphere storage (CAS), which regulates oxygen, carbon dioxide, and humidity to prevent rotting. The study's third objective was to assess the influence of ventilated storage methods on post-harvest onion losses among smallholder farmers in Shinkafi LGA, Zamfara State. The findings reveal that vented storage options significantly reduce post-harvest losses in Shinkafi LGA, Zamfara State. Ventilated storage appears to be a successful approach for reducing losses among smallholder farmers in Shinkafi.

4.4 Recommendations

The loss of farmers’ income during the post-harvest period has been a reoccurring incidence amongst smallholder farmers in Shinkafi LGA of Zamfara State and the methods available to them were examined to determine the effective ways of addressing postharvest losses of onions. Lowering post-harvest losses is essential for enhancing food security, boosting income, and maintaining agricultural livelihoods. The use of conventional techniques can be crucial to reaching this objective. Therefore, the study made the following recommendations:

1) Traditional onion storage methods can reduce post-harvest losses provided the temperature, humidity and light can be controlled as well as ensuring air circulation and prevention of damage due to pests. This will minimize the post-harvest losses to smallholder farmers of Shinkafi Local Government Area and increase their profits. It is effective in storing small quantities of onions
2) The major challenge of ventilated methods of onion storage is temperature variability. For long-term storage and storage of high quantities, it is recommended to combine the ventilated with the traditional methods to prevent temperature variability. This will enhance the quality of onion, and increase the quantity and the profit.
3) Most smallholder farmers store their onions in ventilated rooms however, it is not effective when large quantities of onions are to be stored. Promoting the building of well-ventilated storage facilities by smallholder farmers, such as open-sided or louvred warehouses will reduce the post-harvest losses to farmers.

REFERENCES

1) Amjad, W., Munir, A., Akram, F., Parmar, A., Precoppe, M., Asghar, F., & Mahmood, F. J. C. E. (2023). Decentralized solar-powered cooling systems for fresh fruit and vegetables to reduce post-harvest losses in developing regions: a review. *7*(3), 635-653.
2) Balcilara, M., Thompsonb, K., Guptab, R., & van Eydenb, R. Testing the Testing the Asymmetric Effects of Asymmetric Effects of Asymmetric Effects of Financial Conditions Financial Conditions Financial Conditions in South Africa South Africa South Africa: A Nonlinear Vector Autoregression Approach1.
3) Bulama, Y., Idi, A., Kyari, M., Abuna, A. J. B. J. O. A. R., & ENVIRONMENT. (2024). THE EFFECT OF POST-HARVEST HANDLING PRACTICES ON THE QUALITY AND MARKETABILITY OF HARVESTED ONIONS IN JERE LOCAL GOVERNMENT AREA, BORNO STATE, NIGERIA. *6*(1), 30-38.
4) Chávez-Mendoza, C., & Guevara-Aguilar, A. (2025). Storage of Fruits and Vegetables in Controlled Atmospheres and Its Application in the Preservation of White Onion Quality. In *Engineering Principles for Food Processing Technology and Product Realization* (pp. 135-163): Apple Academic Press.
5) Cramer, C. S., Mandal, S., Sharma, S., Nourbakhsh, S. S., Goldman, I., & Guzman, I. J. A. (2021). Recent advances in onion genetic improvement. *11*(3), 482.
6) Gorrepati, K., Murkute, A., Bhagat, Y., & Gopal, J. J. I. J. o. H. (2018). Post-harvest losses in different varieties of onion. *75*(2), 314-318.

7) Gulati, A., Zhou, Y., Huang, J., Tal, A., Juneja, R., Gulati, A., . . . Agriculture, I. (2021). Innovations in Production Technologies in India. 23-82.
8) Gupta, R. J. S. H. V. V. i. S. A. P., Supply, & Demand. (2013). Onion production: Challenges and ways to meet out the demand of the country. 124.
9) Kusumowardani, N., Tjahjono, B., Lazell, J., Bek, D., Theodorakopoulos, N., Andrikopoulos, P., & Priadi, C. R. J. J. o. B. R. (2022). A circular capability framework to address food waste and losses in the agri-food supply chain: The antecedents, principles and outcomes of circular economy. *142*, 17-31.
10) Nassarawa, S. S., Sulaiman, S. A. J. I. J. o. F. S., & Nutrition. (2019). Extending the shelf life of tomato and onion in Nigeria: A review. *4*(5), 99-111.
11) Nath, A., Meena, L., Kumar, V., & Panwar, A. (2018). Postharvest management of horticultural crops for doubling farmer's income.
12) Nimon, K. F., & Oswald, F. L. (2013). Understanding the results of multiple linear regression: Beyond standardized regression coefficients. *Organizational research methods*, *16*(4), 650-674.
13) Ogedengbe, T. C., Malomo, O. J., Akanji, N. E. J. I. J. O. A. S., Research, Extension, T. I., & Systems, E. (2022). Post-Harvest Losses and Reduction Techniques in Crop Production: A Review. *12*(4), 225-233.
14) Okolie, U. C., Ehiobuche, C., Igwe, P. A., Agha-Okoro, M. A., & Onwe, C. C. (2022). Women entrepreneurship and poverty alleviation: Understanding the economic and socio-cultural context of the Igbo Women's basket weaving enterprise in Nigeria. In *Entrepreneurship and the Informal Sector* (pp. 8-27): Routledge.
15) Onion Farmers Association of Nigeria (2023). Premium newspaper. Sokoto gets first indigenous onion, garlic processing plant (premiumtimesng.com)
16) Osborne, J. W., Waters, E. J. P. a., research,, & evaluation. (2002). Four assumptions of multiple regression that researchers should always test. *8*(1), 2.
17) Peterson, J. (2009). *Seafood Handbook: The Comprehensive Guide to Sourcing, Buying and Preparation*: John Wiley & Sons.
18) Petropoulos, S., Ntatsi, G., & Ferreira, I. J. F. R. I. (2017). Long-term storage of onion and the factors that affect its quality: A critical review. *33*(1), 62-83.
19) Poole, M. A., & O'Farrell, P. N. (1971). The assumptions of the linear regression model. Transactions of the Institute of British Geographers, 145-158.
20) Priya, E., Sinja, V., Alice, R., Shanmugasundaram, S., & Alagusundaram, K. J. A. R. (2014). Storage of onions–a review. *35*(4), 239-249.
21) Rodrigues, A., Almeida, D., García-Falcón, M., Simal-Gándara, J., & Pérez-Gregorio, M. (2010). *Postharvest storage systems affect phytochemical content and quality of traditional Portuguese onion cultivars.* Paper presented at the XXVIII International

Horticultural Congress on Science and Horticulture for People (IHC2010): International Symposium on 934.

22) Senkondo, E., Msangi, A., Xavery, P., Lazaro, E., & Hatibu, N. J. J. o. a. i. s. (2004). Profitability of rainwater harvesting for agricultural production in selected semi-arid areas of Tanzania. *39*(1), 65-81.
23) Shagun, S., Bains, A., Sridhar, K., Dhull, S. B., Patil, S., Gupta, V. K., . . . Sharma, M. J. S. H. (2024). A comprehensive review on impact of post-harvest management and treatment practices on the quality of garlic (Allium sativum L) during storage. *337*, 113586.
24) Shree, S., & Kumari, A. (2019). Postharvest handling, diseases and disorders in bulb vegetables. In *The Vegetable Pathosystem* (pp. 483-507): Apple Academic Press.
25) Singh, D., Sharma, R. R., & Kesharwani, A. K. (2021). Postharvest Losses of Horticultural Produce. In *Postharvest Handling and Diseases of Horticultural Produce* (pp. 1-24): CRC Press.
26) Tripathi, P., & Lawande, K. J. C. H. (2019). Onion storage in tropical region—a review. *7*(2), 15-27.
27) Tröger, K., Hensel, O., & Bürkert, A. (2007). *Conservation of onion and tomato in Niger–Assessment of postharvest losses and drying methods.* Paper presented at the Conference on International Agricultural Research for Development.
28) Yadav, N., Barman, K., & Dadrwal, B. K. Farmer Double Income by Use of Post-Harvest Techniques.
29) Yeshiwas, Y., Alemayehu, M., & Adgo, E. J. H. (2023). The rise and fall of onion production; its multiple constraints on pre-harvest and post-harvest management issues along the supply chain in northwest Ethiopia. *9*(5).